LMT·TOOLS
BELIN
FETTE
KIENINGER
ONSRUD

德国蓝帜金工菲特公司
齿轮加工刀具及加工技术
LMT Fette Gear Cutting Tools and Knowledge

www.lmt-tools.com

LMT Fette Gear Cutting Tools and Knowledge

Bildquellen: Liebherr-Components Biberach GmbH, Biberach an der Riss; Liebherr-Verzahntechnik GmbH, Kempten; Siemens AG, Bocholt
Sources: Liebherr-Components Biberach GmbH, Biberach an der Riss; Liebherr-Verzahntechnik GmbH, Kempten; Siemens AG, Bocholt

高速钢和“速切王”材料的齿轮滚刀
Hobs
for spur gears
HSS/SpeedCore

整体硬质合金滚刀
Carbide hobs
for spur gears

齿轮滚削、倒角系统
Tool systems
ChamferCut

链轮、带轮、矩形花键滚刀
Hobs
for sprockets timing
belt pulleys
splines

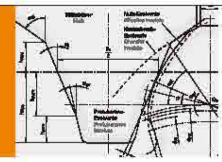
特殊齿形工件的刀具
Tools
for special profiles

蜗轮滚刀
Hobs
for worm gears

可转位硬质合金刀片滚刀
Hobs with
indexable carbide inserts
for spur gears

可转位硬质合金刀片铣刀
Gear milling cutters with
indexable carbide inserts

技术资料
Attachment



Sehr geehrte Kunden und Interessenten,

最新版本的《齿轮切削刀具和技术参数》样本，一贯地坚持了蓝帜公司的新样本理念。

我们生产齿轮刀具已经有百年的历程，我们持续不断地创新产品来满足始终增长的需求。今天，我们提供最大范围齿轮切削刀具给我们的客户。产品范围包括小模数和大模数的粗切和精切刀具。

这本样本是一个产品向导为了您加工齿轮应用优化刀具的选择来服务于您。最新理念，清晰标符和应用推荐数据将支持您。

我们一直致力于将我们的技术资料提供给您，便于了解和应用我们的刀具。

我们期待着为您提供生产合作。

您的齿轮切削加工团队

Dear customers and potential customers,

the newly structured catalogue "LMT Fette Gear Cutting – Tools and Knowledge" consistently pursues the new LMT catalogue concept.

We have been producing cutting tools for gear production for decades already. We have brought innovative developments to serial production status to meet the ever increasing requirements. Today, we offer the widest tool range for gear cutting in the market to our customers. The product range includes small-module and large-module tools for roughing and finishing of gears.

This gear cutting catalog is to serve you as a product guide for the selection of the optimum tool for your application. The newly structured selection criteria, clear symbols and application recommendations will support you in this.

We have also placed great emphasis on the Technical Appendix to provide you with comprehensive information about using our tools.

We look forward to a productive cooperation

Your team for gear cutting

德国蓝帜金属加工技术集团整合了精密工具技术领域一流专家的能力，所汇聚的专业知识使蓝帜金工能制定并向全世界提供刀具解决方案，所涉及的加工材料涵盖从高强度钢至复合材料等范围。

公司拥有1200多名员工和专业的合伙伙伴，可向全球范围内的客户提供全面的刀具、切削材料和服务，满足最多样化的切割和非切割用途以及刀具修磨和刀具管理领域的各项服务的要求。

德国蓝帜金属加工技术集团总部位于德国奥伯科亨，旗下有多家制造公司，包括蓝帜贝林、蓝帜菲特、蓝帜基宁格和蓝帜昂思路，以及生产服务机构和全球经营销售机构。

LMT Tools combines the competences of leading specialists in the field of precision tool technology. This pooled expertise enables LMT Tools to develop and deliver tool solutions world–wide for processing materials ranging from high–strength steel to composite materials.

More than 1,200 employees and a network of specialized partners enable the company to offer its customers worldwide a comprehensive range of tools, cutting materials and services for the most diverse cutting and non–cutting applications as well as various services in the fields of tool reconditioning and tool management.

LMT Tools is based in Oberkochen,Germany. The company group encompasses the manufacturing companies LMT Belin, LMT Fette, LMT Kieninger and LMT Onsrud, production and service facilities and a globally operating sales organization.

LMT • BELIN

蓝帜贝林的总部位于法国拉旺西亚，专门从事塑料、轻金属和复合材料加工领域的精密刀具。蓝帜贝林自2001年起便是集团的一份子，与蓝帜昂思路共同构成集团复合材料加工领域的能力中心。

LMT Belin is based in Lavancia, France, and specializes on precision tools for the machining of plastics, light metals and composite materials. LMT Belin has been part of the Group since 2001 and together with LMT Onsrud forms the Group's competence center for the machining of composites.

LMT • FETTE

蓝帜菲特的总部位于德国汉堡附近的施瓦岑贝克市，是世界上精密铣削刀具、齿轮滚刀、螺纹滚压系统和丝锥的一流制造商。作为蓝帜金工的创始成员，蓝帜菲特于1993年加入蓝帜金工，是集团铣削和螺纹切削以及滚压领域应用的能力中心。

LMT Fette is based in Schwarzenbek near Hamburg, Germany, and is one of the world's leading manufacturers of precision milling tools, gear hobs, thread rolling systems and taps. LMT Fette was a founding member of LMT when it was established in 1993 and is the Group's competence center for applications in the fields of milling and thread cutting and rolling.

LMT • KIENINGER

蓝帜基宁格作为特殊刀具的专业制造商，因挑战加工应用而享有世界级声誉。作为模具制造和零部件加工领域的能力中心，汽车和汽车供应商行业已成为关键领域。

LMT Kieninger has established a global reputation as a specialist manufacturer of specialized tools for challenging machining applications. As a competence center for die and mould making and component machining, the automobile and automotive supplier industries are a key area.

LMT • ONSRUD

蓝帜昂思路专门从事铝材、塑料和复合材料的高速加工刀具。蓝帜昂思路和蓝帜贝林共同构成集团内复合材料加工领域的能力中心。

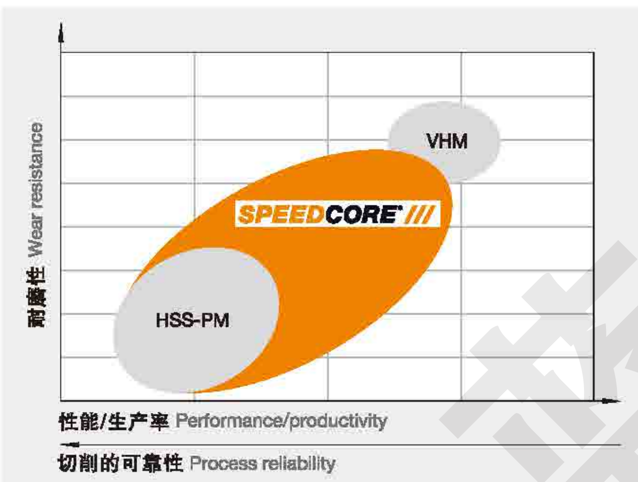
LMT Onsrud specializes in tools for the high–speed machining of aluminium, plastics and composite materials. LMT Onsrud and LMT Belin together form the competence center for the machining of composites within the Group.

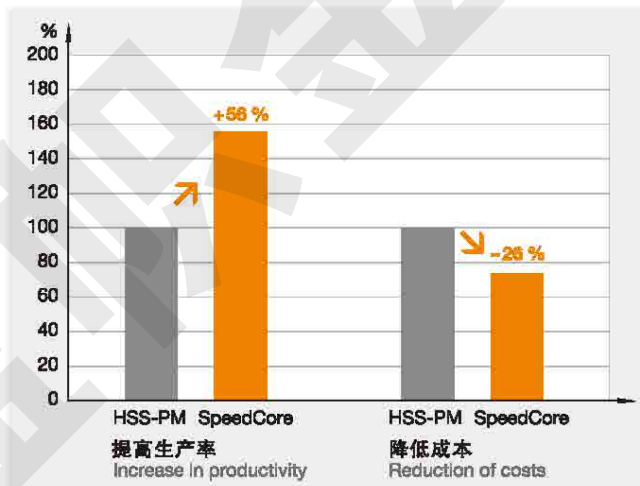
速切王切削材料是为了滚刀新研发的基体材料，增加热硬度的合金元素化合物，与PM4/14粉沫高速钢滚刀相比最少提高30%切削速度。在不降低刀具寿命情况下减少了制造时间，及遵从客户的意愿简化了装夹和易于回收利用。速切王材料配上涂层使刀具达到顶尖的性能易于实现和高可靠性。

SpeedCore is a newly developed substrate for hobs. The increased hot hardness of the intermetallic cutting material allows for cutting speeds of at least 30 % higher compared with HSS-PM4/14 hobs, resulting in shorter production times without sacrificing tool live and ocmplies with the demand of customers for easy handling and easier recycling. Combining the new SpeedCore substrate with a custom coating achieves top performance with easy implementation and high reliability.

优势：
- 提高生产率70%以上。
- 加工工艺可靠（如同粉沫高速钢）
- 在旧设备上易于使用
- 重磨和涂层没有问题

Advantages
- Improved productivity of up to 70 %
- Process reliability (like HSS-PM)
- Easy to implement also on older or unstable machines
- Regrinding and coating possible without problems





速切王应用见网址：www.lmt-tools.de, watched us on YouTube
SpeedCore application see www.lmt-tools.de, watched us on YouTube

加工圆柱渐开线齿轮的直齿轮
和斜齿轮的滚刀
Hobs for producing straight- and helical-tooth spur gears with involute flanks

关于渐开线齿形的直齿轮滚刀的基本图形公差及DIN8000的有关项目在下方的图形中有体现。相对应的，滚刀就是一个蜗杆。如果这个蜗杆带有齿槽，那么齿形经过铲背后就能切削。

这个铲背量是通过专门的加工机床用设置好的工艺来保证的；它很费时，因此费用很高。对于中等精度的滚刀，铲齿就可以了。对于高精密质量的滚刀，必需采用铲磨。

通常，铲齿滚刀可达到DIN3968中的B级精度，铲磨滚刀能达到DIN3968中的A、AA级或更高的精度。最高精度是DIN3968的AA级。再高的精度要求，一般采用按DIN3968　AA级为基础控制公差来保证，来达到对应的DIN3968AAA级，对于所有能够检测的项目按AA级公差的75%的值进行控制。

如果AA级公差受到限制是必需的，这样就可以参照AAA级，但是，可测量的变量和公差限制可用%或者直接用μm给出。例如，精度等级DIN3968的AAA级中的第16和17项控制在AA级的50%以内。

滚刀公差的目的是给予刀具一个相应的精度等级使其达到准确度。在这个滚刀精度等级的基础上，我们能预测相应的齿轮的精度。

从广义上讲，不是所有需求都是要一个“高精度”齿轮，例如：高静音的运行或特殊的齿顶，齿根减薄完全可以通过高精度刀具实现。对于这种需求，我们在滚刀上作一个凹入量，被证明很成功。根据大载荷和齿轮性能的需要，这个适当的凹入量可以从表格N102S、N102S/3、N102/5中选择。必须指出这个刀具的凹入量不完全传输给齿轮。对于小齿数的齿轮，齿轮的齿数越少，有效凸起部分也越少。

The fundamental geometrical concepts of a spur gear hob for generating gears with involute flanks are laid down and explained in detail in DIN 8000. According to this, the basic body of a hob is always a worm. If this worm is now provided with flutes, cutting teeth result. These become capable of cutting by being backed off or relieved.

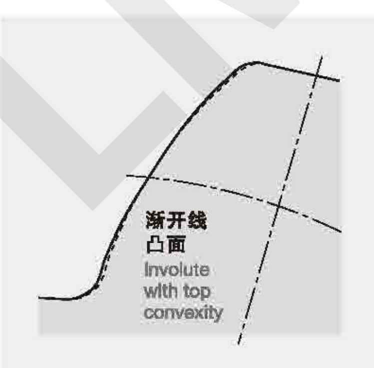
This relieving operation is carried out on machine tools specially developed for this process; it is very time consuming and therefore also expensive. For hobs to moderate accuracy specifications, relief turning is sufficient; for stricter quality requirements the hob is relief ground.

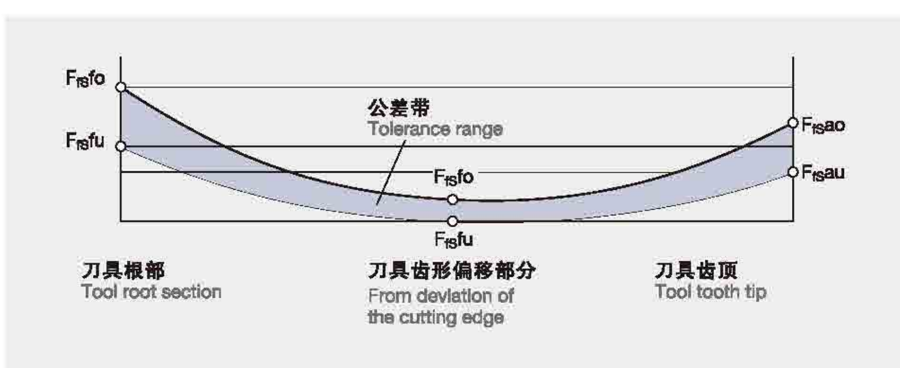
Generally, relief turned hobs achieve quality class B approximately to DIN 3968. Relief ground hobs achieve quality classes A, AA and higher. The highest quality class in DIN 3968 is AA. For exceptionally high quality requirements it is usual to restrict the tolerances of quality class AA still further. Quality class corresponding to AAA to DIN 3868, without comment, means the restriction to 75 % of the AA tolerances for all measurable variables.

If special tolerance restrictions of the AA tolerance are required, this is also done with the AAA reference, but the individual measurable variables and the tolerance restriction are now given in % or directly in mm. E.g. quality class AAA to DIN 3968, item nos. 16 and 17 restricted to 50 % of the tolerance of AA.

The purpose of hob tolerances is to assign the tools to a quality class according to their accuracy. On the basis of the hob quality classes, the expected gear quality can then be forecast.

Not all requirements aimed at a “good gear quality” in the wider sense, e.g. very quiet running or a specific addendum- and dedendum relief are achieved solely through a high cutter quality. For such needs, hobs with a defined crowning depth have proved successful. Depending on the load and the required gear performance, the suitable crowning depth can be selected from the various tables N102S, N102S/3 or N102S/5. It must be noted that the tool depth crowning is not transmitted completely to the gear. The lower the number of teeth of the gear, the less the effective convexity portion.





特殊等级的滚刀公差 公差单位1/1000（微米） Tolerances for hobs with special class tolerance values in $^{1}/_{1000}$ millimetres										
	公差带 Tolerance range	模数 Module								
		0,63–1	1–1,6	1,6–2,5	2,5–4	4–6,3	6,3–10	10–16	16–25	25–40
N 102 S	F_{fs}fo	25	28	32	36	40	50	63	80	100
	F_{fs}fu	12	14	16	18	20	25	32	40	50
	F_{fs}o	4	4	4	5	6	8	10	12	16
	F_{fs}u	0	0	0	0	0	0	0	0	0
	F_{fs}ao	16	16	16	20	24	32	40	50	64
	F_{fs}au	8	8	8	10	12	16	20	25	32
N 102 S/3	F_{fs}fo	12	14	16	18	20	25	32	40	50
	F_{fs}fu	8	8	8	10	12	16	20	25	32
	F_{fs}o	4	4	4	5	6	8	10	12	16
	F_{fs}u	0	0	0	0	0	0	0	0	0
	F_{fs}ao	12	14	16	18	20	25	32	40	50
	F_{fs}au	8	8	8	10	12	16	20	25	32
N 102 S/5	F_{fs}fo	8	8	8	10	12	16	20	25	32
	F_{fs}fu	4	4	4	5	6	8	10	12	16
	F_{fs}o	0	0	0	0	0	0	0	0	0
	F_{fs}u	0	0	0	0	0	0	0	0	0
	F_{fs}ao	8	8	8	10	12	16	20	25	32
	F_{fs}au	0	0	0	0	0	0	0	0	0

可获得的齿轮质量
Attainable gear qualities

单头滚刀 质量等级 Quality grade to DIN 3968 for single-start hobs		可获得的齿轮质量DIN 3962第1–8.78部分(F_f) Attainable gear qualities to DIN 3962 part 1 – 8.78 (F_f)										
		模数范围 Module ranges										
		从 from										
		1–1,6	1,6–2	2–2,5	2,5–3,55	3,55–4	4–6	6–6,3	6,3–10	10–16	16–25	25–40
F_e	AA	7	7	7	8	7	7	7	8	8	7	7
	A	9	10	9	9	9	9	8	9	9	9	9
	B	11	11	11	11	10	11	10	11	11	10	10
	C	12	1)	12	12	12	12	12	12	12	12	12

1) 低于质量等级12
inferior to gear quality 12

单头滚刀的许用公差等级符合DIN3968标准。

总共有16种不同的公差类别，它们部分互相依赖，且属于累积误差。

啮合区域的接触比率误差Fe作为整体误差，对于评估滚刀质量具有重要参考作用。在限制条件下，该参考值也可用来对齿轮齿面形状进行预测。

为了保证滚刀的质量，必须在每次磨刃后对前刀面的形状和位置，齿距和方向允许偏差进行检查。（序号7到序号11）

The permissible deviations for single-start hobs are laid down in DIN 3968.

There are 16 individual deviations, which are partly interdependent, and one cumulative deviation.

The contact ratio deviation Fe within an engagement area, as a collective deviation, is the most informative value when assessing hob quality. It also allows, within limits, to forecast the flank form of the gear.

To maintain hob quality, it is necessary to check the permissible deviations after each sharpening operation for form and position, pitch and direction of the cutting faces (item nos. 7 to 11).

LMT • FETTE

尺寸

滚刀的四种常用尺寸是：刀具直径，刀刃长度，总长度以及内孔直径；例如模数为8，目录号2032；125 × 130/138 × 40。由于刀具尺寸受到测量值和滚齿机性能的限制，以及加工过程中所使用的刀杆尺寸或为了获得特别的切削参数或加工时间，不同的工件形状必须采用不同的刀具尺寸。

滚刀材料

标准切削材料是EMo5Co5 (1.3243)钴高速钢。对于高速切削加工，采用粉末冶金工艺制作的高合金钢被使用。最新速切王"SpeedCore"材料的切削性能超过了粉末高速钢。速切王"SpeedCore"材料含有钴、钼和不含碳铁组成，这样制作的材料与传统的粉末高速钢相比增加了切削的红硬性。硬质合金材料应用于更高的干、湿加工机床及刮削滚刀。

涂层

厚度为2至3μm的硬质涂层能够提高刀具的使用寿命。或提高刀具的切削速度。有关涂层使用的详细信息可以本目录中技术部分第134–136页中查看。

基本齿廓

各种参考齿廓的定义和详细说明可在本目录技术部分的第113–132页中找到。

压力角

压力角同模数一样是决定了齿轮，而决定了工件的切削参数，在确定滚刀基本形状时必须加以考虑。

顶端倒角

为防止刀具顶端损坏，须对其进行倒角处理。倒角尺寸必须适合滚刀加工的需要。为了判断滚刀参数或基本外形的正确性，需获得完整的齿轮切削参数。顶端倒角的尺寸取决于齿轮的齿数，例如，当采用相同的滚刀加工不同齿数的齿轮时，倒角值会随着齿数的减少而减小。当齿数变化较大时，需要多种不同规格的刀具。

有关倒角与齿数关系的相关信息及推荐的倒角尺寸可根据用户要求提供。

Dimensions

The four main dimensions of the hobs are stated in the following sequence: cutter diameter, cutting edge length, total length and bore diameter; e.g. for module 8, cat. no. 2032; dia. 125 × 130/138 × dia. 40. Diverse measurements may become necessary due to the workpiece shape, because of the limitation of the cutter dimensions due to the measurements and performance of the hobbing machine, through the dimensions of the available cutter arbors or to achieve specific cutting parameters or machining times.

Hob materials

The standard material is the high-speed steel EMo5Co5 (1.3243). For higher cutting speeds and feeds, high-alloy high-speed steels are used which were produced with the powder-metallurgy process. An increase in performance over PM-HSS can be achieved by the SpeedCore material. SpeedCore is made from cobalt, molybdenum and carbon-free iron. This combination enables a marked increase of the red hardness of the cutting material compared to traditional PM-HSS substrates. Carbide materials are used for high-performance milling in wet and dry machining or for skiving hobs.

Coating

A hard coating with a thickness of 2 to 3 μm increases the life of the hobs, or permits higher cutting rates. Further information on the coatings can be found on pages 134 to 136 in the technical section of the catalogue.

Basic tooth profiles

The definition and description of the various reference tooth profiles are found in the technical part of the catalogue on pages 113 to 132.

Pressure angle

The pressure angle, as also the module, is determined by the gear cutting data of the workpiece and must be taken into account when deciding on the basic hob profile.

Tip edge chamfer

To protect the tip edges against damage, they are chamfered. This tip edge chamfer can be produced during manufacture with a suitably dimensioned hob. To determine the hob reference or basic profile correctly, the complete gear cutting data are needed. The size of the tip edge chamfer depends on the number of teeth, i.e. when using the same hob for different numbers of gear teeth, the chamfer will decrease with a smaller number of teeth. For a large tooth number range, several different cutters are needed.

Information about these relationships and recommended chamfer sizes can be made available on request.

齿廓修形

齿廓修形的目的是减少或避免配合齿轮在负载情况下相互啮合时发生干涉现象。要确定滚刀的基本形状，必须得到完整的切齿参数或工件图纸。与顶端倒角相似，确定齿廓修形的尺寸取决于齿轮的齿数。

Profile modification

The purpose of the profile modification is to reduce or avoid the interference when the teeth roll into mesh while a gear pair is running under load. To decide on the basic profile of the hob, the complete tooth cutting data or the workpiece drawing are necessary. The size of the profile modification produced depends, similarly as with the tip edge chamfer, on the number of teeth.

挖根（沉割）

挖根即在齿根处形成清根，这样可以避免后序磨削砂轮、衍磨轮接触到齿轮根部。也可以防止磨削或剃削加工过程中的应力集中问题。这一步操作也可以防止磨削或刨削加工过程中产生应力集中现象。

挖根的基本形状没有标准化数值，须根据用户需求而决定。如果您没有相关经验，我们可以给您提供相关建议，如有必要，我们还可为您进行的齿轮切削参数提供参考切削形状。

Protuberance

The protuberance creates a clearance cut in the root of the tooth, so that during the next operation the grinding wheel or the rotary honing wheel does not machine the tooth root. This prevents stress peaks through grinding- or shaving processes.

The protuberance basic profiles are not standardized and are supplied on request to your requirements. If you do not have relevant experience, we can submit suggestions and if necessary prepare profile plots for your gear cutting data.

多头滚刀

使用多头滚刀可以提高滚刀的走刀量。尤其适用于模数较小（模数小于等于2.5）以及齿数很多的情况。当滚刀具有轴向平行切削槽时，应选用多头滚刀以保证导程角度不超过7.5度。这样就可以避免靠近滚刀齿根面位置切削出来的齿轮齿面表面产生质量缺陷。

Multi-start hobs

Multi-start hobs are used to increase hobbing output. This applies particularly in the case of gears with small modules (≤ module 2.5) and relatively large numbers of teeth. In the case of hobs with axially parallel flutes, the number of starts should be selected so that a lead angle of 7.5° is not exceeded. The approaching tooth flanks of the hob can otherwise be expected to produce an inferior surface quality on the gear flanks.

旋向

对于采用普通的单一旋向与齿轮螺旋旋向是一致的；当滚刀旋向为反向时，齿轮螺旋的转向也变为反向。如果直齿圆柱齿轮既可以使用右旋的刀具也可以使用左旋的刀具时，通常使用右旋的刀具进行加工。

Lead direction

With the usual uni-directional hobbing of helical spur gears, the lead direction of the hob and the helix direction of the gear are the same; with contra-directional hobbing they are opposite. In the case of straight spur gears both right-hand- and left-hand cutters can be used. Right-hand cutters are typically used.

顶切刀具

齿轮外圆直径大小由滚刀齿根所在的位置确定。改变齿的厚度也会改变齿轮外圆直径的大小。

Topping cutters

The outside diameter of the gear is topped by the tooth root of the hob. Changes in the tooth thickness also result in changes of the tip circle and root circle diameters.

倒角

当加工直径较大的螺旋直齿圆柱齿轮时，不能通过选用长度过大的滚刀来覆盖整个齿轮的加工区域。为了防止滚刀刀齿在作用区域产生过度磨损，通常需要给滚刀作一个直角倒角。对于双螺旋齿轮，如果工件的两排齿间距相对较小时，两个刀齿都需要进行倒角处理。

Chamfer

When hobbing helical spur gears with large diameters, the hobs cannot always be chosen long enough to cover the entire working area. To prevent excessive wear of the hob teeth in the approach area, the hob is provided with a tapered chamfer. For gears with as well, double-helical teeth, hobs with chamfer may be necessary as well, if the distance between the two tooth rows is relatively small.

根据滚刀采用上升方式或传统方式加工、倒角长度通常为5至6倍的模数值，偏角为5度到10度倒角位置一般位于刀具入口或刀具末端。

Depending on whether hobbing is by the climb or conventional method, the chamfer – generally 5 to 6 x module long and 5° to 10° angle of inclination – is situated on the entering- or leaving end of the cutter.

切削刃前角

除有特别要求以外，滚刀倾角一般为0度。该类型不适用于重载粗切滚刀（该滚刀的倾角一般为+8度），可转位滚刀和刮削滚刀的前角一般可达–10度至–30度。

Rake

Unless otherwise agreed, hobs have a rake of 0°. This does not apply to heavy duty roughing hobs, which have a rake of +8°, and indexable insert and skive hobs, which have a rake of –10° to –30°.

切削槽

切削齿槽数量的增加可以提高滚刀的切削容量以及包络网的密度；但是同时也将降低刀具的有效齿长，除非不断增加刀具直径。对于整体式滚刀，切削槽沿轴线方向的螺旋升角可达到6度，对于螺旋升角可超过6度。

Gashes

A high number of gashes increases the cutting capacity of the hobs and the density of the envelope network; they do however also reduce the useful tooth length, unless the cutter diameter is increased accordingly. For solid type hobs the gashes are up to a helix angle of 6° made axially parallel, and over 6° with helix.

径节DP与周节CP

在使用英语交流的国家，人们通常使用径节和周节来代替模数。最好将上述数值DP与CP转换为模数，并在一般情况下使用模数进行计算。

m = 25,4 / DP
m = 25,4 · CP / 3.1416

DP and CP

In English-speaking countries, diametral pitch and circular pitch are used instead of the module. It is best to convert the above values into module and to proceed with the calculated module in the usual way.

The equations for the conversion into module are:

m = 25.4 / DP
m = 25.4 · CP / 3.1416

具有较多切削槽的带涂层的整体式滚刀比较适合高效率地加工直齿圆柱齿轮。整体式滚刀在性能上比其他组合式滚刀更加稳定。较多的切削槽可以更快地排除加工碎屑。使用涂层也可相应地提高滚刀的使用寿命，而且涂层可以反复喷涂。

Coated solid-type hobs with a high number of gashes are ideally suited to high-performance hobbing of spur gears. The high number of gashes permits a high rate of chip removal, and the tool life is increased substantially by the coating and, where applicable, re-coating.

与传统滚刀相比，高性能滚刀应满足以下要求：
- 更长的刀具使用寿命；
- 更少的加工时间；
- 不低于传统刀具的齿轮加工质量。

Compared to conventional hobs, high-performance hobs are required to have:
- A higher tool life quality and
- shorter machining times
- at least equal if not superior gear quality.

这些要求是相互关联的，比如采取措施缩短加工时间可能会对刀具寿命或齿轮加工质量产生有害的影响。

These requirements are interrelated, such that measures which for example reduce the machining time, may have a detrimental effect upon the tool life or the gear quality.

仅通过提高加工环境质量便可以对滚刀进行优化。根据齿轮的形状、材料以及品质特性，刀具设计以及切削参数的设计必须满足相应的设计要求。

Hobs can be optimized only in consideration of the machining environment. Based upon the geometry and the material and quality characteristics of the gear in question, the hob design and cutting parameters must be matched in such a way that the requirements are broadly fulfilled.

切屑厚度

切屑厚度是滚刀设计和优化过程中的一个重要标准。
切屑厚度为理论上切屑最大允许厚度，它由滚刀刀尖切除。

Tip chip thickness

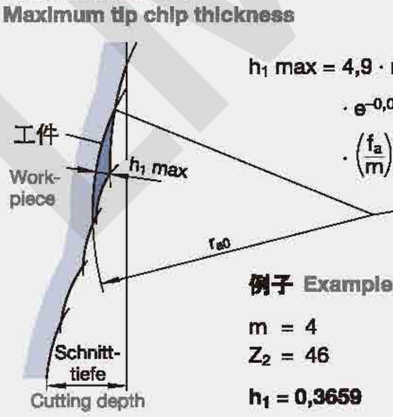
The tip chip thickness is an important criterion for hob design and optimization.

The tip chip thickness is the theoretical maximum chip thickness which can be removed by the tooth tips of the hob.

在计算切屑厚度时应考虑以下滚刀特性和切削参数：
- 模数
- 齿数
- 螺旋角（弧度单位）
- 齿形移位因数
- 滚刀半径
- 切屑槽数量
- 滚刀头数
- 轴向进给量
- 切削深度

The following hob characteristics and cutting parameters are taken into account during calculation of the tip chip thickness:
- Module
- Number of teeth
- Helix angle
- Profile displacement
- Cutter diameter
- Number of gashes
- Number of starts
- Axial feed
- Cutting depth

最大顶刃切削厚度
Maximum tip chip thickness



$$h_1\,max = 4{,}9 \cdot m \cdot Z_2^{(9{,}25 \cdot 10^{-3} \cdot \beta_0 - 0{,}542)} \cdot e^{-0{,}015 \cdot \beta_0} \cdot e^{-0{,}015 \cdot x_P} \cdot \left(\frac{r_{a0}}{m}\right)^{(-8{,}25 \cdot 10^{-3} \cdot \beta_0 - 0{,}225)} \cdot i^{-0{,}877} \cdot \left(\frac{f_a}{m}\right)^{0{,}511} \cdot \left(\frac{a}{m}\right)^{0{,}319} \quad [mm]$$

例子 Example:

$m = 4$	$\beta_0 = 16$	$r_{a0} = 55$	$f_a = 4$
$Z_2 = 46$	$x_P = 0{,}2$	$i = 12/2$	$a = 9$

$h_1 = 0{,}3659$

m = 模数 Module
Z_2 = 齿数 Number of teeth
β_0 = 螺旋角（弧度单位） Helix angle (radian)
x_P = 齿形移位因数 Profile displacement factor
r_{a0} = 滚刀半径 Half hob diameter
i = 切屑槽数量/头数 Number of gashes/number of starts
f_a = 轴向进给量 Axial feed
a = 切削深度 Cutting depth

学术论著：Bernd Hoffmeister 1970
Dissertation by Bernd Hoffmeister 1970

提高刀具使用寿命

增加滚刀切屑槽数是影响刀具使用寿命具有决定性的积极影响的设计方法。当切削长度范围保持不变时，增加切削量是可行的。而且，可以增加刀具寿命。理想切屑槽数的选取取决于切削价值分析或成本核算。成本构成和加工能力的有效发挥也是重要因素。

切屑厚度越小，所能承受的切削力也会减小，因而导致作用在滚刀刀刃上的切削应力降低，从而减少磨损。因此切屑厚度的减小也有助于提高刀具的使用寿命。

如果能够保持滚刀直径不变，增加切屑槽数可以减少重磨加工的次数。

带有20至30个切屑槽和有效刀齿长度重磨加工次数约为10次的滚刀称为多槽刀具。

近几年的研究表明，大多数情况下多切屑槽刀是最佳加工工具。

Longer tool life

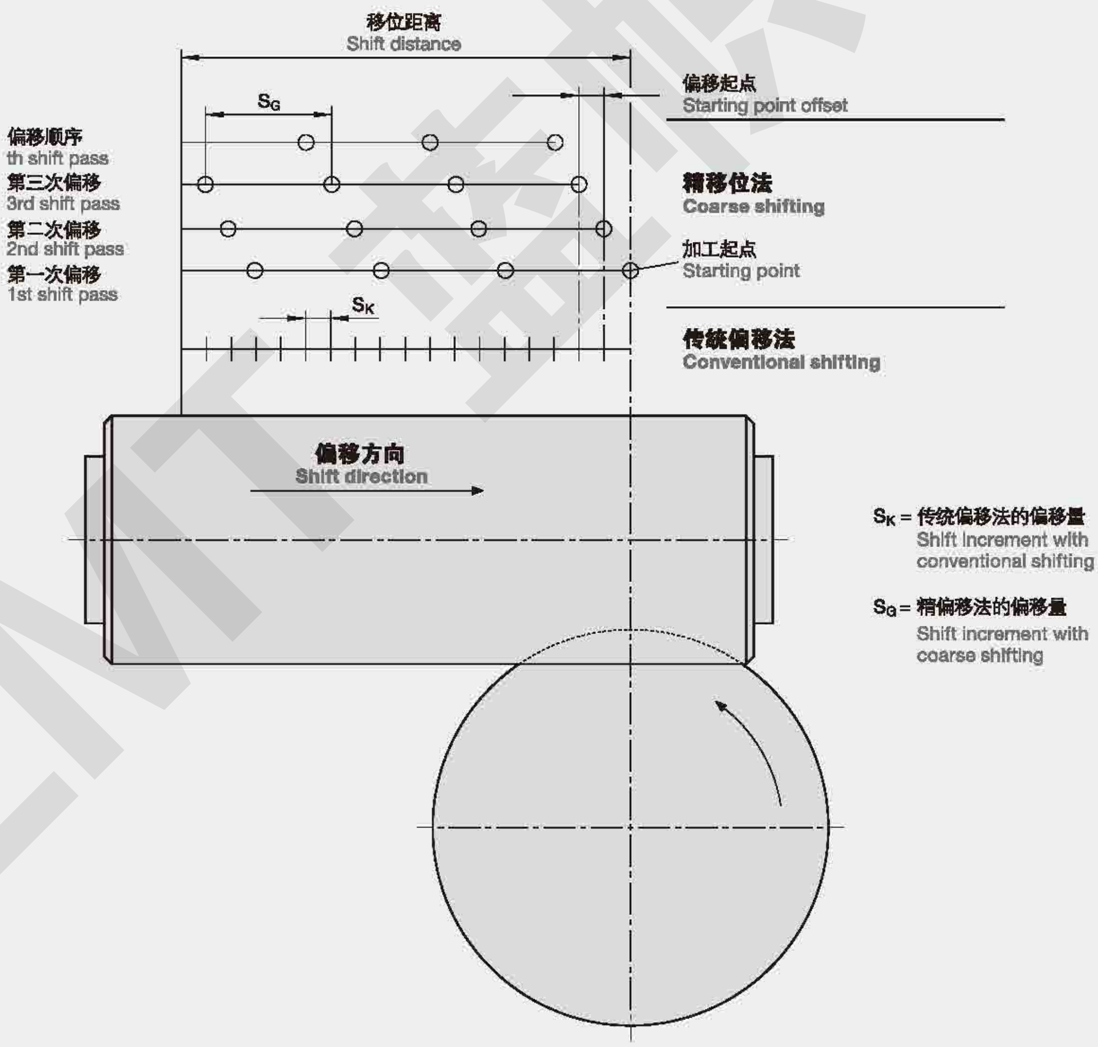
A decisive constructive measure to extend the tool life is to increase the number of gashes. While the length of the cutting edge stays the same, more cutting edges will be available. This increases tool life. The optimum number of gashes can be determined by a cutting value analysis and/or a cost calculation. The cost structure and the capacity utilization of the user also play an important part.

Assuming that the hob diameter remains unchanged, however, an increase in the number of gashes reduces the number of possible regrinds.

Hobs with 20 to 30 gashes and a useful tooth length for approximately 10 regrinds are described as **multi-tooth hobs.**

Developments over recent years have shown that in the majority of cases, the multi-tooth hob is the most suitable tool.

移位方法：粗移位
Shift strategy: Coarse shifting



多切屑槽刀也会产生一个密集性切削网，能使齿轮的齿廓得到修正。这对于具有少量齿数的工件具有特别重要的意义。

为了提高刀具的使用寿命，必须对高效率滚刀进行涂层处理。高硬度的涂层材料可以使切削面和滚刀刀齿面之间摩擦力减小而提高刀具切削速度和进给，从而大大提高刀具的使用寿命。

当滚刀重磨时，刀刃上的涂层便从切削面上脱落。在未涂层切削表面上的凹陷增加，从而减少了刀具的作用寿命。为了将高效率刀具的潜能充分发挥出来，必须对具有高性能滚刀进行重复涂层处理。

如果刀具长度增加，刀具的使用寿命也会明显提高，因为在刀具磨损性能不变的情况下增加刀具长度也会相应地增加刀具的移位（串刀）距离。

切削移位法对刀具使用寿命有重要影响。高性能滚刀的移位方法称为粗移位法。

刀具偏移距离的计算方法类似于将有效偏移距离与能够在两次修磨之间加工的工件数量相除得到。在传统的滚齿机上，标准操作程序是根据上述方法计算得到的移位增量值移动滚刀，然后对其进行重磨处理。经验表明在增加移位增量的情况下对滚刀进行多次移位操作也可以大幅度提高刀具的使用寿命。重要的是每次移位是从起始位置到下一个移位路线上的加工点位置沿移位方向再移动一段最小距离。

粗移位法也有助于对磨损情况作近距离观察，方便将专用的磨损标记粘贴在相应位置，见11页。

缩短加工时间

滚削过程的加工时间（生产时间）一方面取决于待加工齿轮的厚度和齿数，另一方面取决于切削速度、滚刀直径、刀头数量以及轴向进给量。

齿轮的厚度和齿数是固定的几何参数值。切削速度主要取决于齿轮材料，即它的抗拉强度和可加工性。

改变加工时间也是滚刀直径的一种功能，在较小的滚刀直径和切削速度不变的条件下，当滚刀轴的转速增加时，加工所需时间也将减少。同时减小滚刀直径会相应地缩短轴向加工的长度。

A hob with a high number of gashes also generates a denser envelope network, i.e. the profile form of the gear is improved. This is particularly significant for workpieces with a small number of teeth.

In order to achieve a high tool life quality, high-performance hobs must be coated. The high degree of hardness of the coating and the reduction in friction between the chips and the cutting faces and flanks of the cutter teeth permit higher cutting speeds and feeds together with considerably longer tool life.

When the hob is sharpened, the coating is removed from the cutting faces. Pitting increases on the now uncoated cutting faces, and the tool life quality is reduced. In order to exploit the high performance potential of these hobs in full, hobs for high-performance machining must be **re-coated**.

The tool life quality is obviously also increased if the cutter length is extended, since the shift distance is extended equally to the **cutter length.**

The shift strategy has a considerable influence upon the tool life quality. The strategy for high-performance hobbing is described **as coarse shifting.**

The shift increment is calculated in the familiar way by dividing the available shift distance by the number of workpieces or workpiece packs which can be machined between two regrinds. On conventional hobbing machines, the standard procedure was to shift the hob through once by the shift increment calculated in this way, and then to regrind it. Practical experience has shown however that the tool life is raised considerably if the hob is shifted through several times with an increased shift increment. It is important that the starting point for the subsequent shift pass is displaced with each shift by a small distance in the direction of shifting.

Coarse shifting also enables the wear development to be observed closely and the specified wear mark width to be adhered to without difficulty, see fig. page 11.

Shorter machining times

The machining time (production time) for the hobbing process is determined on the one hand by the gear width and number of teeth, and on the other by the cutting speed, hob diameter, number of starts, and axial feed.

The gear width and the number of teeth are fixed geometric values. The cutting speed is largely dependent upon the gear material, its tensile strength and machineability.

The machining time however changes with the hob diameter. With a small hob diameter and with the cutting speed unchanged, the hob spindle and table speeds increase, and the machining time is reduced. At the same time, a reduction in hob diameter results in a reduction in the hobbing distance for axial machining.

在选择滚刀直径时，应注意滚刀切屑槽数会受到滚刀直径的限制。切屑槽数较多的滚刀有较好的刀具寿命和较低的切削应力。

因此，切削直径应该尽量小从而获得规定的切削时间。但过小的切削直径会影响刀具的使用寿命和齿轮的加工质量。

较大的轴向进给和多头滚刀也可以大大降低加工时间。但同时会增加切屑厚度，多头滚刀对切屑厚度的影响比轴向进给的影响更大。

进给速度应尽量高一些，刀头数目应尽量减少。二者影响因素相结合产生最低的切屑厚度。两种参数对于计算加工时间的影响效果是同等重要的，例如加工时间是由进给量和刀具头数决定的。

在达到最大切屑厚度之前，当进给量受进给切痕深度的限制时，刀具头数肯定会增加。

进给切痕深度取决于加工齿轮是否为粗滚齿或精滚齿。

When selecting the hob diameter, note that the number of gashes is limited by this dimension, and that a high number of gashes is required for good tool life and lower cutting forces.

The cutter diameter should therefore only be sufficiently small to enable a specified cycle time to be achieved. An unnecessarily small hob diameter impairs the tool life and gear quality.

High axial feeds and multi-start hobs reduce the machining time considerably. However, they also lead to higher tip chip thicknesses, dependent more strongly by the number of starts than by the increased axial feed.

A relatively high feed should be selected, and the number of starts kept as low as possible. This combination produces the lowest tip chip thickness. The two variables are of equal importance for calculation of the machining time, i.e. the machining time is determined by the product of the feed and the number of starts.

The number of starts always needs to be increased when the feed is restricted by the depth of the feed marks, without reaching the maximum tip chip thickness. The depth of the feed marks depends whether it is for roughing or finish-hobbing.

滚刀加工时间
Machining time (production time) for hobbing

$$t_h = \frac{z_2 \cdot d_{a0} \cdot \pi \cdot (E + b + A)}{z_0 \cdot f_a \cdot v_c \cdot 100}$$

t_h [min] = 加工时间
Machining time

z_2 = 被加工齿轮的齿数
Number of teeth of the gear to be machined

d_{a0} [mm] = 滚刀齿顶圆直径
Tip circle diameter of the hob

E [mm] = 滚刀主长度
Approach length of the hob

b [mm] = 被加工齿轮的齿厚
Tooth width of the gear to be machined

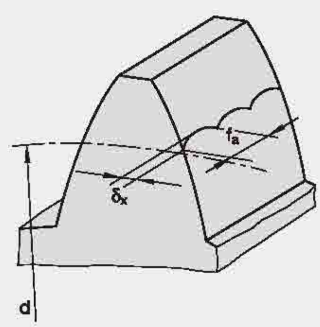
A [mm] = 滚刀空移位距离
Idle travel distance of the hob

z_0 = 滚刀头数
Number of starts of the hob

f_a [mm/WU] = 轴向进给量
Axial feed

v_c [m/min] = 切削速度
Cutting speed

进给标记的深度
Depth on the feed markings



$$\delta_x \text{ [mm]} = \left(\frac{f_a}{\cos \beta_0}\right)^2 \cdot \frac{\sin \alpha_n}{4 \cdot d_{a0}}$$

δ_x [mm] = 进给切痕深度
Depth of the feed marking

f_a [mm/WU] = 轴向进给量
Axial feed

β_0 = 螺旋角
Helix angle

α_n = 齿形角
Profile angle

d_{a0} [mm] = 滚刀齿顶圆直径
Tip circle diameter of the hob

齿轮质量

齿轮质量的好坏主要取决于滚齿机的精度、滚刀质量、工件夹具的稳定性、工件和滚刀的原点径向和轴向跳动。

轴向进给和滚刀直径对进给切痕深度有决定性作用。还要考虑若有的滚齿后的剃削加工或磨削加工等后续精加工工艺，因此必须对进给切痕以及进给量加以限制。

刀具头数和切屑槽数对包络切削误差有很大影响。滚刀外径，切屑槽数，刀具头数，轴向进给和切削深度在计算切屑厚度时都应该加以考虑，它会影响切削力和齿轮的加工质量。对于质量方面，不仅必须确保滚刀质量符合DIN3968标准或针对每种滚削操作制定的类似滚刀标准；也必须检查切屑厚度，进给切痕和包络切削误差，从而确保以上项目在规定的限制范围之内。

小结

滚齿工艺的优化必须充分考虑整个系统，包括滚齿机、工件、滚刀、及切削参数的确定。

如果系统中的一个变量参数发生改变，那么必须从经济性和质量可靠性方面对该变量所能够影响的内容加以检查。

理想的高性能滚刀总能够满足各种类型的齿轮需求。在第34页给出的尺寸表可以作参考，在选用滚刀直径时如果选取范围过大将会加以限制，从而有助于减少成本。

Gear quality

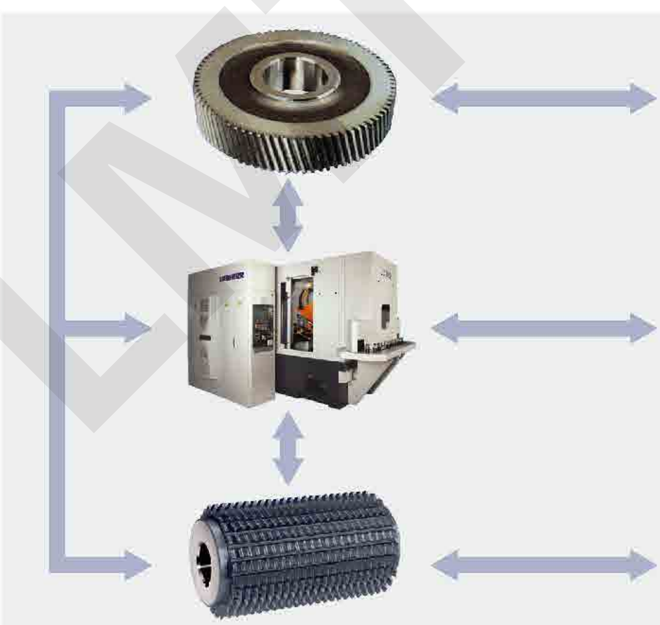
The gear quality is determined primarily by the accuracy of the hobbing machine, the quality of the hob, stable clamping of the workpiece, and zero radial and axial runout of the workpiece and hob.

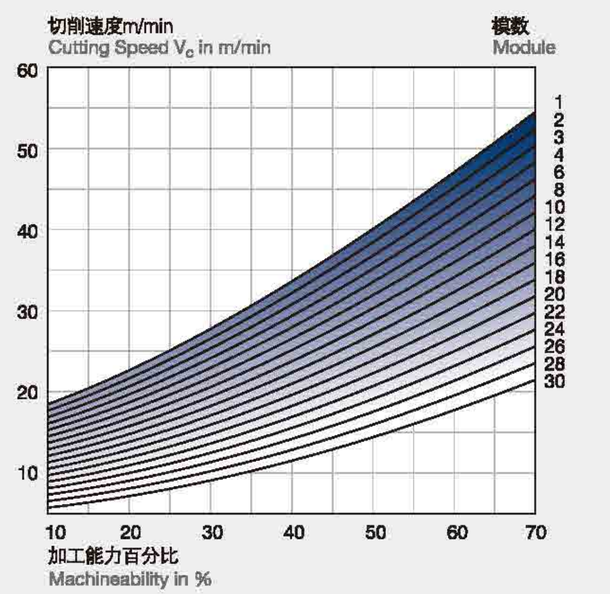
The axial feed and the diameter of the hob are decisive for the depth of the feed marks. In consideration of the gear quality produced during finish-hobbing or subsequent processes such as honing and grinding, the depth of the feed marks and therefore the feed must be limited.

The number of starts and the number of gashes influence the enveloping cut deviations. The hob diameter, number of gashes, number of starts, axial feed, and cutting depth are included in the calculation of the tip chip thicknesses, and therefore influence the cutting forces and also the quality of the gear. With regard to the quality aspects, not only the correct hob quality must be specified to DIN 3968 or comparable hob standards for each hobbing arrangement; the chip thickness, feed marks and enveloping cut deviations must also be checked to ensure that they lie within the specified limits.

Summary

Optimization of the hobbing process requires consideration of the entire system, comprising the hobbing machine, workpiece, hob, and cutting parameters.
Should one variable in this system change, the effects upon the various targets must be examined, with regard to both economical and quality aspects.
An ideal high-performance hob is always geared to the individual application. The size table shown on page 34 should therefore only be regarded as a guide by means of which the huge range of possible hob diameters can be limited and a contribution consequently made towards reduction of the costs.





我们同样可优化你的滚齿工艺
We can also optimize your hobbing process

为了这个目的，我们需要一份完整的工件描述，先前所用的滚刀，加工参数和结果。必须设定一个明确的优化目标。

零件描述:
- 模数
- 压力角
- 螺旋角
- 齿数
- 齿顶园直径
- 全齿深或齿根园
- 齿廓变形系数或设定齿厚标准
- 齿轮宽度
- 材料和抗拉强度
- 被加工零件的数量

对应用的滚刀的描述:
- 滚刀的直径
- 切削刃长度
- 容屑槽数
- 头数
- 材料
- 涂层/未涂层
- 涂层滚刀在修磨后的涂层情况

加工参数的描述:
- 切削速度
- 进给量
- 移位增量值
- 一次装夹工件的数量
- 一次切削/多次切削工艺
- 顺铣或逆铣滚齿

结果的叙述:
- 每一次重磨的使用寿命
- 滚刀上磨损痕迹的长度
- 一个或一组工件的加工时间

如果出现质量问题:
- 工件能达到的质量

阐述优化的目标:

希望可能实现的目标包括
- 较短的加工时间
- 较高的刀具使用寿命
- 较好的齿轮质量

制定要达到的目标应该是适当的，例如，“改善齿轮的质量”会影响加工的时间和加工齿轮的成本。
目标必须因此在剩下的加工结果上通过质量上的和数量上的规范来改善

必须标注受机床影响的参数例如:
- 最大的刀具外径
- 最大的刀具长度
- 最大的刀杆和工作台速度
- 最大的串刀量

For this purpose we require a complete description of the workpiece, the hob previously used, the process parameters, and the results. A clear target must be specified for optimization.

Description of the workpiece:
- Module
- Pressure angle
- Helix angle
- Number of teeth
- Tip circle diameter
- Tooth height or root circle diameter
- Profile displacement factor or standards for setting the tooth thickness
- Width of the gear
- Material and tensile strength
- Number of workpieces to be machined; lot size, if applicable

Description of the hob employed:
- Hob diameter
- Cutting edge length
- Number of gashes
- Number of starts
- Cutting material
- Coated/uncoated
- Coating with hob in new condition, reground with or without re-coating

Description of the process parameters:
- Cutting speed
- Feed
- Shift increment
- Number of workpieces clamped in the pack
- Single-cut/multiple-cut process
- Climb or conventional hobbing

Description of the results:
- Tool life quality per regrind
- Length of the wear mark on the hob
- Machining time per workpiece or workpiece pack

In the event of quality problems:
- Quality attained on the workpiece

Formulation of the optimization objectives:

Possible targets may include:
- Shorter machining times
- Superior tool life quality
- Superior gear quality

When defining the gearing targets, it has to be considered that, for example, the objective “improvement of the gear quality”, influence the machining time and gear generation costs.
The objective must therefore always be supplemented by a qualitative and quantitative specification of the remaining process results.

Limit values imposed by the machine must be specified, such as:
- Max. cutter diameter
- Max. cutter length
- Max. cutter spindle and table speed
- Max. shift distance

加工渐开线齿轮的剃前滚刀表格
Hobs with protuberance for involute gear forms

1 键槽
Keyway

2 20度压力角
Pressure angle 20°

3 单头、右旋
Single-start right-handed

4 单头左旋
Single-start left-handed

5 铲磨
Relief ground

6 含钴高速钢
Cobalt alloyed
high speed steel

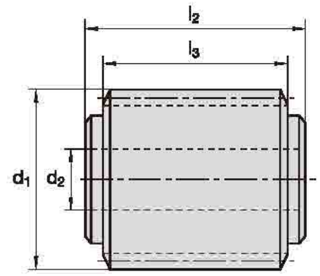
7 “速切王”材料
SpeedCore

8 粉沫高速钢
High speed steel PM

9 涂层
Coatings

10 标准
Standard

11 特殊齿形
Special BP



更详细的内容可在196页找到
You find a general pictogram overview at page 196.

询价单
Inquiry form

日期
Date

公司
Company

用户编号
Customer No.

名称
Name

街道
Street

邮政编码/城市
Post Code/City

电子信箱
E-Mail

齿轮、外花键滚刀
Hobs for gears and external splines

发送你的询价单到： Please send your inquiry to: **Gearcutting@lmt-tools.com**

菲特刀具编号：
LMT Fette-Ident-No.:

工件图纸编号：
Workpiece drawing No.:

刀具图纸编号：
Tool drawing No.:

刀具数量： Qty.: ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

☐ **模数：** Module: ☐ 径节 ☐ 周节

☐ **节距：** Pitch:

压力角：
Pressure angle:

☐ **粗切滚刀** Rough hobbing cutter:
☐ **精切滚刀** Finish hobbing cutter:

基本齿形： Basic profile:

☐ „1" DIN 3972
☐ „2" DIN 3972
☐ „3" DIN 3972
☐ „4" DIN 3972
☐ DIN 5480
☐ ISO 53
☐ BS 2062
☐ AGMA 201.02-1968
☐ AGMA 201.02-1968 STUB

材料： ☐ PM ☐ SpeedCore ☐ HM

涂层： Coating:
☐ TiCN Plus ☐ AL2Plus

☐ **齿轮参数：**
From gear data:

☐ **客户参数：**
From customer data:

齿顶倒角 Semi topping	☐ ja yes ☐ nein no
挖根 Protuberance	☐ ja yes ☐ nein no
全切 Topping	☐ ja yes ☐ nein no
齿顶修缘 Tip relief	☐ ja yes ☐ nein no
齿底全圆弧 Full radius	☐ ja yes ☐ nein no

☐ **铲磨** relief-ground
☐ **非铲磨** unground

刀具参数 Tool data

精度等级 Quality grade: ☐ AAA ☐ AA ☐ A

标准 To standard: ☐ DIN 3968 ☐ N132 ☐ AGMA ☐ BS

非标公差：
Non-standard tolerance:

头数：
Number of starts:

旋向 Direction of starts: ☐ 右 right ☐ 左 left

外径 -Ø (d_1):
Outside diameter (d_1):

切削长度 (l_3):
Cutting length (l_3):

刀具全长 (l_1):
Overall length (l_1):

内孔直径 -Ø (d_2):
Bore diameter (d_2):

槽数：
Number of gashes:

前角：
Rake angle:

客户滚刀槽数：
Number of gashes customer data:
☐ ja yes ☐ nein no

驱动方式 Drive

☐ **轴向键槽 138**
Keyway DIN 138

☐ **右端面键 138**
One right-hand drive slot DIN 138

☐ **左端面键 138**
One left-hand drive slot DIN 138

☐ **双端面键**
Two drive slots

☐ **mit Schaft Typ GP1** Type GP1 shank
☐ **mit Schaft Typ GP2** Type GP2 shank
☐ **mit Schaft Typ GP3** Type GP3 shank
☐ **mit Schaft Typ GP4** Type GP4 shank
☐ **mit Schaft Typ LH1** Type LH1 shank
☐ **特殊柄** Special shank

备注 Notes:

齿轮齿形基本参数
Basic profile from gear data

☐ **模数** Module ☐ 径节 ☐ 周节
☐ **节距** Pitch:

齿数：
Number of teeth:

压力角：
Pressure angle:

螺旋角：
Helix angle:

齿顶圆-Ø:
Tip circle diameter:

齿根圆-Ø:
Root circle diameter:

有效齿顶圆-Ø:
Effective tip circle dia.:

有效齿顶圆 -Ø:
Effective root circle dia.:

齿顶径向倒角总量：
Radial amount of the tip chamfer:

单边齿厚留量：
Stock per flank:

公法线跨齿数：
Number of teeth for checking:

公法线长度 Tooth width:
成品 finished
半成品 milled

球径/棒径：
Ball dia./pin dia.:

球间距
Diametral dimension between balls:
finished
milled

棒间距
Diametral dimension between pins:
成品 finished
半成品 milled

客户给的刀具基本齿形参数
Basic profile data from customer data

齿顶高
Addendum at $p_o/2$:

全齿高
Depth of tooth (h_{P0}):

齿顶圆半径
Tip radius (ϱ_{aP0}):

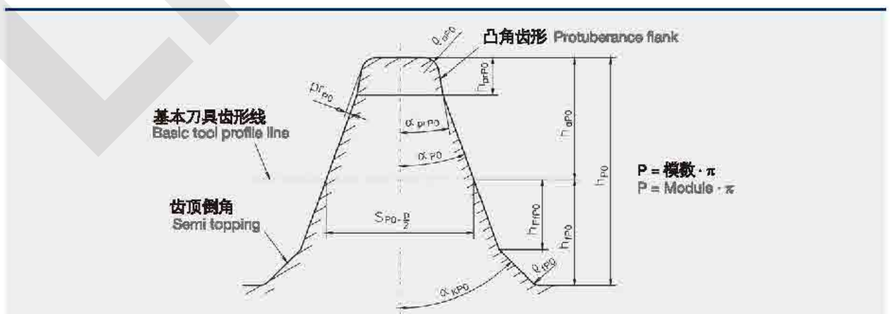
齿根圆半径
Root radius (ϱ_{fP0}):

切深
Depth of cut (frt):

总挖根量
Protuberance amount:

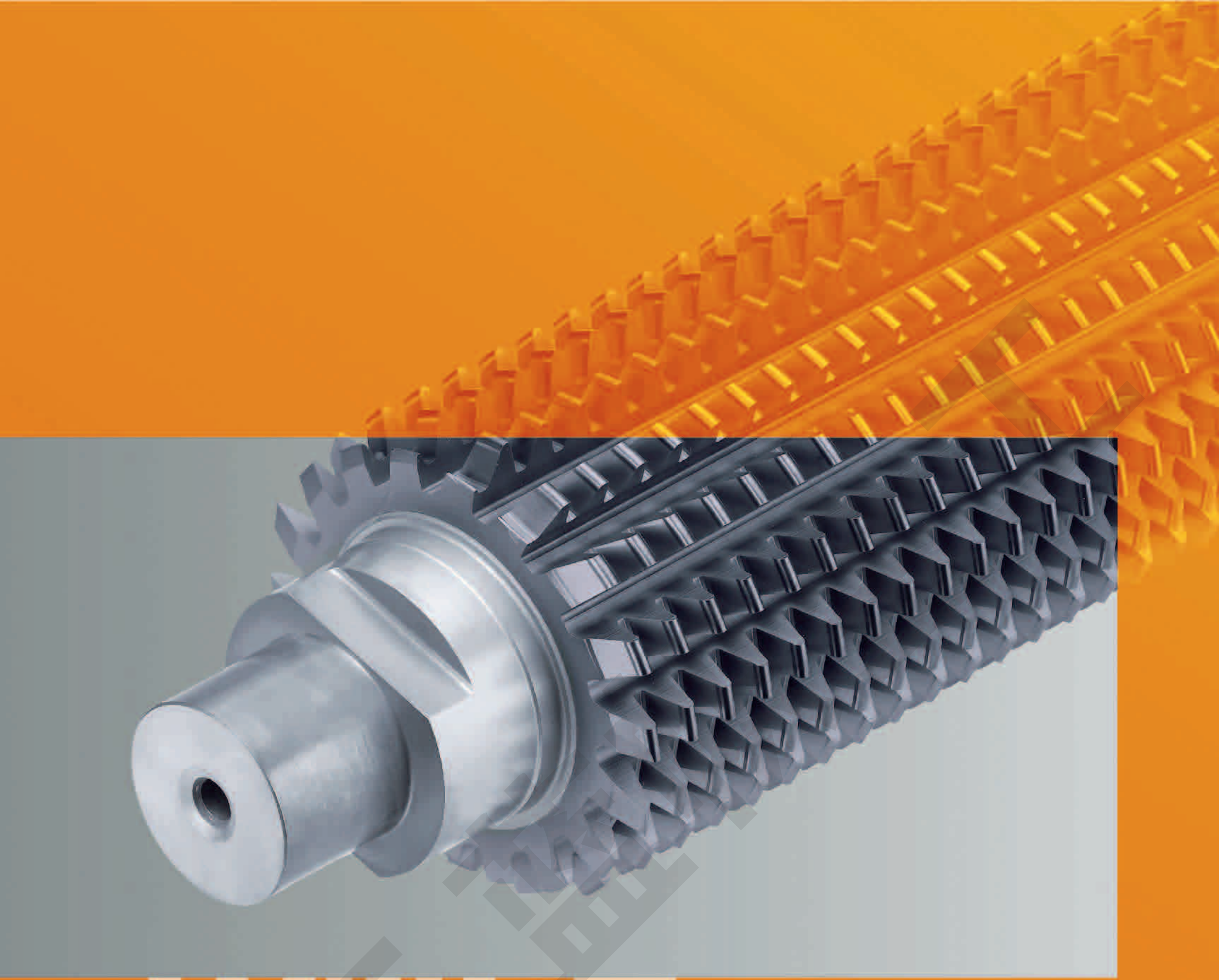
倒角高度
Height of semi topping:

倒角角度
Profile angle semi topping flank:



LMT Tool Systems GmbH
Heidenheimer Strasse 84 · 73447 Oberkochen
Telefon +49 7364 9579-0 · Telefax +49 7364 9579-8000
lmt.de@lmt-tools.com · www.lmt-tools.com

LMT Fette Werkzeugtechnik GmbH & Co. KG
Grabauer Strasse 24 · 21493 Schwarzenbek
Telefon +49 4151 12-0 · Telefax +49 4151 3797
info@lmt-fette.com · www.lmt-fette.com



WÄLZ-FRÄSER

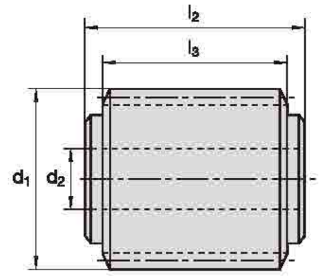
FÜR STIRNRÄDER HSS/SPEEDCORE

HOBS FOR SPUR GEARS HSS/SPEEDCORE

采用高速钢和速切王材料的齿轮滚刀

高速钢和速切王材料的滚刀
Hobs for spur gears, HSS/SpeedCore

RH1 | Relief ground | KHSS-E | Speed Core | HSS-PM[1] | DIN 3968A[1] | DIN 3972 BP II



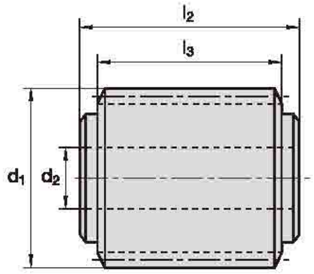
Katalog-Nr. Cat.-No.						2032
m	d_1	l_3	l_1	d_2	z	订货号
1	50	25	31	22	14	1205165
1,25	50	25	31	22	14	1205174
1,5	56	32	38	22	12	1205183
1,75	56	32	38	22	12	1205192
2	63	40	46	27	12	1205209
2,25	70	50	56	27	12	1205218
2,5	70	50	56	27	12	1205227
2,75	70	50	56	27	12	1205236
3	80	63	69	32	12	1205245
3,25	80	63	69	32	12	1205254
3,5	80	63	69	32	12	1205263
3,75	90	70	78	32	12	1205272
4	90	70	78	32	12	1205281
4,5	90	70	78	32	10	1205290
5	100	80	88	32	10	1205307
5,5	100	80	88	32	10	1205316
6	115	100	108	40	10	1205325
6,5	115	100	108	40	10	1205334
7	115	100	108	40	10	1205343
8	125	130	138	40	10	1205352
9	125	130	138	40	10	1205361
10	140	160	170	40	10	1205370
11	160	170	180	50	9	1205389
12	170	185	195	50	9	1205398
13	180	200	210	50	9	1205405
14	190	215	225	50	9	1205414
15	200	225	235	60	9	1205423
16	210	238	248	60	9	1205432
17	220	238	248	60	9	2264410
18	230	260	270	60	9	1205450
19	240	260	270	60	9	1203986
20	250	286	296	60	9	1205478
21	260	290	300	60	9	1203988
22	270	290	300	60	9	2105475
23	280	310	320	60	9	1203990
24	280	310	320	60	9	2107384
25	290	320	330	60	9	2117926
26	310	320	330	80	9	2251168
27	320	330	340	80	9	1203992
28	320	330	340	80	9	1203994
29	340	340	350	80	9	1203996
30	340	340	350	80	9	2117930

[1] 需要时选择 on request

涂层需选择 Coatings on request

渐开线齿轮滚刀
Hobs for involute gear forms

α 20° · RH1 · Relief ground · KHSS -E · Speed Core[1] · HSS -PM[1] · AL2 Plus · DIN 3968A · DIN 3972 BP II



Katalog-Nr. Cat.-No.						2033
m	d_1	l_3	l_1	d_2	z	订货号
1	50	44	50	22	15	1205771
2	63	80	90	27	15	1205773
2,5	70	90	100	27	15	1205775
3	80	110	120	32	15	1205777
4	90	120	130	32	15	1205779
5	100	140	150	32	15	1205781
6	115	140	150	40	15	1205783
7	125	140	150	40	15	1205785
8	140	180	190	50	15	1205787
9	140	180	190	50	14	1205789
10	160	200	210	50	14	1205791

[1] 需要时选择
on request

粗切滚刀具有很高的切削能力，它能满足粗加工齿轮m6以上多齿数和大的齿轮宽度的需要。

它的高切削能力是通过滚刀切削刃特殊的几何结构和相对较多的刀具切削面分配金属移除量来实现的。

由于均分切削刃载荷，即使采用高进给和大的切屑厚度，加工也特别平稳。

这个重载粗切（双切式）滚刀的设计基础是由下列几方面因素决定的：

- 在加工齿轮时，被切除的金属量可以增加2倍，因为齿高比较高，切削槽的数量对常规刀具而言会减少。这将增加每个刀齿的载荷。
- 大约75%金属切除部分是靠滚刀的顶部承担的，这个结果是，特别当粗切时，滚刀齿载荷和磨损非常不均匀。因此，齿顶部的磨损决定了滚刀的寿命，而刀刃的中部及根部却磨损很少。
- 一把高效而经济的滚刀必须要有很多的刀槽数，而加大滚刀的外径，顶部的刀刃数必须大于侧面及根部的刀刃数。

High cutting capacities are achieved with our heavy duty roughing hob when roughing gears from module 6 onwards with high tooth numbers and large gear widths.

These high cutting capacities are made possible by a favourable cutting edge geometry and the distribution of the metal removal capacity over a relatively large number of tool cutting faces.

Because of its even cutting edge load, this tool is particularly quiet in operation, even with maximum feeds and high chip thickness.

The design of the heavy duty roughing hob is based on the following considerations:

- The volume of metal to be removed when cutting gears increases quadratically with the module, whereas the number of gashes, because of the greater profile height, becomes smaller in the usual cutter sizes. This results in a greater load on the individual cutter teeth.
- Approximately 75 % of the metal removal work takes place in the tip area of the hob teeth. This results, particularly when roughing, in an extremely uneven load and wear distribution on the hob teeth. The greater tip corner wear determines the duration of the service life, whereas the cutting edges in the tooth centre- and root area show only very little wear.
- An efficient and economical hob must therefore have a large number of gashes, without making the outside diameter of the cutter too large. The number of tip cutting faces should exceed that of the flank and root cutting edges.

非特重载粗切滚刀极好地满足了这些需求，它有垂直交错齿，它的切削齿在每第二个齿排有完整的齿高，中间齿只有1/3齿高。

这个设计原则是在可使用的直径上制造出20个刀槽。

在刀具中分布10个完整齿对于加工所需公差的齿形来讲足够有余。这个重载粗切滚刀为此同样可以当精切刀用。

依据质量要求，这重载粗滚刀可以是铲齿或铲磨。

在粗加工时，齿顶开槽可以分割切屑片，减少滚刀切削刃的压力和磨损。

粗切滚刀可以在任何一台标准滚刀磨床上进行修磨。一旦固定，刀槽能够保留特殊的槽深，滚刀前刀面有6度的前角，修磨采用加深磨的方法。

粗磨滚刀设计的原则不仅适用于基本齿廓为模数制及DP制的渐开线齿形，同样也适用于所有其它普通齿形和专用齿形。

These requirements are met perfectly by the LMT Fette heavy duty roughing hob with its vertically staggered teeth. The hob teeth only have the full profile height in every second tooth row. The intermediate teeth are limited to about 1/3 of the profile height.

This design principle makes it possible to acommodate 20 flutes on a still practicable hob diameter.

The 10 complete teeth on the hob circumference are generally sufficient for producing the profile shape within the required tolerances. The heavy duty roughing hob can therefore also be used as a finishing tool.

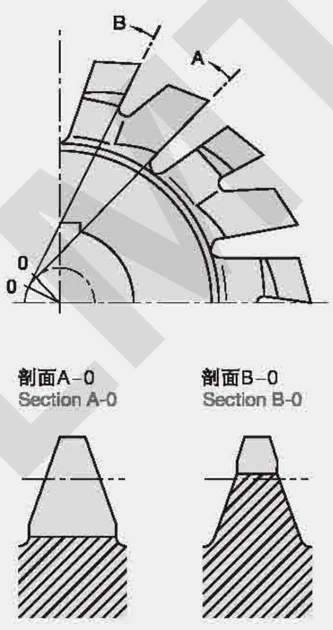
Depending on the quality required, the heavy duty roughing hob is available either relief turned or relief ground.

For roughing, the hob teeth can be provided with offset chip grooves, which divide the chips and reduce cutting forces and wear.

Roughing hobs can be reground on any standard hob grinder. Once set, the gash lead can be retained, independent of the gash depth. Roughing hobs are manufactured with axially parallel gashes up to lead angle of 6°, which is a condition for sharpening by the deep grinding method.

The design principle of the heavy duty roughing hob is of course not limited to the basic profiles for involute tooth systems to module or diametral pitch, but can also be used for all other common profiles and for special profiles.

粗切滚刀的平面图
Face plane of a heavy duty roughing hob

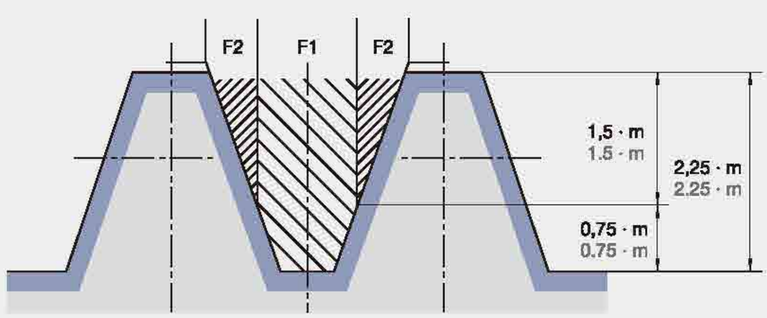


切除金属量在滚刀上的分布

齿顶部分约占 F1 ≈	75 %
齿根部分约占 F2 ≈	25 %
全部切削范围	= 100 %

Metal removal areas on the cutter tooth:

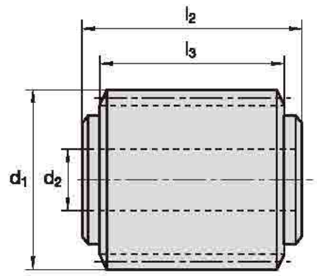
Tooth tip corresponds to area F1 ≈	75 %
Tooth root corresponds to area F2 ≈	25 %
Tooth gash volume	= 100 %



α 20° RH1 KHSS -E HSS -PM [1] AL2 Plus DIN 3972 BP III [2]

Relief turned DIN 3968 B/C

Relief ground DIN 3968A



Katalog-Nr. Cat.-No.						2061	2063
m	d_1	l_3	l_1	d_2	z	订货号	Ident No.
6	150	108	118	50	20	1208017	1208053
7	150	126	136	50	20	1208019	1208055
8	160	144	154	50	20	1208021	1208057
9	160	162	172	50	20	1208023	1208059
10	170	180	190	60	20	1208025	1208061
11	180	198	208	60	20	1208027	1208063
12	190	216	226	60	20	1208029	1208065
13	200	234	244	60	20	1208031	1208067
14	210	252	262	60	20	1208033	1208069
15	230	270	280	80	20	1208035	1208071
16	240	288	300	80	20	1208037	1208073
18	260	318	330	80	20	1208039	1208075
20[3]	287	318	330	80	20	1208041	1208077
20	290	360	372	100	20	1208043	1208079
22	300	396	408	100	20	1208045	1208081
24	310	432	444	100	20	1208047	1208083
27	330	486	498	100	20	1208049	1208085
30	340	540	552	100	20	1208051	1208087

[1] 需要时选择
on request

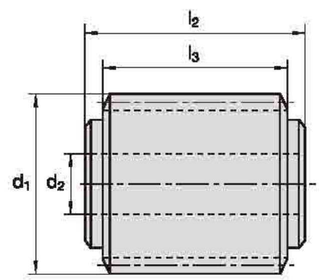
[2] 断屑槽要求时需选择
optionally

[3] 对于滚齿机要求的最大切削外径290mm和最大切削长度330mm
for hobbing machines with max. capacity = 290 mm dia. and for max. cutter length = 330 mm

带凸角的渐开线齿轮滚刀
Hobs with protuberance for involute gear forms

RH1 | LH1 | Relief ground | KHSS-E | Speed Core[1] | HSS-PM[1] | AL2 Plus | DIN 3968A | Special BP[2]

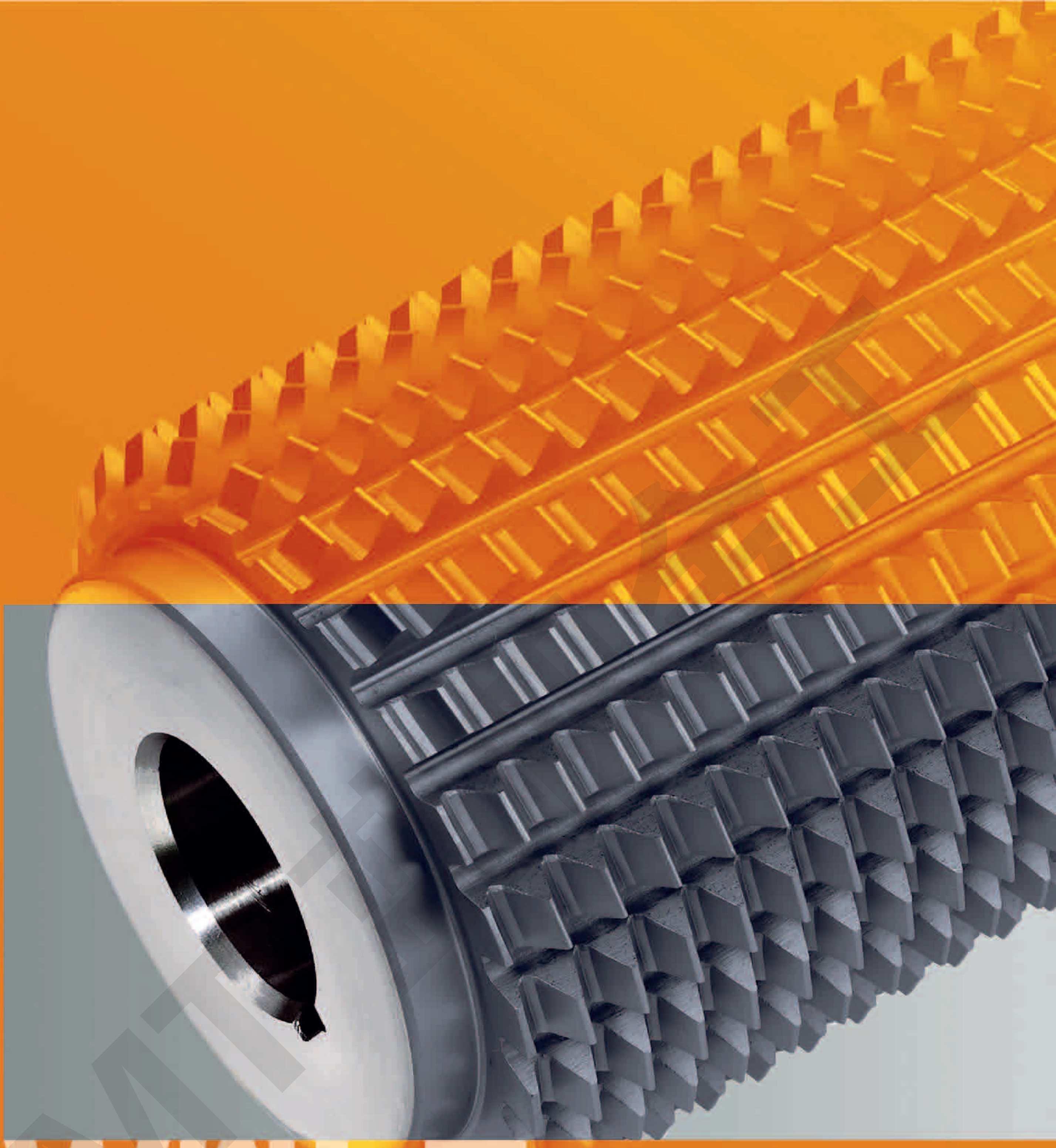
RH | LH



Katalog-Nr. Cat.-No.						2026	
m	d_1	l_3	l_1	d_2	z	订货号	订货号
1	70	50	56	27	17	1223334	1223344
2	70	90	100	27	15	1223326	1223346
3	80	110	120	32	15	1223338	1223348
4	90	120	130	32	14	1223340	1223350
5	100	140	150	32	14	1223343	1223352
6	140	140	150	40	14	1223345	1223355
7	150	140	150	40	14	1223347	1223357
8	160	160	170	50	14	1223349	1223359
9	170	160	170	50	14	1223351	1223361
10	180	180	190	50	14	1223353	1223363
12	200	200	210	60	12	1223356	1223365

[1] 需要时选择
on request

[2] 对于磨前和刮前的粗切滚齿
基本齿形 $h_{a0} = 1,4 \cdot m$, $\varrho_{a0} = 0,4 \cdot m$
齿形单侧的留量：$q_{P0} = 0,09 + 0,0125 \cdot m$
凸角值：
$pr_{P0} = 0,129 + 0,290 \cdot m$ bis Modul 7
$pr_{P0} = 0,181 + 0,235 \cdot m$ größer Modul 7
for rough hobbing prior to grinding or skive hobbing
basic profile: $h_{a0} = 1.4 \cdot m$, $\varrho_{a0} = 0.4 \cdot m$
allowance per flank: $q_{P0} = 0.09 + 0.0125 \cdot m$
protuberance value:
$pr_{P0} = 0.129 + 0.290 \cdot m$ up to module 7
$pr_{P0} = 0.181 + 0.235 \cdot m$ above module 7



WÄLZ-FRÄSER

FÜR STIRNRÄDER HARTMETALL

CARBIDE HOBS FOR SPUR GEARS

加工圆柱齿轮的硬质合金滚刀

加工圆柱齿轮的硬质合金滚刀
Carbide hobs for spur gears

整体硬质合金滚刀准许达到像高速切削（HSC）一样的速度。它的速度明显高于那些高速钢滚刀。

整体硬质合金滚刀要求不断开发滚齿机的额定速度，以适应其应用。

高速切削（HSC）与干加工结合是比较经济的。

现代整体硬质合金滚刀的优越特性

- 高的切削速度
- 短的加工时间
- 长的使用寿命
- 很适合干加工
- 不需要对P类硬质合金重新涂层
- 降低齿轮加工成本

Carbide hobs permit cutting speeds into the high-speed cutting (HSC) range, and significantly higher than those possible with high-speed steel hobs.

The development of suitably rated hobbing machines enables the advantages of carbide hobs to be exploited in practical use.

The combination of high-speed cutting (HSC) and dry machining presents substantial potential for rationalization.

Modern carbide hobs provide the following characteristics:

- High cutting speeds
- Short machining times
- Long tool life
- High suitability for dry machining
- Lower gear production costs (according to the machining task)

硬质合金类型

一般使用K类和P类硬质合金材料。由于其材料组成元素（合金组成元素）以及颗粒度的不同，决定了材料具有相对应的优点和缺点。

由于K类硬质合金表面易与无涂层的基质相结合，所以只能通过涂层才能使用。P类硬质合金则可以在不涂层的情形下使用，因此不需要在重磨后的切削表面再次进行涂层处理，这就大大减少了采用P类硬质合金制成的滚刀的维护成本。

与此相反，细颗粒仅仅应用在K类硬质合金上。细颗粒具有很高的硬度，因此抗磨损能力也很强，强度也高。

因此，与使用P类硬质合金滚刀相比，带有涂层的K类硬质合金刀具通常具有更长的使用寿命，而P类硬质合金刀具在第一次修磨后就失去了切削面的涂层保护，因此必须经常更换。

带/不带冷却液进行切削

在钢材切削过程中，刀刃切削位置会产生大量的热。如果温度达到极限值，刀具的切削刃将会很快损坏。

为了对加工过程中的刀具进行冷却，同时对刀刃进行充分的润滑，过去一段时间往往采用在刀具和工件之间使用冷却液的方法。冷却液还可以除去切削过程中产生的碎屑。

然而，冷却液在生态保护、经济性以及其他许多技术方面存在很多缺点。

冷却液存在着生态保护方面的危害，因为它们会以油泡或油气的形式影响周围环境，从而对人类的健康产生危害。

同样，冷却液也不够经济，因为昂贵的购买和处理费用使之增加了生产成本。如果采用干切削，可以节省齿轮加工过程中高达16%的成本。

另外，从技术角度看使用冷却液也存在很多缺点。在许多滚齿作业过程中使用冷却液会在很多方面影响硬质合金刀刃，例如会导致刀具因为应力裂纹（温度冲击）而过早损坏，因此，湿加工时切削速度限制在250m/min以下（而干加工时速度可达到350至450m/min）。表中给出了有关硬合金滚刀使用冷却液的优点和缺点。

Carbide types

The carbide types generally used are those of the main machining groups K and P. The types present advantages and disadvantages according to their material composition (alloying elements and components) and their grain size.

Whereas K carbides, owing to the tendency of chips to bond to the uncoated substrate, can only be employed fully coated, P carbides can also be employed in uncoated form. There is therefore no need for the cutting face to be re-coated following regrinding. This reduces the maintenance costs for P carbide hobs considerably.

By contrast, fine-grain carbides have as yet only been developed for the K types. Fine-grain carbides permit very high hardness values and consequently a high resistance to wear, combined with excellent toughness.

Consequently, fully coated K substrates generally permit higher tool life qualities when compared with hobs manufactured from P carbides, which lose their cutting face coatings at the first regrind at the latest. P carbide hobs must therefore be changed more frequently.

Machining with and without coolant

The machining of steel materials generates considerable quantities of heat at the point of chip removal. If the temperatures reach excessive levels, the cutting edges of the tool are rapidly destroyed.

In order to cool the tool and at the same time to lubricate the cutting edge, cooling lubricants have in the past been applied to the contact point between the cutting edge and the material to be machined. Cooling lubricants also have the function of flushing away the chips which are produced.

Cooling lubricants, however, have considerable ecological, economic, and in many cases also technological disadvantages.

Cooling lubricants present an ecological hazard since they impact the environment in the form of oil vapour and oil mist, and can present a health hazard to humans.

Cooling lubricants are not economically justifiable, because they increase the production costs owing to the very high costs of their supply and disposal. Up to 16 % of the total gear production costs can be saved by dry machining.

Furthermore, cooling lubricants may pose disadvantages for technological reasons. The use of cooling lubricants in many hobbing operations involving carbide cutting edges, for example, may lead to premature failure of the tool owing to stress cracking (temperature shock). For this reason, cutting speeds are limited to 250 m/min for wet machining (in comparison with 350 to 450 m/min for dry machining). The table shows the advantages and disadvantages of cooling lubricant with regard to carbide hobbing.

干切削的主要问题在于切削温度过高。如果能够注意刀具的设计和采用合理的切削参数，那么由刀具的刀刃部分产生的高达80%的热量是可以通过铁屑带走的。

The main problem with dry machining lies in the increase in cutting temperature. Up to 80 % of the heat which is generated is dissipated with the chips, provided attention has been paid to correct tool design and suitable cutting parameters are employed.

刀具的结构设计取决于待加工齿轮的设计参数。而最重要的影响因素是切屑的厚度。而它是由刀具设计（刀具头数、切削槽数、刀具外径）、工件的几何形状（模数、齿数、切削深度、螺旋角）和所选择的进给量决定的。干切削过程中不但要重点考虑切屑厚度的上限值，还需要考虑它的最小值。铁屑体积越大，单个铁屑所能吸收的热量就越多。必须考虑到要保证在干加工时大部分加工热量要被铁屑带走。

The configuration of the tool is dependent upon the data of the gear to be manufactured. A significant influencing factor is the tip chip thickness, which is derived from the cutter design (number of starts, number of gashes, diameter), the workpiece geometry (module, number of teeth, cutting depth, helix angle) and the selected feed. An important consideration is that dry machining requires observance not only of an upper limit to the tip chip thickness, but also of a minimum thickness value. The greater the chip volume, the greater the quantity of heat which an individual chip can absorb. This must be taken into account in order to ensure that during dry machining, the greater part of the machining heat is dissipated by the chips.

滚齿加工过程中使用冷却液的优点和缺点
Advantages and disadvantages of the use of cooling lubricant during hobbing

	优点 Advantages	缺点 Disadvantages
机床 Machine	■ 有助于清除碎屑 ■ 降低机床的温度 ■ Supports chip removal ■ Lower heating up of the machine	■ 设备复杂（过滤品、泵等等），因此 ■ 需要占用更大的空间 ■ 附加操作的费用支出（维护、电能等） ■ Aggregates (filters, pumps, etc.), therefore: ■ greater space requirements ■ additional operating expenditure (maintenance, power, etc.)
刀具 Tool	■ 冷却刀具 ■ 对摩擦区域起到润滑作用 ■ Cooling of the tool ■ Lubrication of the friction zones	■ 由于裂纹的生成与切削边缘相互垂直，因而会降低刀具的使用寿命（温度冲击） ■ Shorter tool life due to thermal cracks (thermal shock) possible
工件 Workpiece	■ 降低工件温度 ■ 减少尺寸误差 ■ 防腐保护 ■ Lower heating ■ Lower dimensional deviations ■ Protection against corrosion	■ 需要对工件进行清理 ■ Cleaning necessary
环境 Environment	■ 在铸铁加工过程中能粘合石墨粉末 ■ Binding of graphite dust during cast iron machining	■ 对健康有危害 ■ Health risk
更多费用 Further costs	■ 工件回火处理，加快测量速度 ■ Tempering of the workpiece, thus faster measurement	■ 购买费用 ■ 库存费用 ■ 被污染的铁屑，因此： ■ 昂贵的重复利用过程 ■ 处理费用更高 ■ Purchasing costs ■ Inventory costs ■ Contaminated chips, therefore: ■ expensive recycling processes and ■ higher disposal costs

高速切削（HSC）

高速切削的优点有：

- 良好的表面质量、加工时间少（取决于加工条件）
- 切削力小，其原因在于刀具的尺寸精度高，刀具使用寿命长

由于铁屑与切削刃的接触时间短，所产生的热量不会迅速传递到刀具和工件上。因此刀具和工件的温度相对较低。相反，铁屑温度剧烈升高，因而必须迅速移开以防止加工设备温度上升。

在应用实例中，没有采用冷却液的调整切削所导致的工件温度上升到大约为50至60℃。然而，在铁屑产生的位置，在某些情况下的温度会高达900℃，这一点我们可以通过发红的铁屑得出结论。在以上观察的基础上，在高速加工滚齿过程中采用干加工时检验工件的微观切面可以发现其微观结构发生了变化。高速加工形成的齿侧与车削的参考样品作比较可以发现其微观组织并没有发生任何变化。

我们也提到过，高速切削加工必须采用干切削方法。早在20世纪90年代人们已经开始了对高速滚齿的研究。现在的切削工艺已经能够保证在干切削条件下齿轮加工的切削速度达到350m/min以上。

实用实例和切削数据

实践证明，采用整体硬质合金刀具进行齿轮和小齿轮加工的齿轮的模数范围在m=0.5到m=4之间。刀具通常使用稳固的焊接结构用孔式或柄式安装方式加工而成。柄式往往应用于小型刀具。切削速度范围一般在150到350m/min不等，这取决于模数和加工工艺（干加工或冷却液加工）。

图表显示了具有不同抗拉强度的材料采用干加工和冷却液加工时切削速度的不同。该图表的数值适用于整体硬质合金滚刀，模数m=2。

该图明确表明采用干加工能够比冷却液加工获得更高的切削速度。

High-speed cutting (HSC)

The advantages of high-speed cutting are:

- High surface quality and short machining times (depending upon the machining application)
- Low cutting forces, with resulting benefits for the dimensional accuracy of the workpiece and the tool life

Owing to the low contact time between the chip and the cutting edge, the heat which is generated does not have time to flow into the tool or the workpiece. The tool and the workpiece thus remain relatively cold. By contrast, the chips are heated very strongly and must be removed very quickly in order to prevent the machine from heating up.

In an example application, HSC machining without cooling lubricant led to the workpieces being heated to approximately 50–60 °C. At the point of chip generation, however, far higher temperatures occur which under certain circumstances may rise to approximately 900 °C, as indicated by incandescent individual chips. Based upon these observations, a transverse microsection from a workpiece subjected to the dry machining process under optimum machining conditions for the HSC hobbing process was examined for possible changes to the microstructure.

The tooth flanks machined by the HSC process and the reference samples of a turned blank analysed for the purpose of comparison revealed no changes to the microstructure attributable to the machining process.

As already described, HSC machining must be considered together with dry machining. At the beginning of the 1990s the first studies were carried out on HSC gear hobs. Today, this method enables reliable dry machining of gears at cutting speeds of 350 m/min and more.

Applications and cutting data

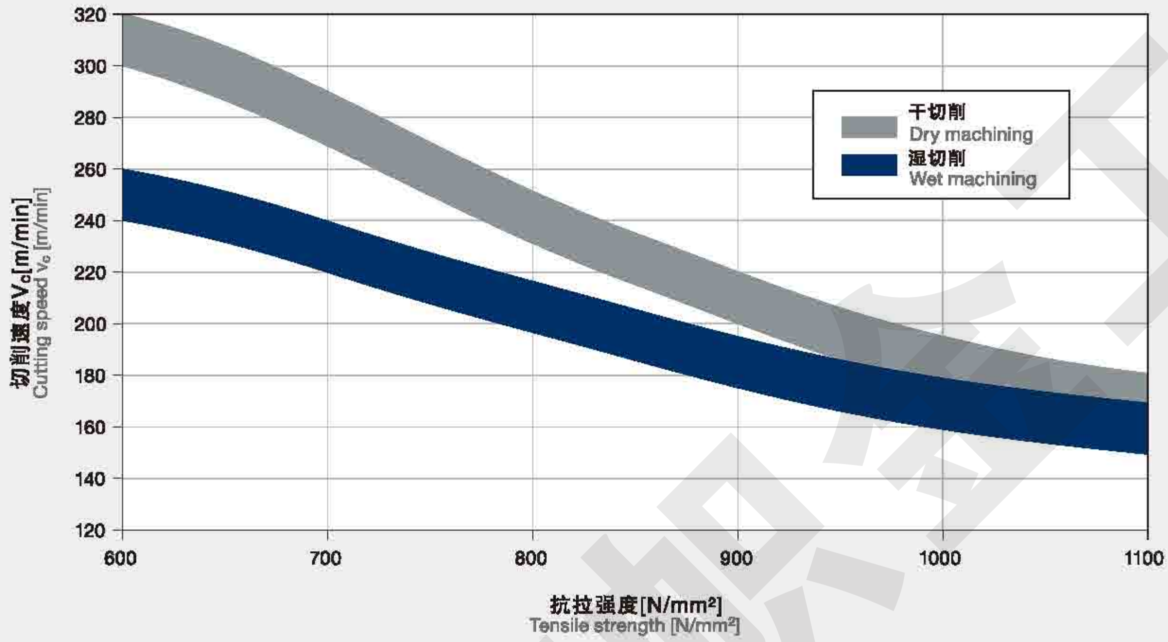
The proven applications for solid carbide tools for gear and pinion manufacture lie in a module range from m = 0.8 to m = 4. The tools are generally manufactured as stable monoblocs with bore- or shank-type mounting arrangement. The shank type is recommended for smaller tools. The cutting speeds are in the range from 150 to 350 m/min, according to the module size and process (dry or wet machining).

The diagram shows the difference in cutting speeds for dry and wet hobbing of materials with a range of tensile strengths. The values in the diagram apply to a solid carbide hob, m = 2.

Substantially higher cutting speeds can be achieved with dry hobbing than with wet hobbing.

LMT·FETTE

不同抗拉强度材料的切削速度对比，整体硬质合金滚刀干和湿加工、模数m2
Cutting speeds for a range of material tensile strengths, carbide hobbing, dry and wet, module 2



磨损情况

齿面磨损是硬质合金滚刀磨损的主要形式。

点蚀是经常在高速钢滚刀发生的磨损现象，但对于硬质合金滚刀一般不会发生。我们偶尔会观察到硬质合金滚刀涂层后在切削刃上有粘屑现象。K类硬质合金滚刀在涂层渗透之后铁屑会粘附在未涂层的切削刃上。因此第一次涂层渗透点必须尽可能的拖延。

磨损的加剧是从一个磨损印痕逐渐向上发展大约0.1mm，并对生产工艺的经济耐受性有很大影响。因此我们建议磨损宽度不得超过0.15mm，且每次进行重磨后必须进行重新涂层。P类硬质合金未涂层切削产生粘屑现象不太多，同此此类滚刀不需要重新涂层。

维护及保养

在对整体硬质合金滚刀进行重磨时，应确保作用在刀尖上的热应力保持最小。我们也推荐对刀刃进行热处理，根据滚刀设计（如正负前角值，切齿宽度），大约可以进行10至20次重磨。

Wear behavior

Flank wear is the chief form of wear occurring on carbide hobs.

Pitting, which occurs on KHSS-E hobs, is not normally significant on carbide hobs. Chipping at the cutting edge following penetration of the carbide coating may occasionally be observed. The chips may adhere to the uncoated cutting edge of K types following penetration of the coating. The point of first penetration of the coating must therefore be delayed as long as possible.

The increase in wear is progressive from a wear mark width of approx. 0.1 mm upwards, and has a considerable influence upon the economic viability of the process. We therefore recommend that a wear mark width of 0.15 mm not be exceeded, and that the cutter be re-coated following each regrind. Chip adhesion to the worn and therefore uncoated cutting edges is much less common with the P types. Re-coating is not therefore necessary with these types.

Maintenance

When regrinding solid carbide hobs, ensure that the thermal stress on the tooth tip is kept to a minimum. A defined edge treatment is also recommended. Depending upon the hob design (e. g. positive or negative rake angle, width of the tooth lands), approximately 10 to 20 regrinds are possible.

使用K类硬质合金材料制作滚刀还需要对其进行“退涂”和“重新喷涂”工艺处理。

有关整体硬质合金滚刀的维护及保养信息可参见第162页内容。

结构尺寸

本尺寸表列出了蓝帜金工FETTE当前储库硬质合金滚刀坯料的尺寸。该坯料没有驱动槽，因此可以根据用户需要将驱动槽置于缘毂左侧或右侧。

蓝帜金工FETTE建议用户，使用端面驱动键槽会减少硬质合金滚刀的切削柄深度。键槽尺寸可以在下表查询。

The “de-coating” and “re-coating” processes are required in addition for hobs manufactured from K type carbide.

Further information on the maintenance of solid carbide hobs can be found on page 162.

Structural dimensions

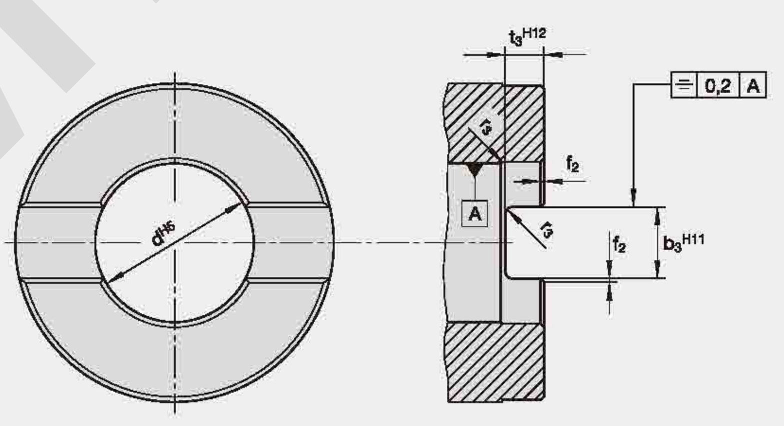
The size table indicates the hob dimensions for which LMT Fette stocks carbide blanks. The blanks do not have drive slots.
A drive slot can therefore be provided on either the left-hand or the right-hand indicator hub, as desired by the customer.

LMT Fette recommends drive slots with reduced gash depth for carbide hobs. The gash dimensions can be found in the table below.

孔 径 Bore diameter	b_3	t_3	r_3	许可偏差 Permissible deviation	f_2	许可偏差 Permissible deviation
8	5,4	2,00	0,6	–0,2	0,4	0,1
10	6,4	2,25	0,8	–0,2	0,5	0,1
13	8,4	2,50	1,0	–0,2	0,5	0,1
16	8,4	2,80	1,0	–0,3	0,6	0,2
22	10,4	3,15	1,2	–0,3	0,6	0,2
27	12,4	3,50	1,2	–0,3	0,8	0,2
32	14,4	4,00	1,6	–0,4	0,8	0,2
40	16,4	4,50	2,0	–0,5	1,0	0,3
50	18,4	5,00	2,0	–0,5	1,0	0,3
60	20,5	5,60	2,0	–0,5	1,0	0,3
70	22,5	6,25	2,5	–0,5	1,2	0,3
80	24,5	7,00	2,5	–0,5	1,2	0,3
100	24,5	8,00	3,0	–0,5	1,6	0,5

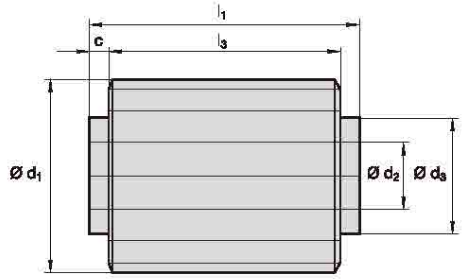
t_3=DIN 138 1/2深度
½ depth to DIN 138

硬质合金滚刀驱动键槽尺寸
Drive slot dimensions of a carbide hob



LMT • FETTE

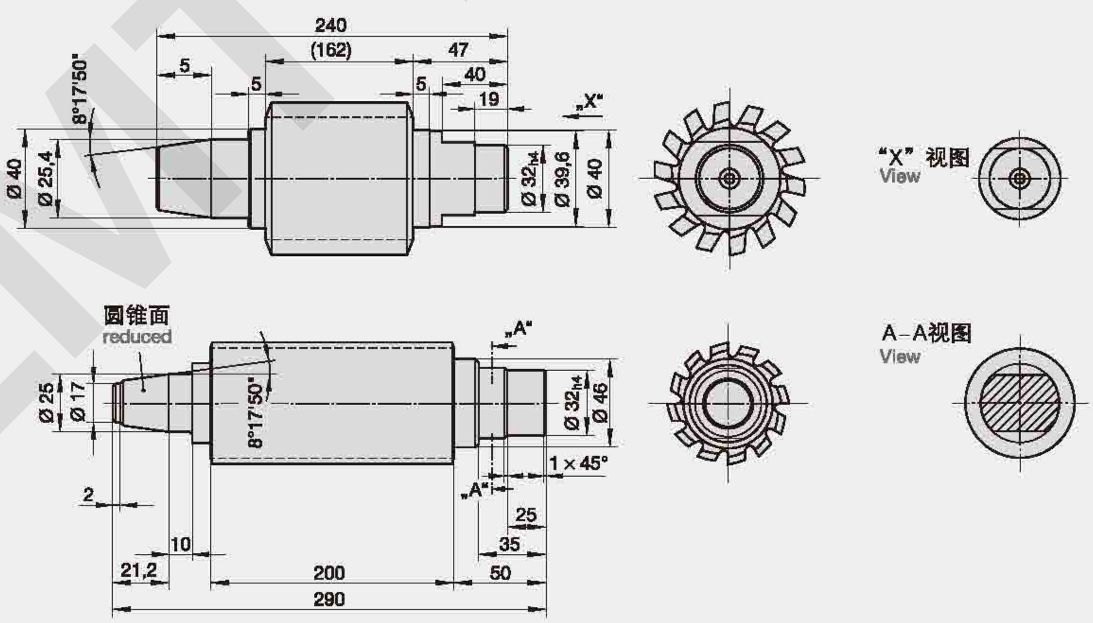
Solid Carbide



推荐尺寸
Recommended dimensions

d_1	l_3	l_1	d_2	c	d_3	h_0	z
				短系列 short			
56	52	70	22	9	42	3	19
63	72	90	27	9	48	4	19
70	100	120	32	10	54	5	19
80	100	120	32	10	54	7	19
90	100	120	40	10	66	8	19
100	120	140	40	10	72	10	19
120	138	160	50	11	80	13	19
				长系列 long			
56	82	100	22	9	42	3	19
63	112	130	27	9	48	4	19
70	160	180	32	10	54	5	19
80	160	180	32	10	54	7	19
90	160	180	40	10	66	8	19
100	180	200	40	10	72	10	19
120	208	230	50	11	80	13	19

可能的柄部尺寸
Possible shank dimensions



工艺及适用范围

刮削加工是利用刮削滚刀对粗切齿轮和淬硬齿轮进行再加工的一种加工工艺。

刮削加工的主要应用领域是直齿和螺旋圆柱齿轮的加工。此外，对外花键，滚压形状和大部分具有特殊形状的齿轮也可以使用刮削加工。有许多情况需要使用这种加工工艺：

齿轮精滚加工

刮削加工可以消除齿轮的淬火变形，改善齿轮的加工质量。

刮削加工在切削金属能力方面比普通的磨削加工工艺要强很多。因此，在大和中等误差的情况下使用刮削加工代替传统的磨削加工是比较经济的。

刮削加工的齿轮精度可以达到DIN3962标准质量等级为6级的精度级别。

齿廓和齿面的修正，例如齿高修形，齿面修形或齿厚修形等都可以采用合适的滚刀和相关加工设备实现。

磨削的准备工作

对齿轮质量要求较高的情况，齿轮是采用磨削工艺加工而成的。如果在进行磨削加工之前采用刮削加工将齿轮的淬火变形去除，就可以大大减少加工所需的费用，同时也可以将毛坯材料刮削到磨削加工所要求的加工精度范围以内。这样可以降低磨削次数，减少加工的费用，同时获得额外的磨削能力。

设计

刮削滚刀的设计特征为负前角，在刀具基面前方，沿着切削进给的方向在刀刃所在的切削平面上，刀刃前角是负的。基面是平行于刀具和刀具轴线的滚刀刀刃所在的平面。

这个负前角是刀具切削面沿着与有效基面（与切削进给方向垂直的面）相交方向倾斜该方向，用这种方式产生刮削。

刀刃顶端区域的负前角比刀齿根部的负前角大。刀刃顶端没有有效的后倾角，因此不能进行曲线加工。所以刮削滚刀只能进行侧齿加工，而挖根刀具适用于齿轮的粗加工工艺。

Process and range of applications

Skive hobbing is a machining process in which skiving hobs are used for cutting **rough-milled** and **hardened gears.**

The main area of application is the hobbing of straight and helical spur gears. In addition, external splines, roll profiles and a large number of special profiles which can be generated by the hobbing method can be machined with the skiving hob. There are various reasons for using this process.

Finish-hobbing of gears

Skive hobbing eliminates hardening distortion and improves the quality of the gear.

The metal removal capacity is considerably higher with skive hobbing than with the usual grinding processes. It is therefore economical to replace grinding by skive hobbing in the range of coarse and medium gear tolerances.

Gear quality grade 6 to DIN 3962 can be quoted as an approximate value for the attainable accuracy.

Profile- and flank modifications, too, such as depth crowning, tooth face setback or width crowning, can be produced by suitable hob profiles and corresponding machine motions.

Preparation for grinding

For high gear quality requirements, the gears are ground. The gear cutting costs can be markedly reduced if the hardening distortion is before grinding removed by skive hobbing, at the same time removing material to the necessary grinding allowance. Grinding times and costs are reduced while gaining additional grinding capacity.

Design

The characteristic design feature of skiving hobs is the negative tip rake angle. The tip rake angle is described as negative when the cutting faces of the teeth lie, in the direction of the cutting motion, in front of the tool reference plane. The tool reference plane is the plane in which lie the tip cutting edges of the axially parallel cutter and cutter axis.

Due to the negative tip rake angle, the flank cutting edges are inclined in relation to the effective reference plane (plane perpendicular to the cutting motion) and in this way produce a peeling cut.

The negative rake angle is greater in the root area of the hob teeth than in the tip area. The tip cutting edges have no effective back rake and cannot therefore generate a curling cut. It therefore follows that the skiving hobs should only produce flank chips and that protuberance cutters are used for roughing the gears.

刀具材料

小的切削厚度和淬硬的齿轮材料对刀具材料的刃口强度提出很高的要求。对于制作刮削滚刀的材料，通常选用ISO标准的K05类到K15类材料。

Tool material

Low chip thickness and hardened gear materials make severe demands on the edge strength of the tool material. As the tool material for skiving hobs, carbides of ISO application groups K 05 to K 15 are used.

设计

根据模数值和要求的精度不同，刮削滚刀的设计通常有三种设计方案：

- 整体硬质合金
  模数小于等于4，FETTE类别号2028
- 焊接式硬质合金，模数大于4，FETTE产品号2129
- 可转位式硬质合金刀片，模数大于等于5，FETTE产品号2153

上述设计中的一种特殊刀具是采用配备了可转位硬质合金刀片的刮削滚刀。这种刀具不需要进行重磨加工。在加工过程中我们只需要将磨损达到最大限度的可转位合金刀片进行旋转或更换。

可以理解，使用刀体、刀座和可转位硬质合金刀片组合而成的组合刀具很难达到整体式刀具相同的加工精度。因此，这种配备可转位合金刀片的刀具特别适用于磨前预备工件的加工。

目前绝大多数的刮削滚刀采用孔式结构。由于加工方面的原因，整体硬质合金刮削滚刀端面的一侧或两端一般带有驱动键槽。对于质量要求很高的刮削滚刀，一般选用带有端面驱动槽的孔形刀具，而不选用带有轴向键槽的刀具。因为制造不带有键槽的高精度孔比较容易，而且在滚齿机上的滚刀跳动也会减少。对于精度要求非常高的情况，也可以选用杆式工具补偿刀柄与刀具之间的跳动。

Designs

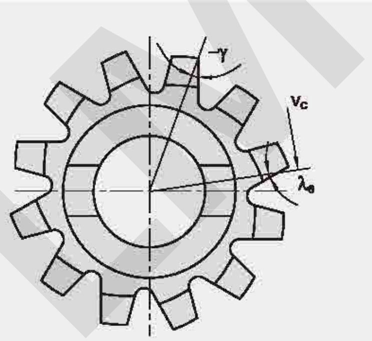
Depending on the module size and the accuracy requirements, 3 skiving hob designs can be basically distinguished:

- Solid carbide
  up to and including module 4
  LMT Fette Cat. no. 2028
- Brazed-on carbide tips
  for modules above 4
  LMT Fette Cat. no. 2129
- Indexable carbide inserts
  for modules from 5 upwards
  LMT Fette Cat. no. 2153

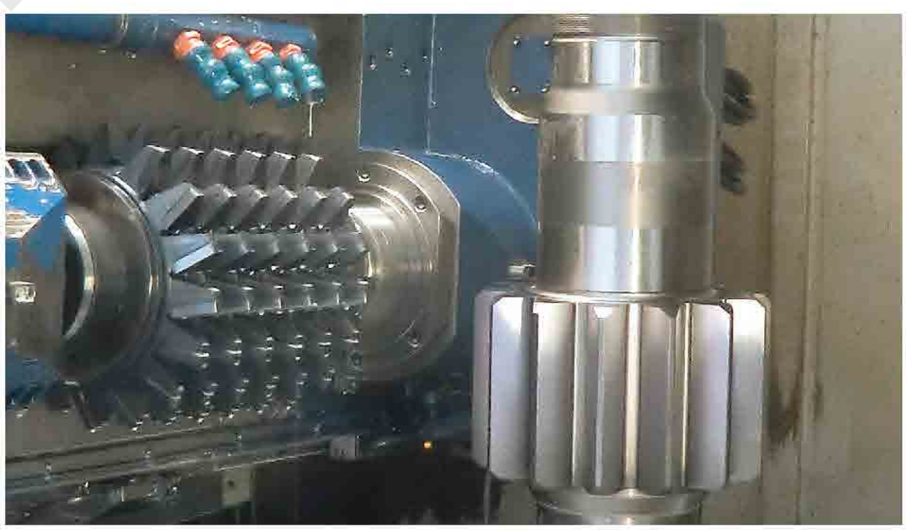
A special position among the above designs is occupied by the skiving hob with indexable carbide inserts. This cutter type does not require regrinding. Only those inserts which have reached the maximum wear mark width are turned or changed.

It is understandable that a hob assembled from cutter body, tooth segments and indexable inserts cannot offer the same accuracy as a cutter in solid carbide. This is why the cutter with indexable inserts is particularly suitable for preparing the workpiece for grinding.

By far the most common skiving hob is the bore type. Solid carbide skiving hobs have a drive slot on one or both ends, for manufacturing reasons. For hobs with a high quality grade, preference should where possible be given to bores with drive slot over those with keyway. A precise bore can be manufactured more easily without a keyway, and the run-out of the hob on the hobbing machine is also reduced. For extreme accuracy requirements, a shank-type tool also permits compensation of the run-out between cutter arbor and cutter.



-γ 刀刃前角
Tip rake angle
λ_s = 刀刃后倾角
Back rake of the flank cutting edge
v_c = 切削速度
Cutting speed



质量等级

刮削滚刀通常根据DIN3968标准的AA级质量等级制作而成。如有需要，整体硬质合金以及焊接式硬质合金也可以按照AAA质量等级标准制作（AA级允许公差的75%）。

Quality grades

Skiving hobs are generally manufactured in quality grade AA to DIN 3968. If required, the solid carbide and brazed-on carbide tip types can also be manufactured in quality grade AAA (75 % of the tolerances of AA).

对于齿轮凹形齿面通常可使用刮削滚刀加工，能够获得较小的凹形齿面。

A concave flank shape is usual for the skiving hob, to achieve a slight tip relief on the workpiece.

刮削加工的准备工作

加工留量取决于齿轮的模数和淬火变形程度。经验显示，模数在2到10之间的误差在0.15到0.30mm/齿侧面之间。

Preparation for skive hobbing

The machining allowance depends on the module size and the hardening distortion. Experience has shown that for the module range 2 to 10 it lies between 0.15 and 0.30 mm/flank.

加工前，齿根必须进行预加工，并保证加工深度，以防刮削滚刀顶刃参加工作。

The tooth root must be pre-machined deeply enough to prevent the tooth tip of the skiving hob from cutting into it.

我们建议使用挖根滚刀FETTE产品号2026。
刮削的齿轮硬度必须符合HRC62+2以内标准。

We recommend hobs protuberance, e.g. LMT Fette Cat. no. 2026.

The hardness of the gear must for the skive hobbing process be limited to HRC 62 +2.

切削速度

切削速度取决于模数的大小和齿轮的硬度。一般情况下，模数为30的切削速度为36m/min，模数为2的切削速度为110m/min。

Cutting speed

The cutting speed depends on the module size and on the hardness of the gear. As an approximate value, a cutting speed of 36 m/min can be recommended for module 30 and of 110 m/min for module 2.

模数更小的情况，切削速度可以达到140m/min到160m/min。但是切削速度过高会降低滚刀的使用寿命，也会对工件结构产生一定的影响。

For the lower modules, higher values between 140 and 160 m/min are also possible. These high cutting speeds do however reduce the service life of the skiving hob and the workpiece structure is increasingly affected.

整体硬质合金刮削滚刀
Solid carbide skiving hob

当工件的硬度达到或超过HRC62时，切削速度首先应该限制在70m/min左右，然后综合考虑切削效果和刀具使用寿命最终确定。

For workpiece hardness values from HRC 62 upwards, the cutting speed should be limited initially to 70 m/min and then optimized in consideration of the cutting result and the service life of the tool.

切削进给

滚刀加工表面的结构会受到进给切痕深度的影响。进给切痕深度随着进给深度的成倍而增加。因此应该区分精加工和粗加工的进给量。

Feed

The structure of surfaces machined with hobs is affected by the depth of the feed marks. The depth of the feed mark increases quadratically with the value of the feed. It is therefore logical to distinguish between feeds for finishing and for roughing.

进给量平均值如下：

精加工：
1.5到2mm/工件转数

粗加工：
4mm以上/工件转数

Approximate value for the feed:

For the finishing cut
1.5 to 2 mm/workpiece rotation

For the roughing cut
up to 4 mm/workpiece rotation

顺铣加工方法

一般情况下选用顺铣加工方法，因为这种加工方法有助于延长刮削滚刀的使用寿命。

Climp hobbing method

Climb hobbing for skive hobbing is preferred since this yields the best service life of the skiving hobs.

滚齿面修整

为了维持滚刀的使用寿命，每次刮削加工时每个滚齿面不应超过0.15–0.20mm。
当质量要求较高时，滚齿加工应通过多次加工完成。在进行最后一次滚齿加工时，每个滚齿的加工厚度应确保在0.1mm左右，以确保对齿轮材料的结构影响至最小。

Removal per flank

To maintain a reasonable service life of the hobs, not more than 0.15 ÷ 0.20 mm/flank should be removed in one cut.

For high quality requirements, hobbing must always be done in several cuts. For the last cut, a removal of 0.1 mm/flank should be aimed at, to affect the structure of the gear material as little as possible.

冷却

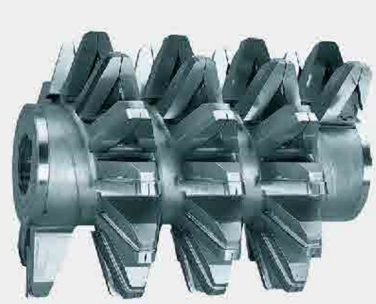
加工过程中应使用切削油确保对加工刀具、工件、夹具和设备的充分冷却，这样可以减少因温度造成的数值误差，并延长滚铣刀具的使用寿命。

Cooling

Intensive cooling of the tool, workpiece, holding fixture and machine with the cutting oils usual for hobbing, the temperature-dependent error values are reduced and the service life of the skiving hobs is extended.

焊接片形硬质合金刮削滚刀
Skiving hob with brazed-on carbide tips

焊接条形硬质合金刮削滚刀
Skiving hob with brazed-on carbide strips



可转位硬质合金刮削滚刀
Skiving hob with indexable carbide inserts

磨损标记宽度
刮削滚刀上的磨损标记宽度不得超过0.15mm。

随着磨损标记宽度的增加，以及刀刃上产生很薄的碎屑偏差，切削力也会逐渐增长。

这些情况会产生以下后果：
加工质量下降，硬质合金刀刃粘屑，经过回火和再淬火处理后齿轮产生结构变形。

通过偏移矫正使磨损保持均匀
磨损现象仅仅发生在刮削滚刀的齿面。磨损标记相对较短，并且沿着啮合线的轮廓线分布。

在完成一个或一组齿轮的滚齿加工后，将滚刀沿轴线方向移动调整，使磨损均匀分布在滚刀齿面切削刃和整个切削刃上。如果滚齿机上安装有同步移位装置，那么这个操作就会变得更加方便。这种移位装置还可以确保沿着切线方向移动时设备工作台进行旋转操作。在对中过程中保持已设置滚齿运动的相对位置。

重磨的刀具使用寿命
重磨的刀具使用寿命等于在两次重磨之间所有滚刀齿加工长度总和。

进行再磨削、刀具要求、刀具费用比等的计算都是依据每个滚齿重磨之间的使用寿命进行的。这取决于待切削齿轮的模数和材料硬度。经验显示，刮削滚刀每个滚刀齿的重磨使用寿命一般在2m到4m之间。

齿轮切削质量
刮削加工时齿轮的切削质量取决于许多因素和参数之间的相互作用关系。例如：

- 刮削滚刀(切削材料，磨削是否正确，精度是否足够高)
- 刚性高的滚齿机
- 滚刀和工件装夹精度和稳定性
- 滚刀定位是否能将跳动减少最低值对中精度
- 是否正确选择切削速度，进给速度和每个滚齿的切削厚度
- 是否符合最大磨损标记宽度要求
- 工件材料、准备和热处理的要求

Wear mark width
The wear mark width on the skiving hobs should not exceed 0.15 mm.

Cutting forces increase with greater wear mark width and with very thin chips deflection of the hob cutting edges will occur.

This may have the following consequences:
quality losses, chipping of carbide cutting edges and excessive structural changes through tempering and re-hardening processes on the gears.

Uniform wear through shifting
Wear only occurs on the tooth flanks of the skiving hobs. The wear marks are relatively short and follow the contour of the engagement lines.

By shifting the hob in the axial direction after hobbing a gear or set of gears, the wear is distributed evenly over the flank cutting edges and over the entire cutting edge length of the hob. This process is further facilitated if the hobbing machine is equipped with a synchronous shifting arrangement. This arrangement ensures that the machine table makes an additional turn when the tangential slide is moved. The relative position of the hob motion then remains as set during centering.

Tool life between regrinds
The life between regrinds of a hob equals the sum of the lengths of all hobbed workpiece teeth between two regrinds of the hob.

The calculation of the life between regrinds, the tool requirement, the proportional tool costs etc. is based on the life between regrinds per cutter tooth. This depends on the module value and on the hardness of the material being cut. Experience has shown the tool life between regrinds to lie between 2 and 4 m per cutter tooth for skive hobbing.

Gear cutting quality
The gear quality when skive hobbing depends on the interaction of a large number of components and parameters, such as:

- Skiving hob (cutting material, correctly sharpened, sufficent accuracy)
- rigid hobbing machine
- accurate and stable clamping of hob and workspiece
- Hob aligned with an absolute minimum of runout
- accurate centering
- correct selection of cutting speed, feed and metal removal per flank
- adherence to the maximum wear mark width
- material, preparation and heat treatment of the workpieces

齿距和齿向偏差是由滚齿机造成的。

齿廓的形状基本上依赖于滚刀的质量。加工参数、工件硬度和刀具磨损情况主要影响切削力，而应力的大小则它会作用到刀具和加工设备，从而影响加工齿轮的质量。
当加工条件良好，操作认真的情况下，齿轮的加工精度可以达到DIN3962的6级标准，齿轮表面粗糙度可达到1到2μm。

滚齿机

原则上，传统的滚齿机也可以用作刮削加工。其关键决定因素是设备的运行状况是否良好。

重要的是要保证滚刀刀杆轴向止推轴承运行良好，并使工作台和进给速度越低越好。

很显然，现代的滚削设备配备有双蜗杆传动和预载液压工作台，以及用于轴向进给的滚珠式蜗杆机构和预载推力轴承为齿轮加工提供很好的加工条件。用于同步偏移和自动对中的装置也是很有用的。

刮削滚刀的维护和保养

当刮削滚刀的磨损达到0.15mm时，应该对其进行修磨使其保持锋利。横向磨削或深度磨削工艺一般使用金刚石砂轮。

由于存在负前角，砂轮必须采用偏心设置。砂轮的偏移量设置依赖于刀具直径值，并在重磨图表中给出，对于每种刀具都有此值。

切削面必须磨削成非常光滑、深度很浅，以防止刀刃产生缺陷和微小粘屑。根据所使用的齿槽大小，必须保证DIN3968规定的公差等级。

Pitch- and tooth trace deviations are caused by the hobbing machine.

The profile shape depends basically on the quality of the hobs. The cutting parameters, the hardness of the workpieces and the wear condition of the cutters affect mainly the cutting forces, which react on tool and machine and thus contribute to the tooth quality.

Under good conditions and with careful working the gear quality grade 6 to DIN 3962 can be achieved with a surface roughness of 1 to 2 mm.

Hobbing machine

In principle, conventional hobbing machines are also suitable for skive hobbing. The decisive factor is the condition of the machine.

It is vital to keep the play in the hob spindle thrust bearing and in the table- and feed drive as low as possible.

Obviously, modern hobbing machines with dual-worm table drive or hydraulic table pre-loading, with circulating ball spindle for the axial feed and prestressed thrust bearing of the hob spindle offer better preconditions for good gear quality. Arrangements for automatic centering and for synchronous shifting are also desirable.

Maintenance of the skiving hob

The skiving hob should be sharpened when the wear mark has reached a width of 0.15 mm. Diamond wheels are used for grinding with the traverse grinding or the deep grinding process.

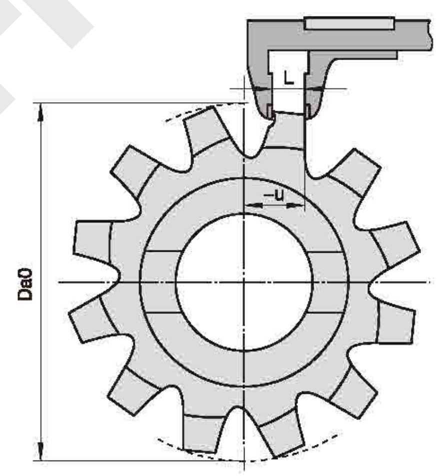
Because of the negative tip rake angle, the grinding wheel must be set off-centre. The measurement for the setting of the grinding wheel depends on the cutter diameter in question and is shown in the regrinding diagram, which is enclosed with every cutter.

Cutting faces must be ground with low roughness depth in order to prevent flaws and micro-chipping on the cutting edges. The tolerances of DIN 3968, insofar as they concern the gashes, must be maintained.

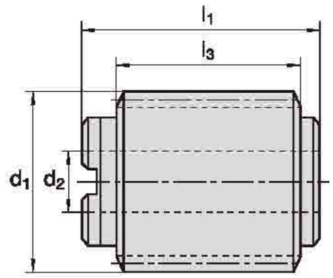
硬质合金刮削滚刀前刀面修磨表
Sharpening table for skiving hobs with indexable carbide inserts

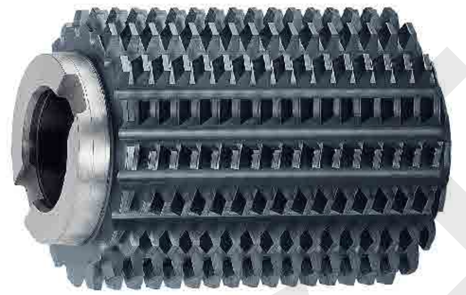
编号 Ident No.		图号 Drawing No.	4-84216
刀具编号 Cutter No.:	R2160	刀号 Tool-No.:	IM155139
模数 Module:	3,27742	压力角 Pressure angle:	25°
凸轮K值 Cam:	4,45	全齿高 Tooth height:	8,2
容屑槽数 No. of gashes:	12		
外径 Outside-Ø (actual dimension)	79,875	错位值 u (actual dimension)	–13,681
齿顶厚度 Tooth tip length (actual dimension)	7		

L	u	Da0	L	u	Da0
7	–13,681	79,875	1,554	–13,261	77,535
6,859	–13,67	79,815	1,416	–13,25	77,475
6,717	–13,66	73,755	1,278	–13,239	77,415
6,576	–13,649	79,695	1,141	–13,229	77,355
6,435	–13,638	79,635	1,003	–13,218	77,295
6,294	–13,627	79,575	0,866	–13,207	77,235
6,153	–13,617	79,515			
6,013	–13,606	79,455			
5,872	–13,595	79,395			
5,731	–13,685	79,335			
5,591	–13,574	79,275			
5,45	–13,563	79,215			
5,31	–13,552	79,155			
5,163	–13,542	79,095			
5,029	–13,531	79,035			
4,889	–13,52	78,975			
4,749	–13,509	78,915			
4,609	–13,439	78,855			
4,469	–13,488	78,795			
4,329	–13,477	78,735			
4,19	–13,466	78,675			
4,05	–13,456	78,615			
3,911	–13,445	78,555			
3,771	–13,434	78,495			
3,632	–13,423	78,435			
3,493	–13,412	78,375			
3,354	–13,402	78,315			
3,275	–13,391	78,255			
3,076	–13,38	78,195			
2,937	–13,369	78,135			
2,738	–13,358	78,075			
2,66	–13,348	78,015			
2,521	–13,337	77,955			
2,382	–13,326	77,095			
2,244	–13,315	77,835			
2,106	–13,304	77,775			
1,963	–13,294	77,715			
1,83	–13,283	77,655			
1,692	–13,272	77,595			



L = 齿顶厚度
Tooth length at tooth tip
u = 错位值
Cutting face offset
Da0 = 外径
Cutter diameter



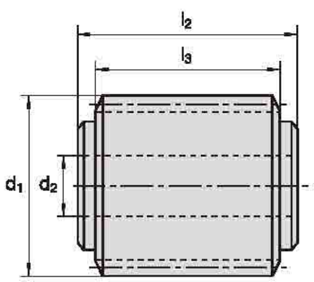


Katalog-Nr. Cat.-No.						2028
m	d_1	l_3	l_1	d_2	z	Ident No.
2	80	100	120	32	15	2352890
2,5	80	100	120	32	15	2352891
3	90	100	120	40	15	2352892
3,5	100	120	140	40	15	2352893
4	100	120	140	40	15	4021516

[1] 基本齿形 h_{a0} =1,15 · m, ϱ_{a0} = 0,1 · m
Basic profile h_{a0} = 1.15 · m, ϱ_{a0} = 0.1 · m

焊接硬质合金刮削滚刀
Skiving hobs with brazed-on carbide inserts

RH | Relief ground | Car-bide | DIN 3968 AA | Special BP [1)]



Katalog-Nr. Cat.-No.						2129
m	d_1	l_3	l_1	d_2	z	Ident No.
4,5	130	130	150	40	12	1223135
5	130	130	150	40	12	1223139
5,5	160	140	160	50	12	1223137
6	160	140	160	50	12	1223146
7	170	140	160	50	12	1223155
8	170	150	170	50	12	1223164
9	180	150	170	50	12	1223173
10	190	160	180	50	12	1223182
11	220	180	200	60	12	1223191
12	220	190	210	60	12	1223208
13	240	200	220	60	12	1223253
14	250	220	240	60	12	1223217
15	250	230	250	60	12	1223262
16	260	240	260	60	12	1223226
17	260	250	270	80	12	1223271
18	270	270	290	80	12	1223235
19	270	280	300	80	12	1223290
20	280	290	310	80	12	1223244

[1)] 基本齿形 $h_{a0} = 1,15 \cdot m$, $\varrho_{a0} = 0,1 \cdot m$
Basic profile $h_{a0} = 1.15 \cdot m$, $\varrho_{a0} = 0.1 \cdot m$

WERK-
ZEUG-
SYSTEME

CHAMFERCUT
TOOL SYSTEMS
CHAMFERCUT

滚齿、倒角的刀具系统

滚齿、倒角刀具系统
Tool Systems, ChamferCut

快速倒角和高效成本的去毛刺
ChamferCut – fast and cost-efficient deburring

齿轮完成齿形加工之后，紧接着出现的问题是，如何去毛刺
目前，在生产中有各种不同的方法对齿轮进行倒角，包括滚压、挤压、切削和人工去毛刺。

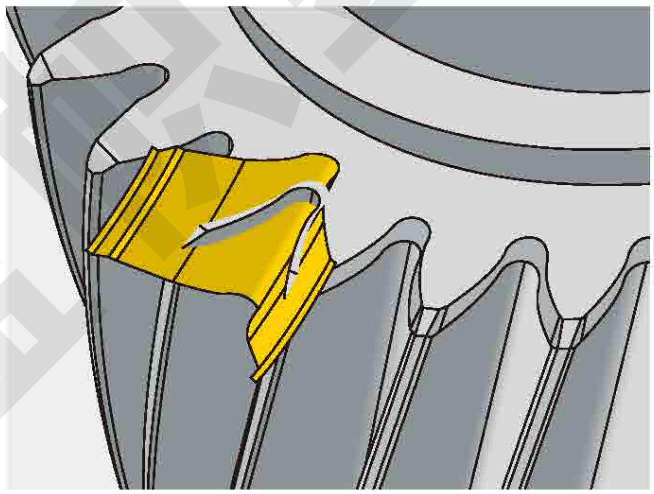
这些方法都需要单独的设备或机床，因此，需要额外的加工时间，成本很高。

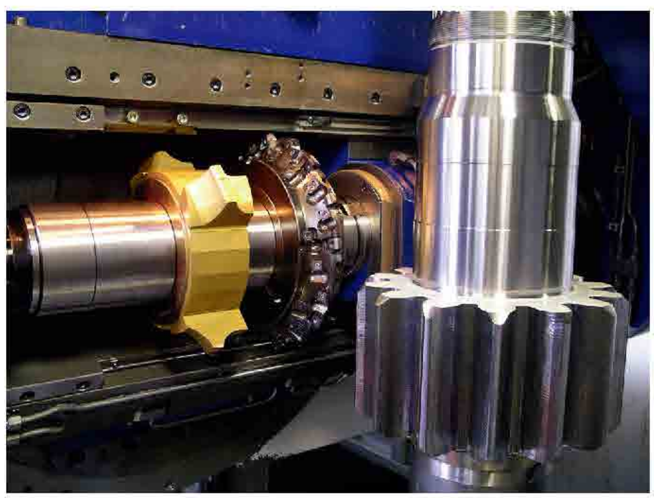
Following the cutting phase in gear-cutting procedures, the problem then arises of deburring the workpieces.
At the moment, various different procedures are used in industry to chamfer gears, including deburring by rolling, compressing, cutting and manual reworking. These methods need separate devices and machines, making them time-consuming and expensive.

蓝帜金工FETTE开发的滚齿–倒角刀，为去毛刺工艺节省了成本和时间

所有的刀具——（滚刀和去毛刺刀）都装在同一根芯轴上。当使用FETTE滚刀加工完齿轮的齿形后，装在同一芯轴上的FETTE倒角刀开始工作。

LMT Fette has developed the ChamferCut to save costs and time in the deburring process.
All tools for gear cutting and deburring are mounted on one arbor. After the gear has been cut with a LMT Fette hob, the LMT Fette ChamferCut clamped on the same arbor is employed.





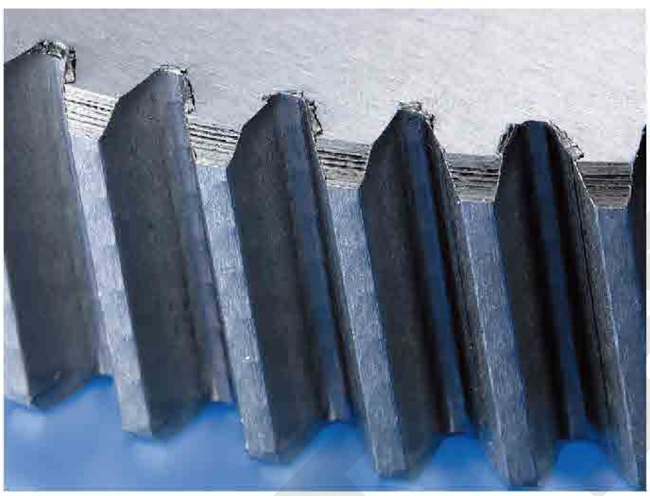
倒角去毛刺由两把倒角刀来完成

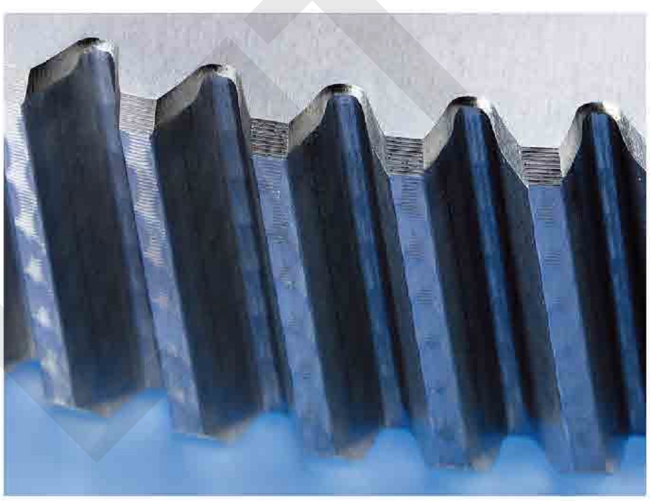
第一个倒角刀，用于去除齿轮上端面的毛刺，并且沿齿轮的齿廓形成均匀的倒角。第二个倒角刀，同样地去除底部的毛刺并倒角。因此，加工之后，齿轮完成了倒角和去毛刺工序，不需要再进行后续的加工。

使用蓝帆金工FETTE滚齿-倒角刀的整个加工过程，可以通过机床的软件实现。这个软件是机床另外配置的，需要跟您的机床供应商联系。

Two ChamferCut tools for optimum deburring.
The first ChamferCut is responsible for deburring the top side and creates a uniform chamfer. The second ChamferCut is then responsible for this same task on the lowe side. The result is a chamfered gear that needs no additional machining.

The whole chamfering process with LMT Fette ChamferCut can be controlled as an option with machine software.
Please contact your machine dealer.
ChamferCut is patented.





滚齿倒角的应用见：www.lmt-tods.de,看我们youtube视频
ChamferCut application see www.lmt-tools.de, watched us on YouTube

切削分析 Cutting analysis	
齿轮参数 Gear data	
模数 Module mn	1,5
齿数 No. of teeth za	30
螺旋角 β Helix angle β	20°
滚刀参数 Hob data	
外径 Outside-Ø	70
头数 No. of threads	4
切削时间 Cutting time	
每个工件的切削时间 Cutting time per part	5,28 sec

新发明的倒角刀
可在几秒钟内高速高效去毛刺
Innovation in gear-cutting tools.
Fast, cost-efficient deburring with ChamferCut in just seconds

使用蓝帜金工FETTE滚齿–倒角刀的优点：

- 滚齿和去毛刺在一台机床上完成
- 所有刀具装在一根芯轴上
- 切削过程由机床的软件控制
- 无需后续加工或人工去毛刺
- 不需要额外的设备或刀具来完成去毛刺
- 高质量
- 高刀具寿命

Economic chamfering of gears with the LMT Fette ChamferCut

- Gear cutting and deburring on one machine
- All tools are clamped on one arbor
- Gear cutting software controls the production process
- No machine or manual reworking
- No additional machinery or tools needed for deburring
- High quality
- High tool life

蓝帜金工菲特的倒角刀优化了齿轮的生产

蓝帜金工菲特的倒角刀将为你的产品进行特殊地制造。请告诉我们你产品的参数，我们将对滚刀和倒角刀进行前期报价。请将询价表包括你的地址发送给我们。

LMT Fette ChamferCut for optimising the production of gears

LMT Fette ChamferCut will be manufactured according to the special requirements for your production. Please inform us of the required parameters for your product and we will prepare a quotation for the required hob and the LMT Fette ChamferCut. Please enter your details including address and send us the inquiry form.

询价单
Inquiry form

日期 Date	公司 Company	街道 Street	LMT·TOOLS
	用户编号 Customer No.	邮政编码/城市 Post Code/City	
	名称 Name	电子信箱 E-Mail	

倒角刀
ChamferCut

发送你的询价单到： Please send your inquiry to: Gearcutting@lmt-tools.com

倒角刀的应用根据滚齿机的刀架尺寸数据确定。

工艺流程满足下面条件：

- **每一把倒角刀完成齿轮的顶部和底部加工**
- **在加工齿轮时倒角刀的外径“d”可以假定与滚刀外径相同**
- **倒角刀的距离“h”能被设定为0.3×d**
- **齿轮轴和倒角刀轴的距离“a”可以按下面公式计算**

$$a \approx \sqrt{\left(\left(\frac{d}{2}\right)^2 - h^2\right)} + \frac{d_f}{2}$$

“d”是齿轮的根径

下面被论述的条件必须被验证，是否碰撞机床的夹紧元件，机床的夹紧元件是否能按需要连结。

The areas of application for the ChamferCut are determined by the machine room dimension of hobbing machine.

The following conditions apply for the procedure:

- One ChamferCut each is required for the top and bottom face of the gearing
- The ChamferCut diameter “d” can be assumed to be the same as the hob diameter for the gear
- The distance “h” of the ChamferCut can be taken as 0.3 x d.
- The distance “a” between the gear axle and the axle of the ChamferCut is then calculated as follows:

$$a \approx \sqrt{\left(\left(\frac{d}{2}\right)^2 - h^2\right)} + \frac{d_f}{2}$$

“d_f” = the root diameter of the gear.

Under the conditions described, it must be examined whether a collision with the clamping element can be ruled out or whether the clamping element can be adapted to the requirements.

我们需要下面的参数来计算倒角刀
We need the following details to calculate the ChamferCut tools

齿轮参数 Gear data

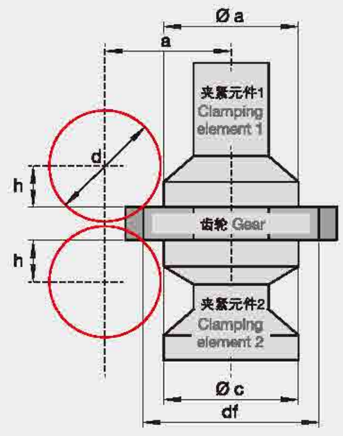
模数 Module:	
压力角 Pressure angle:	
根径 Root diameter:	
每齿侧的留量 Machining allowance per flank:	
齿面方向 Flank direction (R/L):	
被测齿数 No. of measuring teeth:	
顶圆直径 Tip diameter:	
螺旋角 Helix angle:	
公法线长度 Base tangent length:	

Oder Or

量球直径 Diametrical ball dimension:	
球间距 Base tangent length:	
球间距 Base tangent length:	

夹紧元件 Clamping elements

直径a: Clamping diameter a:	
直径c: Clamping diameter c:	
齿轮切削刀具编号 Ident-No. of the gear-cutting tool:	



LMT Tool Systems GmbH
Heidenheimer Strasse 84 · 73447 Oberkochen
Telefon +49 7364 9579-0 · Telefax +49 7364 9579-8000
lmt.de@lmt-tools.com · www.lmt-tools.com

LMT Fette Werkzeugtechnik GmbH & Co. KG
Grabauer Strasse 24 · 21493 Schwarzenbek
Telefon +49 4151 12-0 · Telefax +49 4151 3797
info@lmt-fette.com · www.lmt-fette.com

WÄLZ-FRÄSER

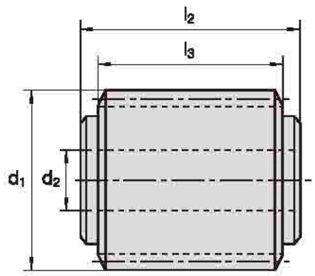
FÜR KETTENRÄDER
ZAHNRIEMENSCHEIBEN
STECKVERZAHNUNGEN

HOBS FOR SPROCKETS
TIMING BELT PULLEYS
SPLINES

链轮、同步带轮、花键滚刀

链轮、同步带轮和花键滚刀
Hobs for sprockets, timing belt pulleys and splines

RH1 | Relief ground | KHSS -E | Speed Core 1) | HSS -PM 1) | AL2 Plus 1) | DIN 8196 | DIN 8187 | DIN 8188

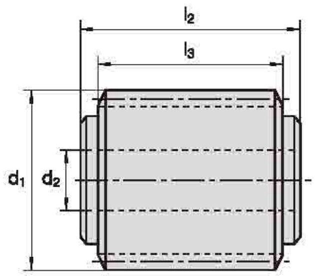


Katalog-Nr. Cat.-No.						2301
节距 Pitch	滚子直径 Roller-/barrel-Ø	d_1	l_1	d_2	z	Ident No.
5	3,2	56	38	22	12	1226204
6	4	56	38	22	12	1226213
8	5	63	38	27	12	1226231
9,525	6,35	70	46	27	12	1226268
12,7	7,92	80	56	32	12	1226286
12,7	7,75	80	56	32	12	1226286
12,7	7,77	80	56	32	12	1226286
12,7	8,51	80	56	32	12	1226295
15,875	10,16	90	69	32	10	1226302
19,05	11,91	100	88	32	10	1226320
19,05	12,07	100	88	32	10	1226320
25,4	15,88	110	108	40	10	1226339
31,75	19,05	125	133	40	10	1226357
38,1	22,23	140	150	40	10	1226366
38,1	25,4	140	150	40	10	1226375
44,45	25,4	160	170	50	9	1226384
44,45	27,94	160	170	50	9	1226393
50,8	28,58	170	190	50	9	2111640
50,8	29,21	170	190	50	9	1226419
63,5	39,37	190	235	50	9	2110189
63,5	39,68	190	235	50	9	2110189
76,2	47,63	225	290	60	9	2110188
76,2	48,26	225	290	60	9	2108994

1) 需要时选择
on request

LMT • FETTE

RH1 | Relief ground | KHSS-E | Speed Core[1] | HSS-PM[1] | AL2 Plus[1] | DIN 3968A



Katalog-Nr. Cat.-No.							2342
节距 Pitch	齿数范围 Tooth number range	d_1	l_3	l_1	d_2	z	Ident No.
T 2,5 se	12– 20	50	25	31	22	14	1228006
T 2,5	21– 45	50	25	31	22	14	1228015
T 2,5	46– 80	50	25	31	22	14	1228024
T 5 se	10– 14	56	32	38	22	14	1228033
T 5 se	15– 20	56	32	38	22	14	1228042
T 5	21– 50	56	32	38	22	14	1228051
T 5	51–114	56	32	38	22	14	1228060
T 10 se	12– 15	70	50	56	27	14	1228079
T 10 se	16– 20	70	50	56	27	14	1228088
T 10	21– 45	70	50	56	27	14	1228097
T 10	46–114	70	50	56	27	14	1228104
T 20 se	15– 20	90	80	88	32	14	1228113
T 20	21– 45	90	80	88	32	14	1228122
T 20	46–119	90	80	88	32	14	1228131

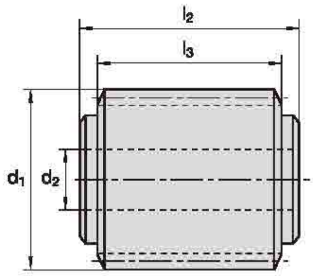
[1] 需要时选择
on request

“se”齿数范围在20齿以内，超过20齿时等于正常齿形
The “se” tooth gap form is applied up to 20 teeth incl., over 20 teeth = normal profile.

顶切刀具
Topping cutter

Wälzfräser für DIN-Profile
Hobs for DIN profiles

RH1 | Relief ground | KHSS -E | Speed Core[1] | HSS -PM[1] | AL2 Plus[1] | DIN 3968A | DIN ISO 5294

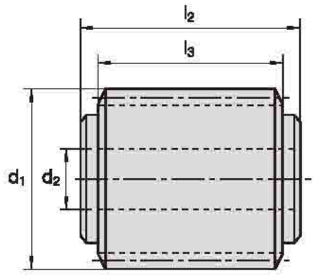


Katalog-Nr. Cat.-No.							2352
节距 Pitch	齿数范围 Tooth number range	d_1	l_3	l_1	d_2	z	Ident No.
0,08 MXL	10 bis to 23	50	25	31	22	14	1203010
	ab up 24	50	25	31	22	14	2257398
1/8 XXL	ab up 10	50	25	31	22	14	1203012
1/5 XL	ab up 10	56	32	38	22	14	1228300
3/8 L	ab up 10	70	50	56	27	14	1228319
1/2 H	14–19	70	63	69	27	14	1228328
1/2 H	ab up 20	70	63	69	27	14	1228337
7/8 XH	ab up 18	100	80	88	40	14	1228346
1 1/4 XXH	ab up 18	115	100	108	40	14	1228355

[1] 需要时选择
on request

顶切
Topping cutter

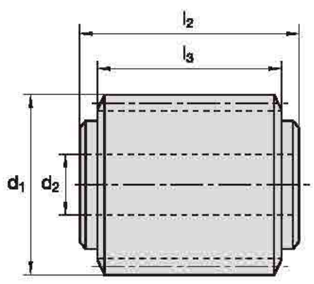
RH1 | Relief ground | KHSS-E | Speed Core[1] | HSS-PM[1] | AL2 Plus[1] | DIN 3968A | DIN 5480



Katalog-Nr. Cat.-No.						2472
m	d_1	l_3	l_1	d_2	z	Ident No.
0,6	50	25	31	22	14	1233919
0,8	50	25	31	22	14	1233928
1	50	25	31	22	14	1233937
1,25	50	25	31	22	14	1233946
1,5	56	32	38	22	14	1233955
2	63	40	46	27	14	1233964
2,5	70	50	56	27	14	1233973
3	70	50	56	27	14	1233982
4	80	63	69	32	14	1233991
5	90	70	78	32	14	1234008
6	100	80	88	32	14	1234017
8	115	100	108	40	14	1234026
10	125	130	138	40	14	1234035

[1] 需要时选择
on request

RH1 | Relief ground | KHSS-E | Speed Core[1] | HSS-PM[1] | AL2 Plus[1] | DIN 3968A | DIN 5462



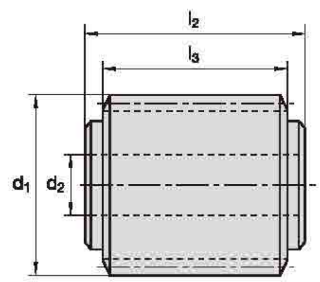
Katalog-Nr. Cat.-No.							2452
m	花键轴 名义尺寸 Spline shafts nominal size	d_1	l_3	l_1	d_2	z	Ident No.
1,6	15 x 12	56	32	38	22	12	1233018
1,6	17 x 14	56	32	38	22	12	1233018
1,6	18 x 15	56	32	38	22	12	1233018
1,6	20 x 17	56	32	38	22	12	1233018
1,6	22 x 19	56	32	38	22	12	1233018
1,6	25 x 22	56	32	38	22	12	1233018
1,75	28 x 25	56	32	38	22	12	1233027
1,75	30 x 27	56	32	38	22	12	1233027
1,75	32 x 28	56	32	38	22	12	1233027
1,75	35 x 31	56	32	38	22	12	1233027
1,9	38 x 34	63	40	46	27	12	1233036
1,9	40 x 36	63	40	46	27	12	1233036
1,9	42 x 38	63	40	46	27	12	1233036
2	45 x 41	63	40	46	27	12	1233045
2	48 x 44	63	40	46	27	12	1233045
2	50 x 45	63	40	46	27	12	1233045
2	52 x 47	63	40	46	27	12	1233045
2	55 x 50	63	40	46	27	12	1233045
2	58 x 53	63	40	46	27	12	1233045
2	60 x 55	63	40	46	27	12	1233045
2,1	62 x 57	63	40	46	27	12	1233054
2,1	65 x 60	63	40	46	27	12	1233054
2,1	68 x 62	63	40	46	27	12	1233054
2,1	70 x 64	63	40	46	27	12	1233054
2,1	72 x 66	63	40	46	27	12	1233054
2,1	75 x 69	63	40	46	27	12	1233054
2,1	78 x 72	63	40	46	27	12	1233054
2,1	80 x 74	63	40	46	27	12	1233054
2,25	82 x 76	70	50	56	27	12	1233063
2,25	85 x 79	70	50	56	27	12	1233063
2,25	88 x 82	70	50	56	27	12	1233063
2,25	90 x 84	70	50	56	27	12	1233063
2,25	92 x 86	70	50	56	27	12	1233063
2,25	95 x 89	70	50	56	27	12	1233063
2,25	98 x 92	70	50	56	27	12	1233063
2,25	100 x 94	70	50	56	27	12	1233063

[1] 需要时选择
on request

Hobs for serrated shafts with straight flanks for involute flank form on the component

LMT • FETTE

RH1 | Relief ground | KHSS -E | Speed Core[1] | HSS -PM[1] | AL2 Plus[1] | DIN 3968A | DIN 5481



Katalog-Nr. Cat.-No.							2462
节距 Pitch	轴名义尺寸 Serrated shaft nominal size	d_1	l_3	l_1	d_2	z	Ident No.
0,842	7 x 8	50	25	31	22	16	1233410
1,01	8 x 10	50	25	31	22	16	1233429
1,152	10 x 12	50	25	31	22	16	1233438
1,317	12 x 14	50	25	31	22	16	1233447
1,517	15 x 17	50	25	31	22	16	1233456
1,761	17 x 20	56	32	38	22	16	1233465
2,033	21 x 24	56	32	38	22	16	1233474
2,513	26 x 30	56	32	38	22	16	1233483
2,792	30 x 34	56	32	38	22	16	1233492
3,226	36 x 40	56	32	38	22	16	1233508
3,472	40 x 44	63	40	46	27	16	1233517
3,826	45 x 50	63	40	46	27	16	1233526
4,123	50 x 55	63	40	46	27	16	1233535
4,301	55 x 60	63	40	46	27	16	1233544
4,712	60 x 65	70	50	56	27	16	1233553
4,712	65 x 70	70	50	56	27	16	1233553
4,712	70 x 75	70	50	56	27	16	1233553
4,712	75 x 80	70	50	56	27	16	1233553
4,712	80 x 85	70	50	56	27	16	1233553
4,712	85 x 90	70	50	56	27	16	1233553
4,712	90 x 95	70	50	56	27	16	1233553
4,712	95 x 100	70	50	56	27	16	1233553
4,712	100 x 105	70	50	56	27	16	1233553
4,712	105 x 110	70	50	56	27	16	1233553
4,712	110 x 115	70	50	56	27	16	1233553
4,712	115 x 120	70	50	56	27	16	1233553
4,712	120 x 125	70	50	56	27	16	1233553

[1] 需要时选择
on request

WERKZEUGE

FÜR SONDERPROFILE

TOOLS FOR SPECIAL PROFILES

专用齿形刀具

压缩机转子滚刀
Hobs for compressor rotors

转子是螺杆压缩机的多头螺纹进给的螺杆，它们成对安装在机壳内。

Rotors are the multi-thread feed screws of a screw compressor, which are arranged in pairs inside a housing.

螺杆螺纹的啮合有对称或不对称的齿形。

The meshing screw threads have a symmetrical or an asymmetrical profile.

转子的无噪音转动和高效率是由转子轮廓制造的精确度来决定的。

Quiet running and good efficiency of the rotors are determined by the accuracy of the rotor profiles.

滚刀在转子加工过程能带来如下的良好结果：
- 高螺距精度
- 由于排屑均匀和平稳变形小
- 方便滚刀保养，重磨只修磨刀刃表面

The advantages of hobbing produce favourable results in rotor manufacture:
- High pitch accuracy
- Low distortion owing to even, constant chip removal in all gaps
- Trouble-free maintenance of the hob, which is reground only on the cutting faces.

使用此技术加工转子需要改进转子和滚刀齿廓的分析程序和在精密滚刀制造领域有很高的标准。

The use of this technology for rotor manufacture requires the development of the required analysis programs for rotor and hob profiles and high standards of manufacturing in the area of precision hobs.

对滚齿机的刚性，输出功率，热稳定性和进给精度都有很高的要求。

High demands are placed on the rigidity, output, thermal stability and feed accuracy of the hobbing machines.

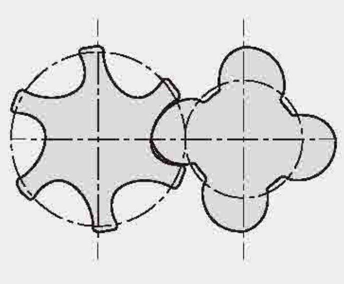
滚刀的成功使用决定于刀具制造商和转子生产商或设计者彼此就生产约束对齿形外形、间隙的总和和间隙的分布的影响进行沟通的程度，这个过程允许现代和经济性生产，质量和产量首要依赖刀具和机床上。

The successful use of hobs also depends on the degree to which the tool manufacturer on the one hand and the rotor producer or -designer on the other hand communicate with each other about the production constraints imposed on profile shape, amount of "backlash" instead of "play" distribution. This process then does allow modern and economical production, when quality and output depend primarily on the tool and the machine.

阳转子
Male rotor

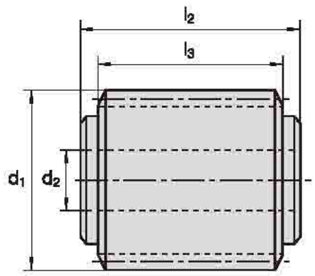
阴转子
Female rotor

转子：主视图
Rotors: face plane view



转子粗滚刀
Hobs, for roughing, for rotors

RH1 HSS-PM AL2 Plus[1)]



Katalog-Nr. Cat.-No.						2091	
m	d_1	l_3	l_1	d_2	z	转子直径 Rotor diameter	齿轮高度 Profile height
≈ 5,2	112	90	106	40	16	47/44,5	≈ 10,2
≈ 9,1	140	154	170	50	16	81,6	≈ 17,5
≈ 11,4	170	184	200	60	16	102	≈ 22
≈ 14,2	212	234	250	60	16	127,5	≈ 27,5
≈ 18,2	265	299	315	80	16	163,2	≈ 35,5
≈ 22,7	305	319	335	100	16	204	≈ 44
≈ 22,7	335	319	335	100	16	204	≈ 44

这结构尺寸是转子外形测量的近似值

L/D = 1.65

当订货时，请提供转子零件的加工图和有关在主视图上的齿形数据。（坐标的列表）

由于尺寸原因，不是所有的转子都能由滚刀展成的，此外，刀具的选择同样受已有工艺和现有的机床的影响。

菲特：主要介绍为加工转子的滚切过程
菲特：能为此与客户用相当多的经验去讨论产品
菲特在用滚刀加工转子方面处于领先地位。因此菲特能根据积累的丰富经验为用户提供建议。

这种滚切方式的优点是无疑的可以概括如下：
- 快速而可靠地生产表面质量高和齿廓和螺距精度高的转子。
- 转子的齿顶端密封带和齿根处的密封槽能在一次加工中完成。
- 由于转子精度恒定，滚切转子可以在任何时候互换。
- 由于滚刀只修磨前刀面，刀具的维护简单而经济。

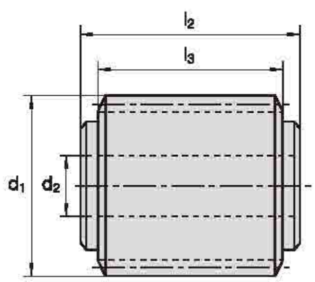
The structural dimensions are approximate values for rotor measurements L/D = 1.65.

When ordering, workpiece drawings of the rotors and data about the profile at the face plane (list of coordinates) must be made available.

Owing to their size, not all rotors can be generated by hobbing. Furthermore, the choice of tools is also influenced by the process already in place and the machines which are available.

LMT Fette played a leading part in the introduction of the hobbing process for the manufacture of rotors.
LMT Fette can therefore call upon considerable experience in advising its customers.

The advantages of the hobbing method are undisputed and can be summarized as follows:
- Quick and trouble-free production of rotors with good surfaces and accurate profiles and pitch.
- The sealing strips on the tooth tip and the sealing grooves in the tooth root of the rotors can be generated in one operation with the flanks.
- Hobbed rotors can be exchanged at any time, thanks to their uniform accuracy.
- Simple and economical maintenance of the tools, since the hobs are only sharpened on the cutting face.



Katalog-Nr. Cat.-No.					2092	
m	d_1	l_3	l_1	d_2	转子直径 Rotor diameter	齿轮高度 Profile height
≈ 5,2	140	74	90	60	47/44,5	≈ 10,2
≈ 9,1	190	124	140	80	81,6	≈ 17,5
≈ 11,4	236	154	170	80	102	≈ 22
≈ 14,2	265	196	212	100	127,5	≈ 27,5
≈ 18,2	300	249	265	100	163,2	≈ 35,5
≈ 22,7	305	299	315	100	204	≈ 44
≈ 22,7	335	299	315	100	204	≈ 44

1) 窄范围参照DIN 3968
narrowed in accordance with DIN 3968

2) 需要时选择
on request

这结构尺寸是转子外形测量的近似值
L/D=1.65

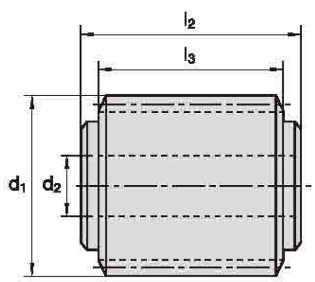
The structural dimensions are approximate values for rotor measurements L/D = 1.65.

全部的轮廓，包含密封带和槽，可以一次加工完成，转子的外径磨制成精加工尺寸。

The entire profile, including the sealing strip and slot, is machined in one operation. The outside diameter of the rotors is ground to finish size.

当订货时，请提供转子零件的图形和有关的主视图上的齿形数据（坐标的列表）。

When ordering, workpiece drawings of the rotors and data about the profile at the face plane (list of coordinates) must be made available.



Katalog-Nr. Cat.-No.					2094	
d_1	l_3	l_1	d_2	z	主动轴 Drive spindle D x d[2)]	从动轴 Trailing spindle D x d[2)]
100	52	60	32	16	18 x 10,8	10,8 x 3,6
100	55	63	32	16	20 x 12	12 x 4
112	72	80	32	16	30 x 18	18 x 6
118	82	90	32	16	35 x 21	21 x 7
125	87	95	40	16	38 x 22,8	22,8 x 7,6
140	98	106	40	18	45 x 27	27 x 9
150	104	112	50	18	52 x 31,2	31,2 x 10,4
160	110	118	50	18	60 x 36	36 x 12
180	122	132	50	18	70 x 42	42 x 14

1) 窄范围参照DIN 3968
2) D=外径 d=内径
3) 需要时选择

1) narrowed in accordance with DIN 3968
2) D = Outside diameter, d = Inside diameter
3) on request

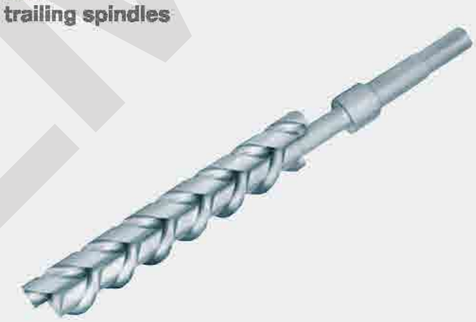
的有尺寸为推荐值，必须适配于滚齿机的长度和外径的工作空间。

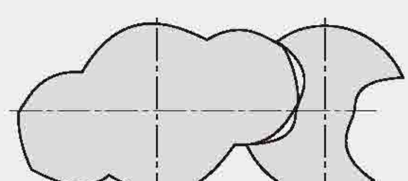
当订货时，请提供下列加工数据：主视图的齿形测量值，外径，内径，导程和旋向–正常情况下，主动轴为右旋，从动轴为左旋。

The overall dimensions shown are recommended values and may be adapted to the working space of the hobbing machine both in length and in diameter.

When ordering, the following workpiece data must be made available: measurements about the profile at face plane, outside diameter, inside diameter, lead and direction of lead – normally drive spindle right-hand, trailing spindle left-hand.

主动轴和从动轴
Drive and trailing spindles





除了通常的直齿廓蜗杆铣刀我们也制造特殊铣刀用于加工任何螺旋式齿轮。
此类零件是：
液体和气体螺杆式泵，挤压机蜗杆，多头渐开线传动蜗杆。

图1：零件：传动螺杆付，2头，螺杆泵；
刀具：精齿形铣刀，直前刀面，铲磨。

图2：零件：液压进给泵中的主动和从动轴；
刀具：精铣刀，交错齿，铲磨。

图3：零件：螺杆压缩机的雌转子；
刀具：粗铣刀，镶刀条，交错齿，

我们有编制好的设计程序，对于所需螺旋线可以设计出相应的铣刀。

如果铣刀齿形尚不明确，我们需要依照图4提供有关的所切螺旋线的数据，即：

- 螺旋线的导程H
- 主平面的坐标中的 r, ϱ, α_s 或轴平面坐标中的 r, a, α_A

在轴平面坐标：可建立等式
$a = \text{arc}\,\varrho \cdot H/_{2\pi}$
$\tan \alpha_A = \tan \alpha_s \cdot H/_{2\pi}$

In addition to the usual worm milling cutters with straight flanks, we manufacture special cutters for producing any desired screw type gears by the single indexing method. Such workpieces are, for example, screw pumps for liquids and gases, extruder worms, multi-start involute worms for drives etc.

Fig. 1:
Workpiece: conveyor screw pair, 2-start, for a screw pump; tool: profile finishing cutter, straight teeth, relief ground.

Fig. 2:
Workpiece: drive- and trailing spindle of a liquid feed pump; tool: profile finishing cutter, staggered teeth, relief ground.

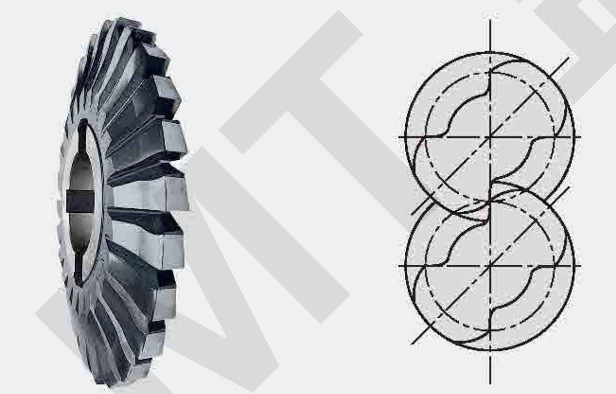
Fig. 3:
Workpiece: female rotor of a screw compressor; tool: profile roughing cutter with inserted blades, staggered teeth.

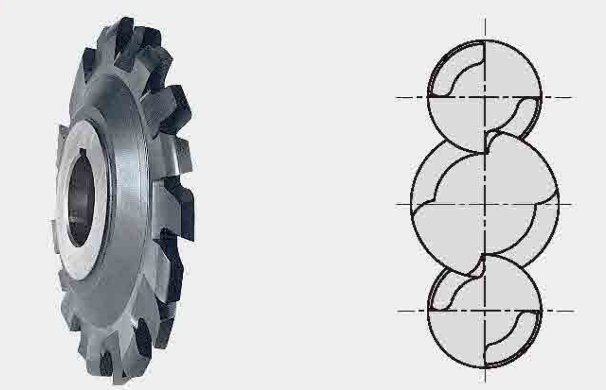
We have at our disposal universal computer programs to determine the cutter profiles for any desired form of thread.

If the cutter profiles are not yet known, we require data in accordance with **fig. 4** about the screws to be cut, i. e.:

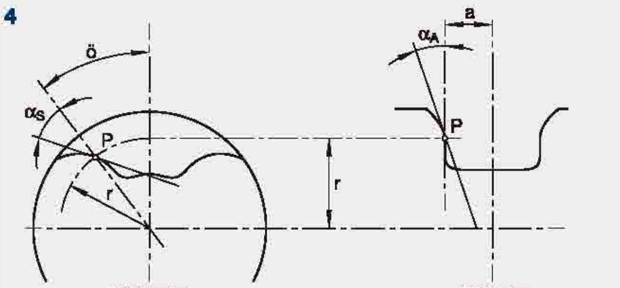
- the lead of the screw H
- the coordinates in the face plane r, ϱ, α_s or axial plane coordinates r, a, α_A

Coordinates in the axial plane are found with the equation
$a = \text{arc}\,\varrho \cdot H/_{2\pi}$
$\tan \alpha_A = \tan \alpha_s \cdot H/_{2\pi}$

1


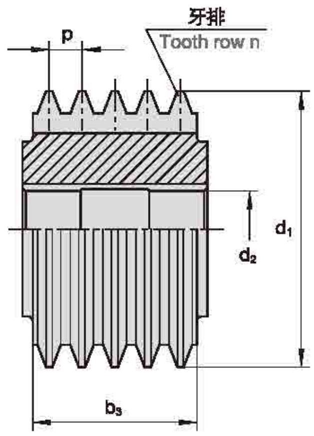
2


3


4


端截面图
Cross-section in face plane

轴截面图
Cross-section in axial plane



目录编号 Cat.-No.	2560					
	z = 14		z = 18		z = 22	
m	d_1	d_2	d_1	d_2	d_1	d_2
1	70	27	100	32	125	40
1,25	70	27	100	32	125	40
1,5	70	27	100	32	125	40
1,75	70	27	100	32	125	40
2	90	32	125	40	160	50
2,25	90	32	125	40	160	50
2,5	90	32	125	40	160	50
2,75	90	32	125	40	160	50
3	110	32	140	40	180	50
3,25	110	32	140	40	180	50
3,5	110	32	140	40	180	50
3,75	110	32	140	40	180	50
4	125	40	160	50	200	60
4,25	125	40	160	50	200	60
4,5	125	40	160	50	200	60
4,75	125	40	160	50	200	60
5	125	40	160	50	200	60

[1] 需要时选择
on request

成组式齿条铣刀是用在普通平面铣床和专用的自动齿条铣床上，为此不存在标准化的尺寸。以上表格提供指导，并方便选择铣刀的总体尺寸。刀具的宽度取决于模数和牙排数（n）。

$b_3 = m \cdot \pi \cdot n$

对于大的齿宽刀具（40mm以上）采用螺旋槽形式（3～5右螺旋角），此刀具同样能制造成顶切刀具。对于m5以上齿轮，我们推荐成组式齿条铣刀，见目录号2561。

除非指定，我们都推荐DIN39721型。

为了正确地处理你的订单，除了齿轮数据外，我们还需要刀具的牙排数。

Rack tooth gang cutters are used on the conventional horizontal milling machines as well as on the special automatic rack milling machines. Standardized constructional dimensions therefore do not exist. The above table is intended for guidance and should facilitate the selection of milling cutter overall dimensions. The cutter width depends on the module (m) and the number of tooth rows (n).

$b_3 = m \cdot \pi \cdot n$

For larger cutter widths (over 40 mm) the helical-fluted version is preferable (3–5° RH helix). The tools can also be made in the form of topping cutters. For gear sizes above module 5, rack gang milling cutter sets are recommended.

Unless otherwise specified, we supply with basic profile I to DIN 3972.

To process your order correctly, we need in addition to the gear data the required number of tooth rows on the cutter.

滚切工艺的优点是，除了能加工标准齿形，也可以加工滑移齿轮，皮带轮和链轮，以及很多特殊齿形，其中有一些例子在这里列出。

能加工常见特殊齿形的滚刀在本目录前面章节已经作了阐述，这些特形滚刀能加工转子，螺杆轴。

特殊齿形是指那些没有包括在标准齿形在内的所有齿形。
这大部分常见的专用用途滚刀是：束束轮，进给轮，传送带轮，卷轴轮、纸板卷轮、多刃齿形，开槽盘子，轨道轮。

特殊齿形要求将滚刀设计成定装形式。齿形螺旋线在滚刀的全长上不具有相同的形状，其齿形或牙形是变化的。这些滚刀在轴向必须调整对工件或滚齿机中心线保证其啮合到预期的位置来制造专用齿形。

如果这个齿形标准允许，定装滚刀能被设计几种定装和较长的刃长，以便提高效益。对于小齿形尺寸和多齿数工件的高效切齿方法是采用多头定装正切滚刀来加工。刀具的头数和刀齿齿数是与刀具容屑槽的数量相同的。

滚削加工方法的议题是清楚地适合于特殊齿形的加工在每个独特的情况，如果有图样的帮助，就有可能。对于所有齿轮切削应用，大批量工件，在外径上齿形重复的具体齿形，请咨询蓝帜菲特富有经验的研发和设计工程师。

The hobbing process with its wellknown advantages is, in addition to the standard operating- and slip gears as well as gears for belt and chain pulleys, also suitable for a large number of special profiles, of which a few examples are shown here. Hobs for particularly frequently used special profiles have been dealt with in detail in the earlier sections of this catalogue, such as the special-purpose hobs for rotors.

The term "special profiles" applies to all profile types which are not covered by a standard.

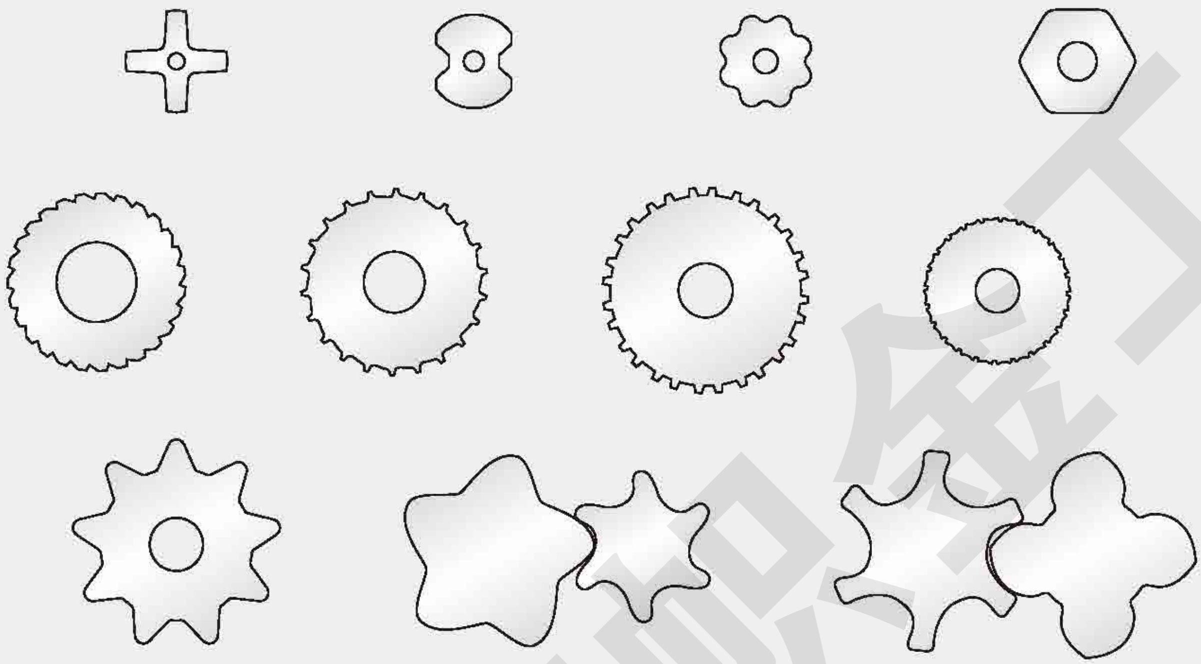
The most common types are special-purpose hobs for: ratchet wheels, feed- and conveyor wheels, conveyor rolls, cardboard rolls, multi-edge profiles, slotted plates, orbit gears and cyclo gears.

The special form of certain special profiles often makes it necessary to design the cutter as a single-position hob. The profile helix is in this case not uniformly shaped over the entire length of the hob, but the cutter teeth or tooth portions have varying profile forms. These hobs have to be aligned in their axial direction with the workpiece and/or centre line of the machine, to make sure that the specially shaped teeth are meshing in the intended position.

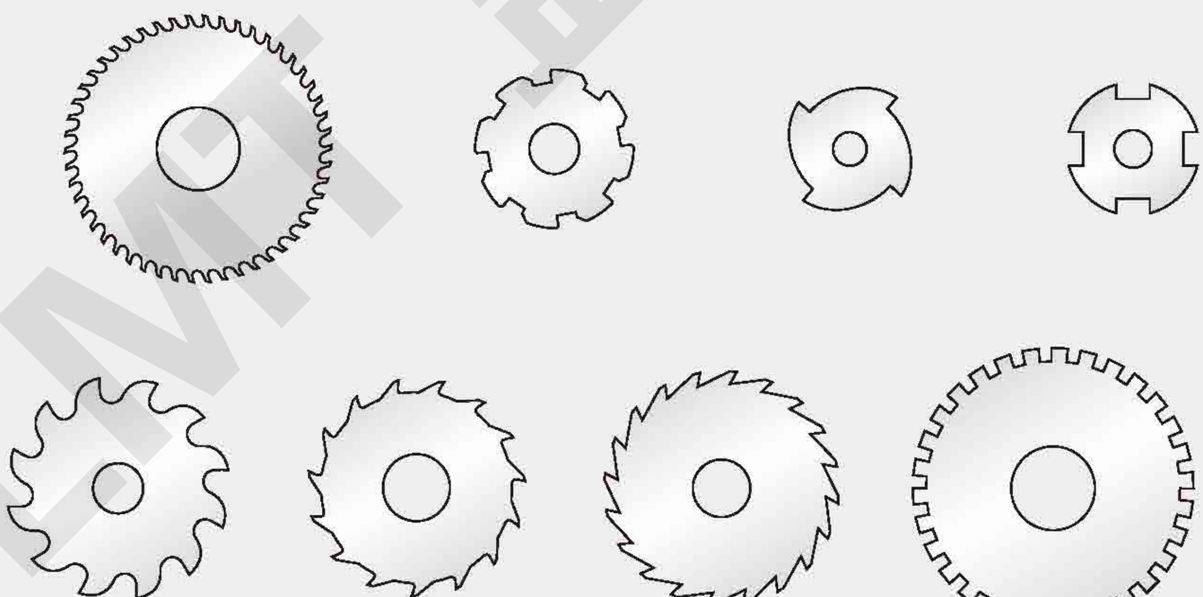
If the standardized profile allows it, single-position hobs can be designed for several positions and with a greater overall length to increase efficiency. A particular economical solution for small profile dimensions and greater cog numbers are multi-start single-position fly-cut hobs. With these cutters, the number of starts and the tooth number are identical to the number of gashes.

The question if the hobbing method is suitable for special profile shapes should be clarified in each individual case – if possible, with the help of drawings. For all gear cutting applications with a large number of workpieces with a profile shape that is repeated on the outer diameter, consult the experienced engineers of the LMT Fette development and design departments.

适用于展成法滚削加工的齿形示例
Examples of special profiles which can be generated by hobbing



适用于定装法滚削加工的齿形示例
Example of profiles which can be hobbed with single-position hobs



WÄLZ-FRÄSER

FÜR SCHNECKENRÄDER

HOBS FOR WORM GEARS

蜗轮滚刀

蜗轮滚刀的尺寸规格是由蜗轮的参数来确定的。

The specification factors of worm gear hobs are determined essentially by the worm gear data.

为了避免传动蜗杆在蜗轮中发生干涉用于加工蜗轮的滚刀在任何情况下其节圆直径都不能小于蜗杆的基圆直径。由于是铲背加工，滚刀的直径在重磨后会减小。因此，蜗轮滚刀的节圆直径在新的状态之下必须大于蜗杆的节圆直径。这个尺寸是由模数、基圆直径和头数组成的函数决定的。

In order to prevent edge bearing of the driving worm in the worm gear, the hobs used for producing the worm gears must under no circumstances have a pitch cylinder diameter that is smaller than the centre circle diameter of the worm. Owing to the relief machining, the diameter of the hob is reduced by sharpening. The pitch cylinder diameters of the worm gear hob in the new condition must therefore be greater than those of the worms. This dimension is determined as a function of the module, the centre circle diameter, and the number of threads.

一把新的蜗轮滚刀的外径可以通过下列方法计算：
蜗杆的基圆直径

蜗杆的基圆直径
+
节圆增加量
+
2 x 蜗轮齿高
+
2 x 顶部间隙

The outside diameter of a new worm gear hob is thus calculated as follows:

Centre circle diameter of the worm
+
Pitch circle increase
+
2 x addendum of the worm
+
2 x tip clearance

齿形形式
蜗轮滚刀的齿形形式是由传动蜗杆的齿形来决定的，这些不同的形式已经在DIN3975中成为标准，根据其产生方式，在ZA、ZN、ZI和ZK形蜗轮之间是有区别的。

Flank forms
The flank form of a worm gear hob is determined by the flank form of the driving worm. The various flank forms are standardized in **DIN 3975**, which distinguishes between **ZA, ZN, ZI** and **ZK** worms, according to the generating method.

- ZA型蜗杆在轴截面是直线齿形，这种齿形形式要求当用梯形车削刀具加工时，应将切削刃放在轴向平面上。
- ZN型蜗杆，在法截面是直线齿形，这种齿形是当使用梯形车削刀具时，在轴线高度进行设定而完成的。它的切削刃位于与平均导程角成夹角的平面上，蜗杆齿形就是通过这种设定加工产生的。
- ZI型蜗杆在主平面上是渐开线齿形这个齿形制造如下：由铣削或磨削形成的直线，此直线与蜗杆轴线所在的法平面形成的角度为压力角“a_0”来加工产生的。
- ZK形是蜗杆在轴平面有一个凸出的面，这个蜗杆齿形的加工是由一个两边呈锥度的蜗轮向下旋转，并与平均导程角方向成压力角a蜗轮齿轮的对称线通过轴线的交点，在此位置完成蜗杆的齿形。

- The **ZA worm** has a straight-line flank profile in its axial plane. This flank form is optained when a trapezoidal turning tool is applied so that its cutting edges are in the axial plane.
- The **ZN worm** has a straight-line flank profile in its normal plane. This flank form is achieved when a trapezoidal turning tool set at axis height is applied so that its cutting edges lie in the plane inclined by the center lead angle and the worm profile is generated in this setting.
- The **ZI worm** has involute flanks in its face plane. This flank form is produced, for example, when the worm profile is generated by a straight-lined cutting or grinding element whose axis is inclined to the worm axis by the center lead angle and to the normal plane on the worm axis by the pressure angle “α_0”.
- The **ZK worm** has a convex flank form in the axial plane. This worm form is generated when a double taper wheel trued under the pressure angle “α_0” is inclined into the center lead angle, where the line of symmetry of the wheel profile passes through the intersection of the axes and generates the worm profile in this position.

除此标准化齿形外，还有特别的形式，以下是经常使用的齿形。

DUPLEX（双螺旋）蜗杆在左侧和右侧齿面有不同的导程。其结果为，蜗杆上的齿厚在导程方向连续变化，与蜗轮相对应的蜗杆也可以调节间隙。

Besides the standardized flank forms, there are special forms, of which the hollow flank form is the most used.

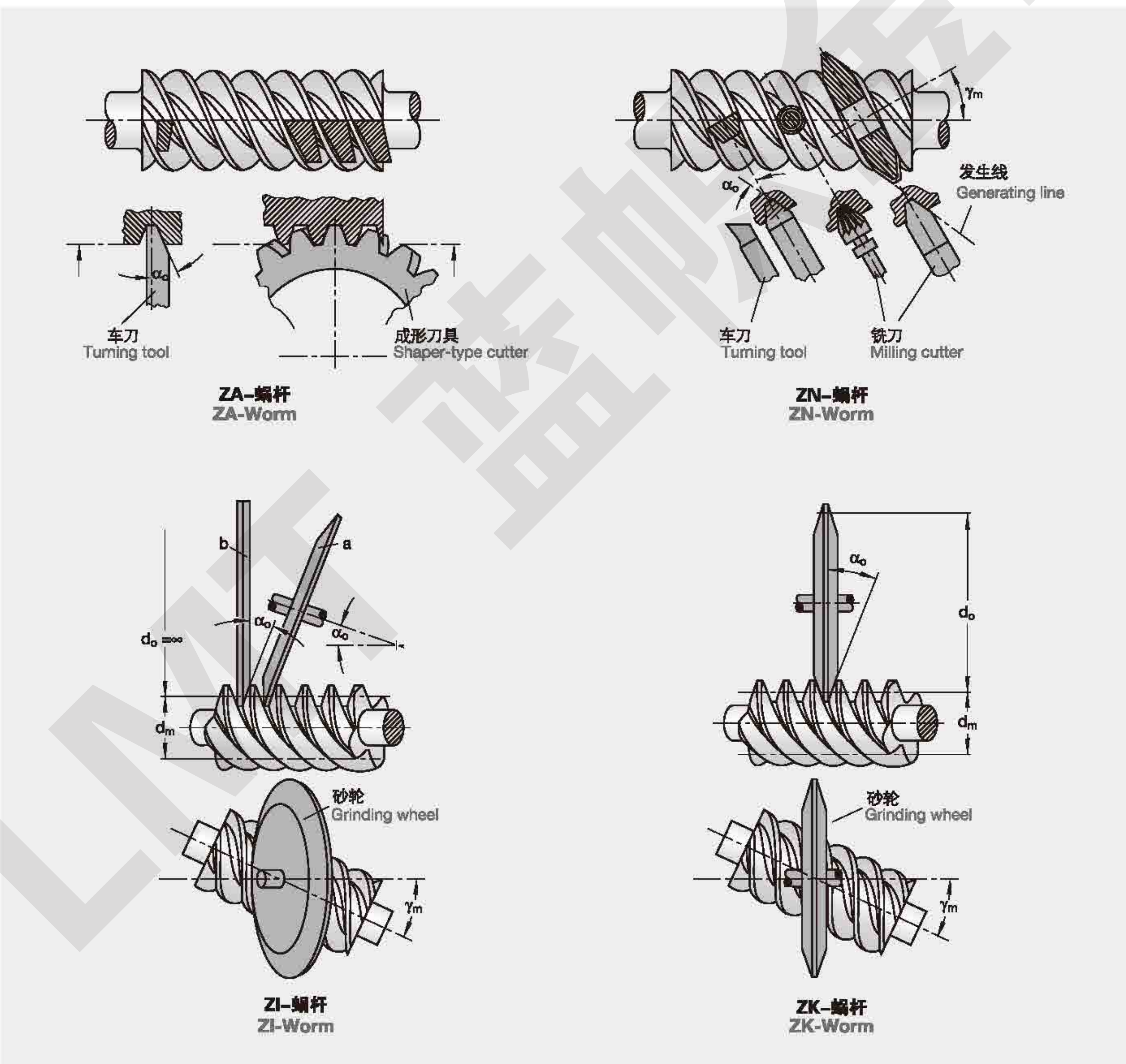
The above worm profile forms can also be used in **Duplex** worm drives. Duplex worms have different leads on the left- and right-hand flanks. As a result, the tooth thicknesses on the worms change continuously in the course of the lead, and an axial displacement of the worm in relation to the worm gear makes it possible to adjust the backlash.

工艺和设计

蜗轮滚刀有好几种设计方式，以下是它们的区别：

Processes and designs

Worm gear hobs are available in a range of designs. A distinction is drawn between the following types:



径向法

滚刀为圆柱形。它加工蜗轮时，径向全齿高切入，通过微小距离实现切向变形，这样可以改善齿形的包络曲线。这种切削方法具有最短的加工时间而且被用来加工螺旋角到8° 的蜗轮。切削刃长度最少不能小于加工蜗轮所需的长度。当然较长的滚刀可以窜刀。

Radial method

Cylindrical hobs are employed for this method. The hob enters the worm radially to full tooth depth, and can be displaced tangentially by a small distance in order to improve the enveloping cut on the flanks. This hobbing method has the shortest machining time and is generally employed for worm gear hobs with helix angles up to approximately 8°. The cutting edge length must be at least as long as the penetration length for the worm gear to be machined. Longer hobs can of course also be shifted.

切向法

切向法适用于单头和多头的蜗杆传动；此时滚齿机必须配备切向滚齿刀架。滚刀有比较长的锥度导向，用来削除较多的金属材料。圆柱形部位的每个滚刀头位置保证一到两个整齿高用做精加工滚齿。在开始加工之前，将滚刀安放在中心位置，滚刀和蜗轮的相交部分必须切向穿过。在确定了合适的进给量后，确定齿廓的包络切削量可以根据要求进行修改。由于长期使用切向加工，这种加工方法会比径向加工所需要的时间更长。

用作切向滚齿加工的最简单结构的蜗轮滚刀是单头或多头的快速切削滚刀。快速切削滚刀是每个刀头上只配备一个完整切削齿的滚刀，因而这种滚刀比较简单造价较低，但它切削金属的能力也相对较小。

Tangential method

This method is suitable for single- and multiple-start worm drives; the hobbing machine must however be equipped with a tangential hobbing head. The hobs have a relatively long taper lead section, which must remove the greater part of the metal. The cylindrical region contains one or two finishing teeth per hob start. The hob is set to the centre distance prior to the commencement of machining, and the penetration range between the hob and the worm gear must then be traversed tangentially. By selection of suitable feed values, the enveloping cuts which determine the tooth form can be modified as required. Owing to the long tangential runs, this method results in substantially longer hobbing times than the radial method.

径向滚削的蜗轮滚刀
Worm gear hob for radial hobbing

双螺旋蜗轮滚刀
Duplex worm gear hob

切向加工的蜗轮滚刀
Worm gear hob for tangential hobbing

径向加工的杆式蜗轮滚刀
Shank-type worm gear hob for radial hobbing

蜗轮剃削

对于高精度的蜗轮加工来说，通常选用蜗轮剃削工艺精加工经粗滚加工后的蜗轮。蜗轮剃削刀的切削的精度可以达到十分之几毫米，后角也可以达到最小，并具有较多的切削槽数。所有的蜗轮滚刀，它们的尺寸形状与驱动蜗杆最相似，因此也能够加工出最佳的接触范围。

Shaving worms

For high-precision worm gears, shaving worms are also employed for finish profiling of rough-hobbed worm gears. Shaving worms have pitch circle enlargements of only a few tenths of a millimetre, minimum relief angles, and a high number of gashes. Of all worm gear hobs, their dimensions most closely resemble those of the driving worm, and they therefore also produce the best bearing contact patterns.

径向加工方法

采用固定中心距

现代CNC滚齿设备的使用使FETTE能够研究使用更为经济的刀具进行加工。过去的蜗轮滚刀在每次进行修磨后必须加以调整，例如接触关系必须进行重新定位。这就造成生产成本的增加。

新的加工方法采用了圆柱径向滚刀，这种滚刀的齿面是沿轴向铲背的。这样，当螺旋倾角较大时（大于8度）它用来替换通常使用的切向滚刀。刀具的加工参数可以根据新的加工条件进行设置。

在第一次使用时将刀具的设置进行优化，然后根据刀具的使用寿命采用相同的中心距和加工刀刃角度对刀具进行设置。在认真选择加工布局后，接触关系可以根据蜗轮的要求在每次修磨后得到。

由于这种刀具属于径向滚刀类型，因此与传统的切向滚刀相比，这种滚刀有加工时间短的优点。

Radial Method

with constant centre distance

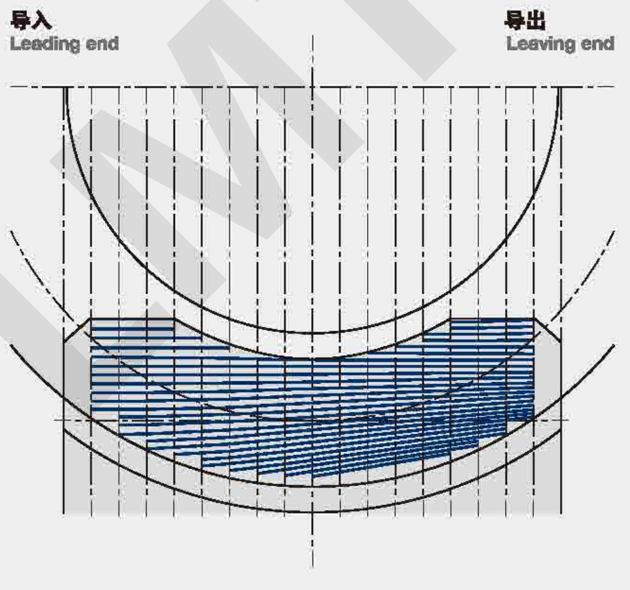
The use of modern CNC hobbing machines has enabled LMT Fette to develop a method which permits the use of economical tools. The worm gear hobs used in the past had to be re-adjusted each time they were reground, i. e. the bearing contact pattern had to be relocated. This entails high production costs.

In the new method, cylindrical radial hobs are employed, with flanks that are axially relief-machined. The usual tangential hobbing is thus replaced at higher helix angles (> 8°). The tool setting can be calculated as for the new condition. The setting is optimized when the tool is first used, and the tool is then used with the same centre distance and tool cutting edge angle over the entire lifespan.

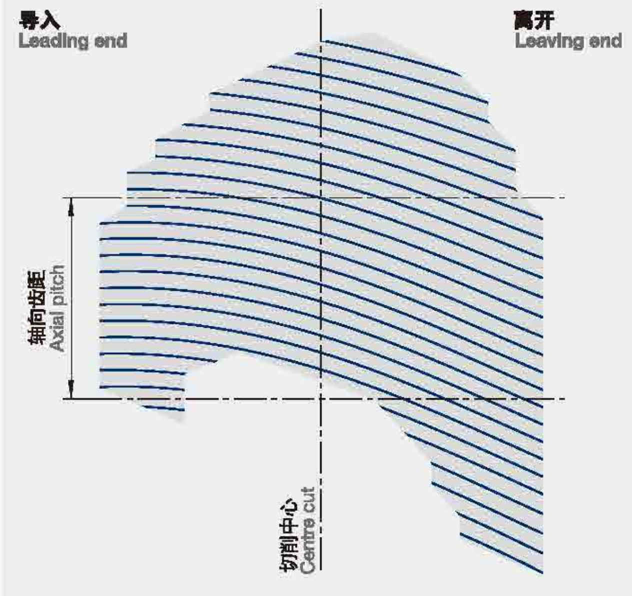
By careful selection of the arrangement, a bearing contact pattern is produced which can be attained reliably by each regrind according to the requirements of the worm gear.

Since the tools are radial hobs, this hob concept has the advantage of shorter hobbing times in comparison with conventional tangential hobbing.

蜗轮齿面接触线
Contact lines on the worm gear flank



啮合区域
Engagement area



啮合区域和接触关系方式

确定蜗轮齿形和啮合区域的基本参数包括：模数、齿数、齿形变形量以及相关联的螺旋线。
现在，使用强大的个人计算机可以很精确地实现蜗轮啮合情况的复杂计算

在实际情况中，接触关系方式的接触面可以达到50%至70%。FETTE公司的软件能够帮助我们的专业部门完成最佳的刀具设计方案。
因此现在可以精确而稳定地设计出具有大量头数的蜗轮滚刀。但是还必须指出，齿轮的啮合区域首先由齿轮制造商决定，刀具制造商只能减小其尺寸。
在滚齿加工过程中接触关系方式的接触比必须大于1。从理论上讲，此时用户提出对刀具的调整问题可以由FETFE公司通过计算机进行模拟实现。从而完成相关的修正。我们的应用工程师还可以提供现场支持。下图给出了所选情况的计算结果。

订货说明：

蜗轮滚刀在加工时可以制成带有键槽或驱动槽的孔式滚刀，也可以制成杆式滚刀。通常在加工时选用造价比较便宜的孔式滚刀。但是如果滚刀的直径过小，齿廓很高，那么在加工时应该选用杆式滚刀，右侧的图示内容用来判断加工时选用孔式滚刀合适还是杆式滚刀合适。如果选用的是杆式滚刀，请按照图中所示方法提供滚齿机的类型以及滚刀加工区域的尺寸。

Engagement area and bearing contact pattern

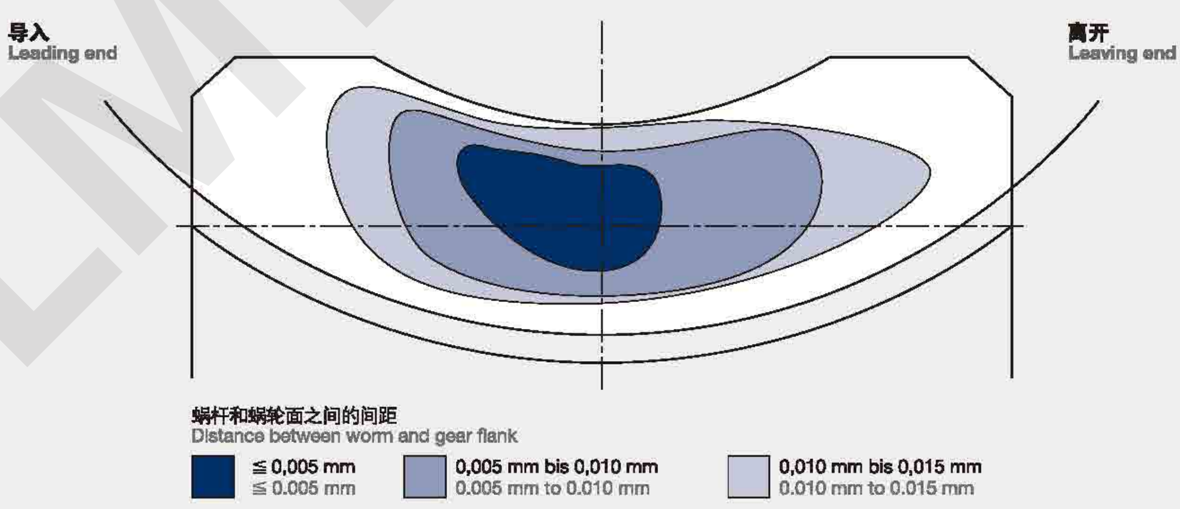
The essential variables which determine the tooth form of the worm gear and the engagement area are as follows: module, number of teeth, profile displacement, and the associated worm. The complex computation of the engagement conditions in the worm gear can now be performed very precisely by means of powerful computers.

In practice, bearing contact patterns with a pattern contact area of 50–70 % are desirable. The LMT Fette software enables our specialist department to produce the optimum tool design. Worm gear hobs with high numbers of starts can thus now be designed very accurately and reliably. It must be pointed out however that the engagement area is determined in advance by the gear manufacturer, and can only be reduced in size by the tool manufacturer. The bearing contact pattern during hobbing must be generated such that an contact ratio of > 1 is produced. Cases in which the user is presented with a tool adjustment problem can be simulated theoretically by LMT Fette on the computer. A corresponding correction can thus be made.
Our applications engineers are also available for on-site assistance.
Selected calculations are shown in the diagrams.

Instructions for ordering

Worm gear hobs can be manufactured as bore-type hobs with keyway or drive slot, or as shank-type hobs. Generally, preference is given to the less expensive bore-type hobs. However, if the hob diameters are very small and the profiles very high, it may be necessary to select a shank type. The diagram on the right can be used to determine whether a bore-type hob is suitable or a shank-type hob is required. If the shank version is selected, please quote the make and type of the hobbing machine and the dimensions of the working area or of the shank-type hob, as shown in the diagram.

蜗轮面局部剖面图
Topography of the worm gear flank



由于以上原因，零部件的尺寸无法实现标准化。他们的尺寸必须符合驱动蜗杆的技术数据以及滚齿工艺要求。

制造滚刀时要求具有以下数据信息：
- 轴向模数
- 压力角
- 蜗杆节圆直径
- 螺旋方向及头数
- DIN3975标准的齿廓(A，N，I或K)

上述数据也可以以蜗杆或蜗轮图纸的形式提交。

如无特别说明，滚刀可按以下标准设计：
- 齿顶高 = 1.2 × m
- 全齿高 = 2.4 × m
- 无顶切
- 齿形铲磨
- 径向铣削的圆柱滚刀导向角度约为8度
- 带导向端的切向滚刀导向角大于8度

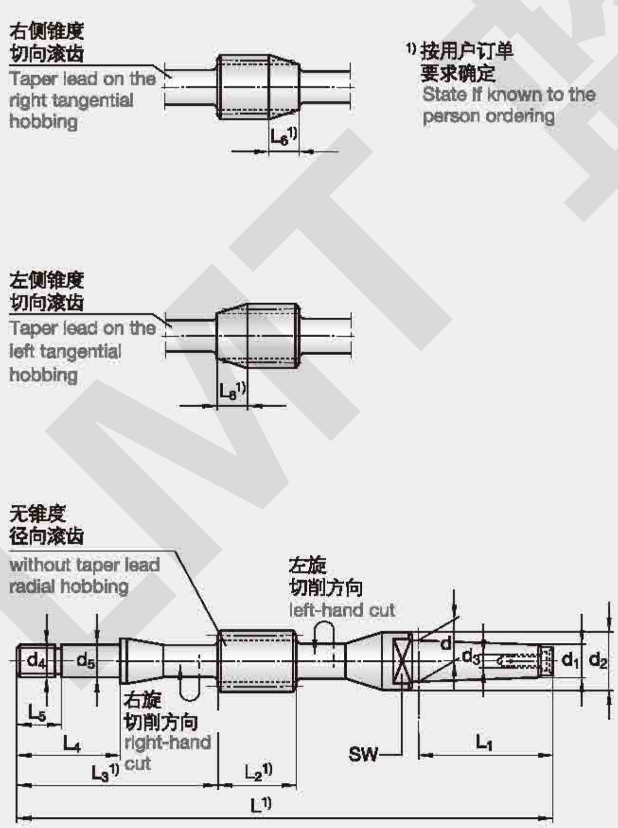
The component dimensions cannot be standardized for the reasons given above. They must be adapted to the technical data of the drive worms and to the hobbing processes.

The following information is required for manufacture of these hobs:
- Axial module
- Pressure angle
- Pitch circle diameter of the worm
- Number and direction of starts
- Flank form to DIN 3975 (A, N, I or K)

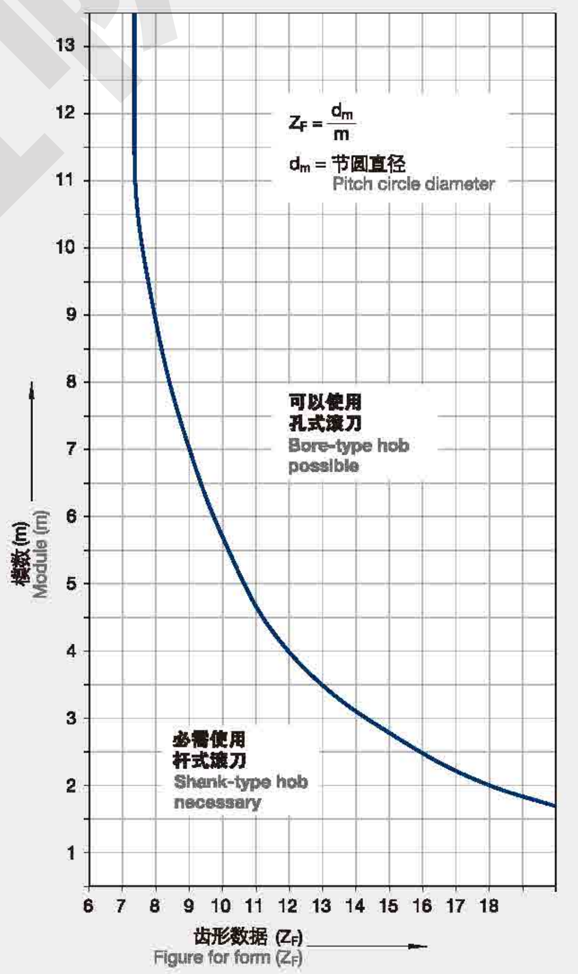
The above data can of course also be supplied in the form of worm and worm gear drawings.

Unless otherwise specified, the hobs are designed as follows:
- Addendum = 1.2 × m
- Tooth height = 2.4 × m
- Non-topping
- Tooth profile relief ground
- Cylindrical hob for radial milling up to a lead angle of approx. 8°
- Hob for tangential hobbing, with lead on the leading end, if lead angle > 8°

柄部尺寸
Shank dimensions



孔式滚刀与杆式滚刀
Bore-/shank-type hob



可转位硬质合金圆柱齿轮滚刀

WÄLZ-FRÄSER

MIT HARTMETALL-WENDEPLATTEN FÜR STIRNRÄDER

HOBS WITH INDEXABLE CARBIDE INSERTS FOR SPUR GEARS

可转位硬度合金圆柱齿轮滚刀
Hobs with indexable carbide inserts for spur gears

40多年以来，我们的工程师已经研发了可转位硬质合金齿轮切削刀具，过去刀片采用焊接方式，但现在通常采用可转位刀片结构设计了。这能与切削材料很好地相匹配和专用的几何参数，这项技术的优点如下面所列出：

- 快速应用
- 快速转换切削刃
- 100%地质量稳定
- 高切削价值/高性价比
- 经济性好，可转位刀片可采用多切削刃
- 对被切削材料进行优化加工
- 硬质合金的材料，几何参数和涂层很好组合
- 采用新的可转位硬质合金刀片改进现有的刀具

接下来，蓝帜菲特公司为您提供一个全面范围的可转位刀片刀具：

- m6~100粗切和精切，刀条型式
- m6~45粗切和精切，单头和多头滚刀
- 转子铣刀
- 特殊的解决方案

我们现代可转位硬质合金刀片技术能使齿轮精加工达到高的精度等级，今天齿轮制造业对切削工艺可靠性和短的切削时间是最主要的要求，在这方面蓝帜菲特公司在接下来将做更多讲解，我们的专家将高兴地给您指导。蓝帜菲特可转位刀片系列：创新、高性能、通用和可信赖。

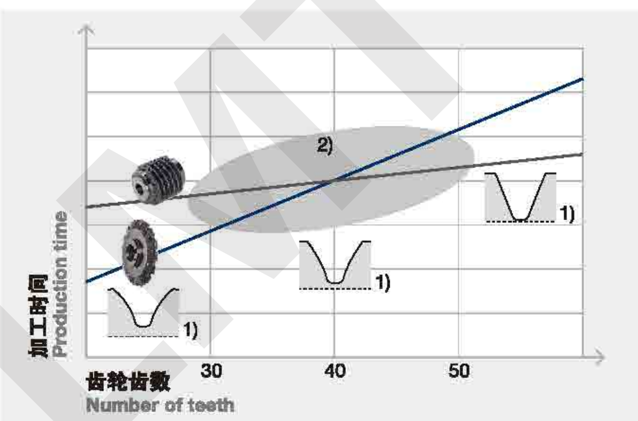
For over 40 years, our engineers have been developing gear cutting tools with indexable carbide insert. Cutting inserts used to be soldered, but nowadays they are usually constructed as indexable insert designs. This enables perfect matching of the cutting material and the geometry to the individual application of the tool. The benefits of this technology are characterized by the following criteria:

- Quick availability
- Quick change of the cutting edges
- 100 % reproducible quality
- Enables high cutting values/labor values
- Economical, due to indexable inserts with multiple cutting edges
- Optimization of the material to be machined
- Matching of carbide substrates, geometries and coatings
- Innovation on existing tools with new indexable carbide inserts

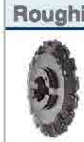
On the following pages, LMT Fette offers you a comprehensive range of tools with indexable inserts for:

- Segmented tooth form cutters, module 6 to 100 for roughing and finishing
- Gear hobs, single and multi-start versions, module 6 to 45 for roughing and finishing
- Rotor milling cutter
- Special solutions

Our modern indexable carbide inserts technology enables us to achieve superior accuracy classes for the finishing of gears. Process reliability and short machining times are the main criteria for the manufacturing of gears today. Find out more about LMT Fette's know-how on the following pages. Our experts will be happy to advise you. LMT Fette indexable insert systems: innovative, high-performance, universal and reliable.



1) 齿的形状取决于被加工齿轮的齿数
Gear profile depending on the number of teeth
2) 齿轮铣刀和机夹可转位刀片滚刀的应用取决于客户提供的被加工齿轮参数。
The application of a gear milling cutter or ICI hob in this range is depending on the application data from the customer.

粗加工/精加工 Roughing-/Finishing cutters		精度等级 Quality
	可转位齿轮铣刀 模数：6–70 **Gear milling cutter with indexable inserts** Module: 6 to 70	最高9级 up to wheel quality 9
	ICI滚刀 模数：6–45 Ein- und Zweigängig **ICI hob** Module: 6 to 45, One and two-starts	B/C bis AAA/A B/C to AAA/A

蓝帜菲特其它齿轮刀具的产品范围 Other gear cutting tools LMT Fette product range	
	倒角刀系统 ChamferCut
	整体滚刀 Solid hobs

其它模数可单独询价
Other modules on request.

模数6以上齿轮的粗加工可以用这种非常经济的现代刀具实现。

设计构想是用经济的可转位硬质合金刀片与众所周知的滚切优势的结合。在规定的时间内，可以在高切削速度下切除大量金属。

重磨对于传统滚刀是必需的，在这里没有必要。这节省了修磨成本和换刀时间。单个刀齿上的磨损痕迹因过程而异。对于大齿轮，它们可以通过移位来部分地实现等同。因此滚刀在齿宽上总是有不同的磨损痕迹。

当使用转位刀片时，这些刀片在达到了最大的磨损痕迹宽度时被旋转或替换。

更换转位刀片或刀条，不用将滚刀从机床上卸下来，这样就节省了待工时间。更换转位刀片需要使刀片牌号与齿轮材料匹配。

为了成功使用这些硬质合金刀具，要求机床有足够好的刚性和所需的转速及驱动功率。

The hobbing of gears form module 6 onwards can be carried out extremely economically with these modern tools.

The design concept is the combination of the known advantages of the hobbing process with the performance of carbide and the economy of indexable inserts. Using indexable carbide inserts, large volumes of metal can be removed within a given time at high cutting speeds.

Regrinding, which is necessary with conventional hobs, is eliminated. This saves the cost of sharpening and of tool changes. The wear marks on the individual cutter teeth vary according to the process. In the large-gear sector, these can only be partly equalized by shifting. Hobs therefore always contain teeth with different wear mark widths.

When using inserts, only those inserts need to be indexed or replaced which have reached the maximum wear mark width. To change the indexable inserts or the segments, it is not necessary to remove the cutter from the machine. This results in short hobbing machine downtimes.

Changing the indexable carbide inserts also makes it possible to match the carbide grade optimally to the gear material.

To use these carbide tipped tools successfully, it is necessary to have hobbing machines which offer sufficient rigidity as well as the required speed and drive power.

结构

菲特的可转位刀片滚刀包含一个刀体，在它上面用螺钉拧上刀条和可转位硬质合金刀片，后者通过压紧螺钉固定在刀条的刀座里。

圆柱刀体上有一条螺旋凹槽。凹槽的侧面根据刀体的导程进行了磨削。

这个经磨制的圆柱外园部分总是保持在两个凹槽之间，对刀条起着支承作用，刀条上通过两个圆柱销在凹槽的引导下决定其位置。刀条是通过螺钉固定在刀体上。转位硬质合金刀片的刀座在刀体上切向安装。

如果可能的话，在刀条上，刀片是交错排列的。这个用途是保持作用在刀体上的轴向的反作用力和在齿轮上的切向力尽可能地小。可转位硬质合金刀片必须完全覆盖刀具切削刃。可转位刀片数和所有的分布取决于刀片的尺寸和齿轮的尺寸。为了给予刮削或磨削最佳的预留量，可转位刀片硬质合金滚刀可以在齿轮上即产生根切或倒角（见下方图示）。

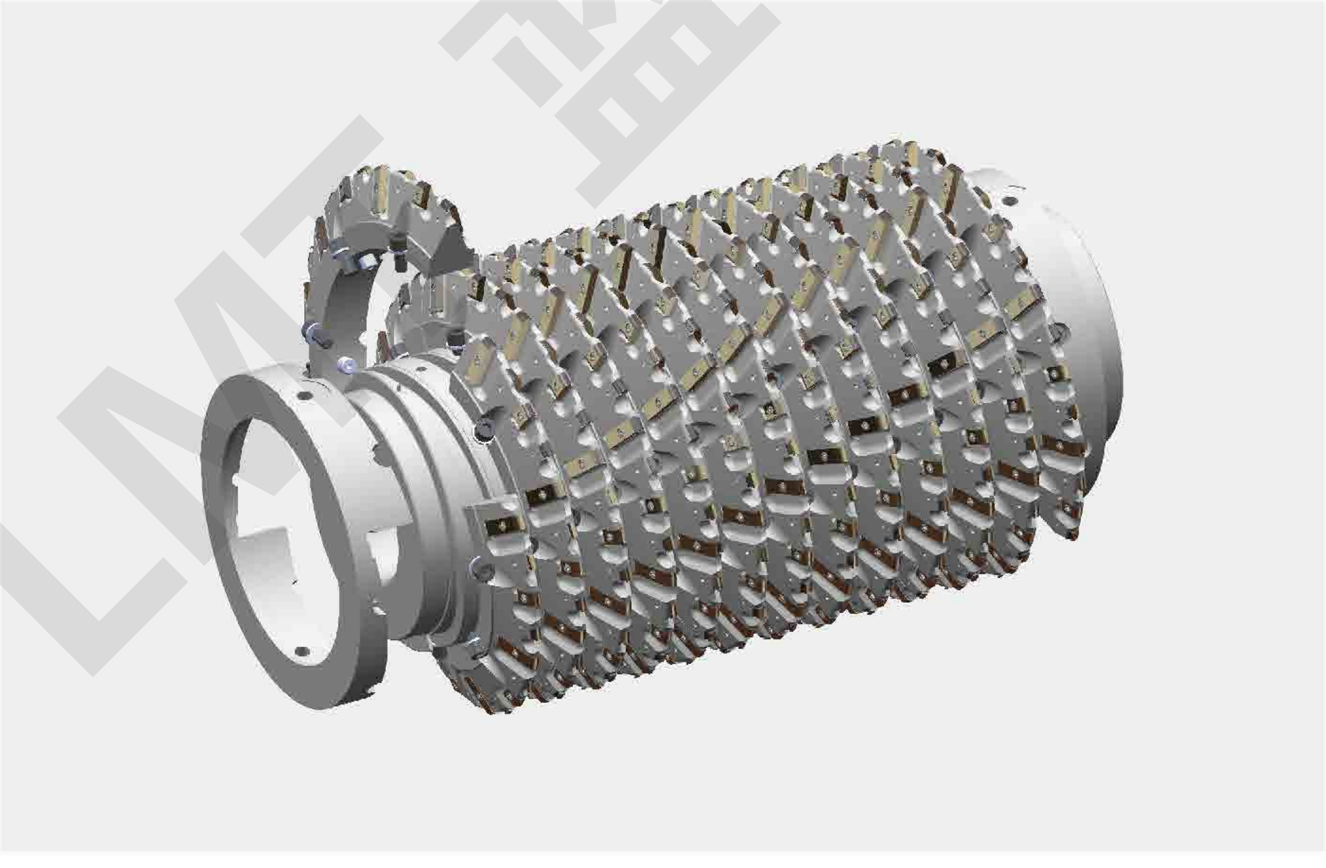
Construction

LMT Fette carbide indexable insert hobs consist of a cutter body, onto which the tooth segments are screwed and indexable carbide inserts. The latter are held by clamping screws in the insert seats of the segments.

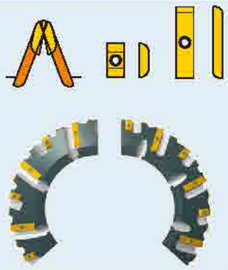
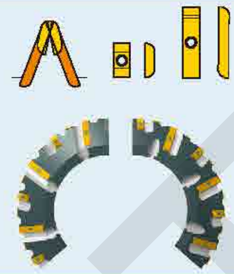
A helical groove has been recessed into the cylindrical cutter body. The flanks of the groove ground according to the cutter lead. The parts of the ground cylindrical shell which remain between the groove windings act as support surfaces for the tooth segments. Cylindrical pins arranged in the tooth segments are guided in the groove and determine the position of the segments. The segments are fixed to the cutter body by inhex screws.

The seats for the indexable carbide inserts are arranged tangentially on the tooth segments. Within a segment, the seats are arranged alternately if possible. The purpose of this arrangement is to keep the axial reaction forces on the cutter and the tangential cutting force components on the gear as low as possible.

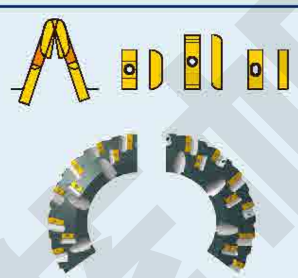
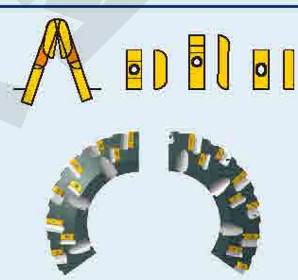
The indexable carbide inserts must completely cover the cutting edges of the cutter tooth. The necessary number of indexable inserts and their arrangement depend on the dimensions of the inserts and on the size of the gear. To render the pre-cutting of the gear optimal for skive hobbing or grinding, the carbide hobs with indexable inserts can be made so that they produce both a root clearance cut and a chamfer on the gear (see fig. below).



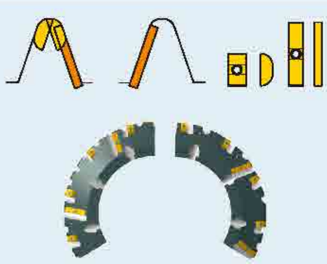
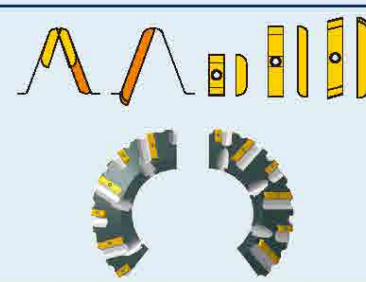
生产率 Productivity →

粗加工 Pre-machining		
模数16以下 有凸角粗加工 Roughing with a protuberance		
Z_{eff}	70%在齿顶 75 % in the tip	100 %
可转位刀片切削刃 Cutting edges of indexable inserts	4/4	4/4
精度等级 Accuracy class	B/C	B/C
齿轮精度 Gear quality	10–12	10–12
生产率 Productivity	75 %	100 %

生产率 Productivity →

粗加工 Pre-machining		
模数16以下 有凸角粗加工 Roughing with a protuberance		
Z_{eff}	75 % im Kopf 75 % in the tip	100 %
可转位刀片切削刃 Cutting edges of indexable inserts	4/4/4	4/4/4
精度等级 Accuracy class	B/C	B/C
齿轮精度 Gear quality	10–12	10–12
生产率 Productivity	75 %	100 %

生产率 Productivity →

精加工 Finish-machining		
精铣 Finish-milling		
Z_{eff}	50 %	100 %
可转位刀片切削刃 Cutting edges of indexable inserts	4/4	4/2
精度等级 Accuracy class	AAA/A	AAA/A
齿轮精度 Gear quality	8级以上 up to 8	8级以上 up to 8
生产率 Productivity	50 %	100 %

所有刀具尺寸参照结构系列尺寸
双头刀具也可以制造
All tool dimensions in accordance with structural dimension series.
2-thread tools available on request.

双头滚刀–保证质量的快速加工

单头硬质合金可转位刀片滚刀的使用无论是在技术或优化上都是十分成熟的。现我们向您介绍更具优势的双头滚刀：它是创新的提高生产率降低切削时间并实现更好的表面精度和齿形精度。

Double-start hob – the fast solution for quality

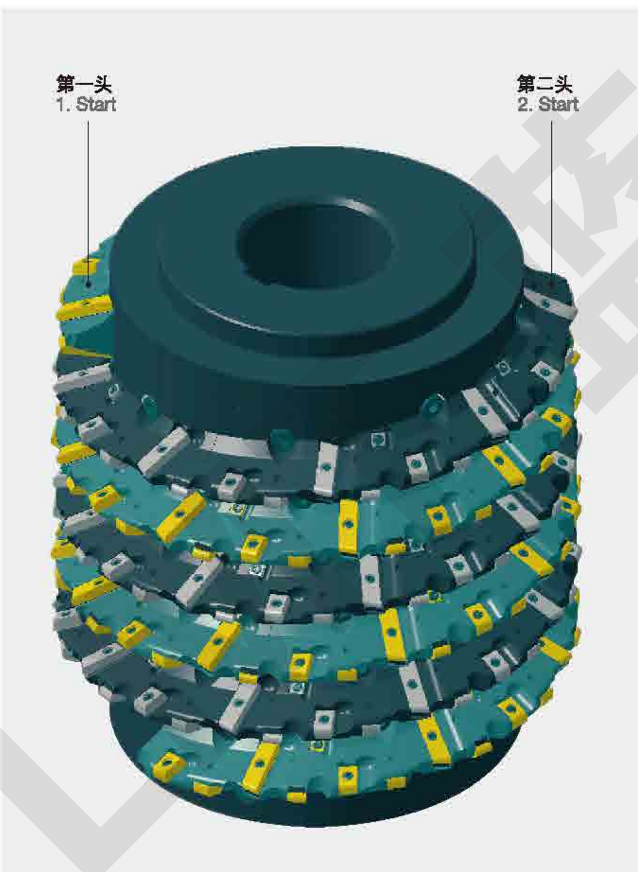
Single-start indexable carbide inserts hobs (ICI) are easy-to-use, technologically advanced and optimized. We are shifting gears for you with the double-start Indexable Hob. This innovation allows you to reduce your production and set-up times, while achieving a better surface finish and gear profile accuracy on top.

优点

- 很低的加工费用
- 缩短的加工时间，高的生产率
- 安全可靠的生产
- 很低的装备费用
- 刀具费用降低
- 刀具使用寿命长
- 适应不同的轮廓加工（已经实现6种齿形）
- 不用刃磨
- 高的齿轮加工质量（小的进给切痕）—到精度8级
- 硬质合金可转位刀片的最佳更换
- 合适的硬质合金种类和涂层

Benefits

- Lower machining costs
- Shorter manufacturing times, higher productivity
- Safe production
- Low set-up costs
- Low tool costs
- Long tool life
- Design with different profiles (already realized 6 profiles)
- No resharpening
- High gear cutting quality (small feed markings) – up to Quality 8
- Optimal changing of carbide indexable inserts
- Adjusted carbide types and coatings



节约时间 = 126分钟
Saving = 126 min machining time

指导方针：进给切痕深度5μm。
Guideline: Depth of feed marks 5 μm.

例如：精滚一个齿圈
Example: Finish hobbing a gear rim

模数 Module	m	:	12
压力角 Pressure angle	E∢	:	20°
齿数 No. of teeth	z	:	231
齿宽 Gear width	b	:	150
材料 Material		:	42 CrMo 4

工具 Tools

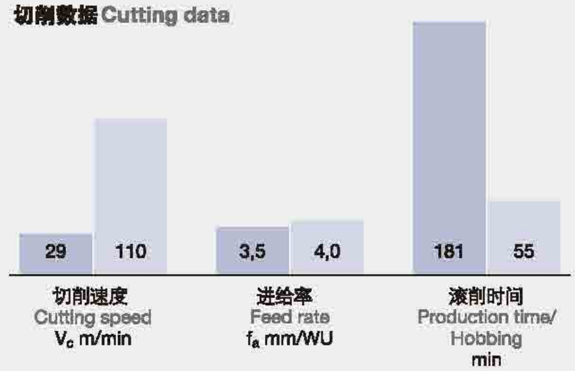
双头可转位硬质合金滚刀
Double-start gear hob with indexable carbide inserts

外径 Outside diameter	280
容屑数 Number of gashes	eff. 16
头数 Number of starts	2

重切粗滚刀
Heavy duty of roughing hob

外径 Outside diameter	220
容屑数 Number of gashes	22
头数 Number of starts	2

切削数据 Cutting data



询价单
Inquiry form

日期
Date

公司
Company

用户编号
Customer No.

名称
Name

街道
Street

邮政编码/城市
Post Code/City

电子信箱
E-Mail

LMT·TOOLS

Wendeplatten-Wälzfräser für Stirnräder und Zahnwellen
Hobs with indexable inserts for straight gears and external splines

请送你的询价单到： Please send your inquiry to: **Gearcutting@lmt-tools.com**

菲特刀具编号：
LMT Fette-Ident-No.:

工件图纸编号：
Workpiece drawing No.:

零件材质：
Part material:

抗拉强度：
Tensile strength:

刀具图纸编号：
Tool drawing No.:

所询刀具数量(件)： ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐
Quantity (pieces)

☐ **模数** Module ☐ DP ☐ CP
☐ **节距** Pitch:

压力角
Pressure angle:

☐ **粗加工滚刀** Roughing hob
☐ **精加工滚刀** Finishing hob

基本齿形
Basic profile:

☐ „1" DIN 3972 ☐ „2" DIN 3972
☐ „3" DIN 3972 ☐ „4" DIN 3972
☐ DIN 5480 ☐ ISO 53
☐ BS 2062 ☐ Sonderprofil Other profile
☐ AGMA 201.02-1968
☐ AGMA 201.02-1968 STUB

☐ **零件齿形部位参数：**
From part data:

☐ **刀具齿形：**
From tool profile:

齿顶倒角 ☐ 是 yes ☐ 否 no
Semi topping

齿根挖根 ☐ 是 yes ☐ 否 no
Protuberance

齿顶修缘 ☐ 是 yes ☐ 否 no
Tip relief

齿底全圆弧 ☐ 是 yes ☐ 否 no
Full radius

备注 Notes:

刀具参数 Tool data

精度等级 ☐ AA ☐ A ☐ B ☐ B/C
Quality grade

标准选择 ☐ DIN 3968 ☐ AGMA ☐ BS
To standard

非标公差：
Non-standard tolerance:

头数：
Number of starts:

旋向 ☐ **右旋** right ☐ **左旋** left
Direction of starts

外径 (d_1):
Outside diameter (d_1):

切削刃长 (l_3):
Cutting length (l_3):

刀具总长(l_1):
Overall length (l_1):

内孔直径 (d_2):
Bore diameter (d_2):

有效切削齿数：
Number of eff. teeth:

涂层 ☐ AL2Plus ☐ Nanotherm
Coating

驱动方式 Drive
☐ **轴向驱动 DIN 138**
Keyway DIN 138
☐ **右端面键 DIN 138**
One right-hand drive slot DIN 138
☐ **左端面键 DIN 138**
One left-hand drive slot DIN 138
☐ **双端面键**
Two drive slots

机床参数 Machine data

机床种类：
Type of machine:

最大串刀长度：
max. shift length:

最大刀具外径：
max. tool diameter:

最大刀具长度：
max. length:

☐ **湿式切削** wet cutting
☐ **干式切削** dry cutting

零件参数 Part data

☐ **模数** Module ☐ DP ☐ CP
☐ **节距** Pitch:

齿数：
Number of teeth:

压力角：
Pressure angle:

螺旋角：
Helix angle:

齿顶圆：
Tip circle diameter:

齿根圆：
Root circle diameter:

有效齿顶圆直径
Effective tip circle dia.:

有效齿根圆直径
Effective root circle dia.:

齿顶径向倒角总量：
Radial amount of the tip chamfer:

单面齿厚留量：
Stock per flank:

公法线跨齿数：
Number of teeth for checking:

公法线长度 Tooth width:
成品 finished
半成品 milled

球径/棒径：
Ball dia./pin dia.:

球间距：
Diametral dimension between balls:
成品 finished
半成品 milled

棒间距：
Diametral dimension between pins:
成品 finished
半成品 milled

分度圆弧齿厚 Tooth thickness:
分度圆直径
Pitch line dia.

齿幅宽 (mm):
Gear width (mm):

零件年产量：
Workpieces p.a.:

最大允许进给切痕：
max. feed mark:

刀具基本齿形参数 Tool basic profile data

齿顶高 $p_o/2$ (h_{aP0}):
Addendum at $p_o/2$:

全齿高 Depth of tooth (h_{P0}):

齿顶圆半径 Tip radius (ϱ_{aP0}):

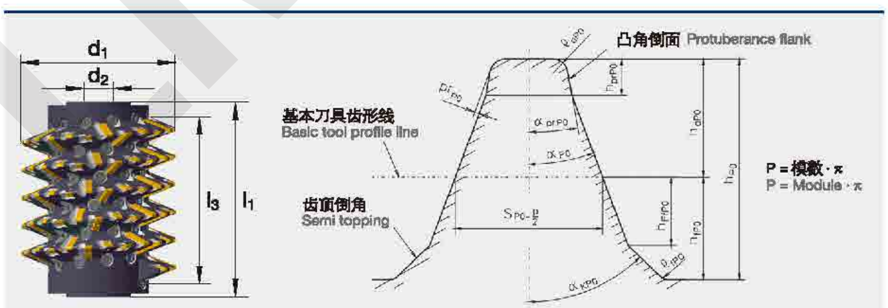
齿根圆半径 Root radius (ϱ_{fP0}):

切深 Depth of cut (frt):

总挖根量 (pr_{P0}):
Protuberance amount:

倒角高度 (h_{FfP0}):
Height of semi topping:

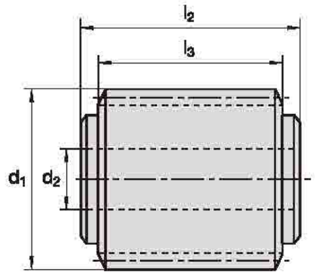
倒角角度 (α_{KP0}):
Profile angle semi topping flank:



LMT Tool Systems GmbH
Heidenheimer Strasse 84
73447 Oberkochen
Telefon +49 7364 9579-0
Telefax +49 7364 9579-8000
lmt.de@lmt-tools.com
www.lmt-tools.com

LMT Fette Werkzeugtechnik GmbH & Co. KG
Grabauer Strasse 24
21493 Schwarzenbek
Telefon +49 4151 12-0
Telefax +49 4151 3797
info@lmt-fette.com
www.lmt-fette.com

Car-bide Special BP [1)]

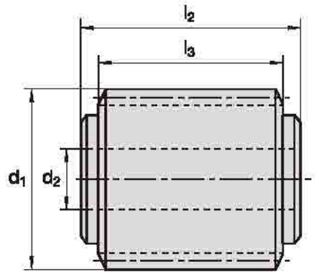


Katalog-Nr. Cat.-No.	2163

m	d_1	刀齿排列数 Tooth raws	Z_{eff}		l_3	端面键 Drive slot l_2	轴向键 Keyway l_2	d_2
5,5	270	30	15	15	120	180	165	80
6	270	30	15	15	130	190	175	80
7	270	30	15	15	152	215	200	80
8	270	30	15	15	174	235	220	80
9	270	30	15	15	196	255	240	80
10	270	30	15	15	217	285	270	80
11	300	34	17	17	239	300	285	80
12	300	34	17	17	261	325	310	80
14	300	34	17	17	304	370	355	80
16	300	34	17	17	348	415	400	80
18	300	34	17	17	392	360	445	80
20	300	34	17	17	436	505	490	80
22	360	38	19	16	415	485	470	80
24	360	38	19	16	453	520	505	80
5,5	240	26	13	20	123	177	165	60
6	240	26	13	20	135	192	180	60
7	240	26	13	20	157	212	200	60
8	240	26	13	20	179	232	220	60
9	240	26	13	20	202	257	245	60
10	240	26	13	20	224	282	270	60
11	270	30	15	15	239	297	285	60
12	270	30	15	15	261	322	310	60
14	270	30	15	15	304	367	355	60
16	270	30	15	15	348	412	400	60
22	5圈 5 convolutions							
24								
5,5	210	23	12	18	123	176	165	50
6	210	23	12	18	135	191	180	50
7	210	23	12	18	157	211	200	50
8	210	23	12	18	179	231	220	50
9	210	23	12	18	202	256	245	50
10	210	23	12	18	224	281	270	50
11	240	23	12	17	239	297	285	60
12	240	23	12	17	261	332	310	60
14	240	23	12	17	304	367	355	60

[1)] 需要时选择
on request

1)



Katalog-Nr. Cat.-No.	2153

m	d_1	刀齿排列数 Tooth raws	Z_{eff}		l_3	端面键 Drive slot l_2	轴向键 Keyway l_2	d_2
5,5	270	30	15	15	120	180	165	80
6	270	30	15	15	130	190	175	80
7	270	30	15	15	152	215	200	80
8	270	30	15	15	174	235	220	80
9	270	30	15	15	196	255	240	80
10	270	30	15	15	217	285	270	80
11	300	34	17	17	239	300	285	80
12	300	34	17	17	261	325	310	80
14	300	34	17	17	304	370	355	80
16	300	34	17	17	348	415	400	80
18	300	34	17	17	392	360	445	80
20	300	34	17	17	436	505	490	80
22	360	38	19	16	415	485	470	80
24	360	38	19	16	453	520	505	80
5,5	240	26	13	20	123	177	165	60
6	240	26	13	20	135	192	180	60
7	240	26	13	20	157	212	200	60
8	240	26	13	20	179	232	220	60
9	240	26	13	20	202	257	245	60
10	240	26	13	20	224	282	270	60
11	270	30	15	15	239	297	285	60
12	270	30	15	15	261	322	310	60
14	270	30	15	15	304	367	355	60
16	270	30	15	15	348	412	400	60
22	5圈 5 convolutions							
24								
5,5	210	23	12	18	123	176	165	50
6	210	23	12	18	135	191	180	50
7	210	23	12	18	157	211	200	50
8	210	23	12	18	179	231	220	50
9	210	23	12	18	202	256	245	50
10	210	23	12	18	224	281	270	50
11	240	23	12	17	239	297	285	60
12	240	23	12	17	261	332	310	60
14	240	23	12	17	304	367	355	60

1) 基本齿形 $h_{a0} = 1{,}15 \cdot m$, $\varrho_{a0} = 0{,}1 \cdot m$
Basic profile $h_{a0} = 1.15 \cdot m$, $\varrho_{a0} = 0.1 \cdot m$

Wälzfräser mit Wendeplatten
Hobs with inserts

可转位硬质合金齿轮铣刀

ZAHN-FORM-FRÄSER

MIT HARTMETALL-WENDEPLATTEN

GEAR MILLING CUTTERS WITH INDEXABLE CARBIDE INSERTS

可转位硬质合金齿轮铣刀
Gear milling cutters with indexable carbide inserts

生产和创新
齿轮切削专家

在任何大负载的传动中总是能发现一些大的齿轮箱。这些齿轮箱被用于风电行业、船舶行业以及机床建筑行业。在这些齿轮箱中，内齿轮或外齿轮的工作精度非常高。这些零件的制造有着不同加工工艺。一百多年以来，蓝帜菲特一直致力于大模数齿轮刀具的生产。在这期间，我们的客户也很依赖于我们在刀具开发过程中积累的经验以及不断革新的技术与应用。现在，加工工艺的安全性和加工效率是生产中最重要的因素。现代齿轮加工设备与可转位刀具的技术由此而产生。蓝帜菲特可以提供全范围的粗加工及精加工用的滚齿刀具和齿轮铣刀。

蓝帜菲特齿轮铣刀：高效、创新、通用，是您可信赖的。

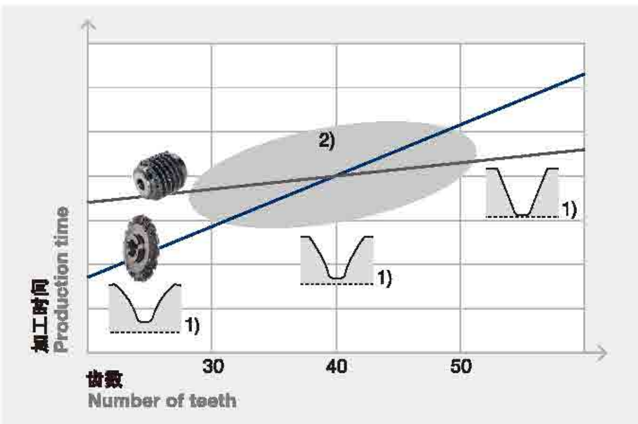
Productive and innovative:
Gear cutting experts

They can be found wherever large loads and forces are in motion: large gear units. These units are used in industries such as wind energy, marine industry and machine construction. In these gear units, the gearwheels, with external and internal gears, work with the highest precision. These components are produced with different manufacturing processes. For more than 100 years, LMT Fette has been manufacturing gear cutting tools for the production of large-module gearwheels. During this time, our customers have been relying on our know-how gained in the development and use of state-of-the-art tool technology.
Today, process safety and short machining times are the most important criteria for manufacturing. Modern gear cutting machines use tools with indexable insert technology for this purpose. LMT Fette offers a comprehensive range of hobs and gear milling cutters for roughing and finishing machining operations.

LMT Fette gear milling cutters: Innovative, powerful, universal and reliable.

蓝帜菲特ICI滚刀
与ICI齿轮铣刀的对比

Comparison
LMT Fette ICI hob /
LMT Fette gear milling cutter with indexable inserts



[1)] 齿的形状取决于被加工齿轮的齿数。
Gear profile depending on the number of teeth
[2)] 齿轮铣刀和机夹可转位刀片滚刀的应用取决于客户提供的被加工齿轮参数。
The application of a gear milling cutter or ICI hob in this range is depending on the application data from the customer.

齿轮铣刀(单排齿)和ICI滚刀都可用于齿轮的粗加工。如何选择这两种刀具取决于被加工齿轮的批量和齿数。

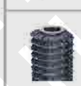
当齿轮的模数较大、且齿数很多时，滚齿的效率更高。当齿轮的批量较小，或齿数较少时，用齿轮铣刀更合适。以上图表供您参考如何选择合适的刀具。

从节省成本的方面看，齿轮铣刀无论是在刀具采购成本还是刀具消耗性成本上都比ICI滚刀更实惠。

齿轮铣刀根据客户需求可设计为粗加工和精加工用刀具。以下目录中所列尺寸的粗铣刀刀盘，蓝帜菲特都可以在较短的交货期内供货。

蓝帜菲特大模数齿轮加工范围
LMT Fette product range for large gears

粗加工/粗加工 Roughing-/Finishing cutters		精度等级 Quality
	**可转位齿轮铣刀** 模数：6–70 **Gear milling cutter with indexable inserts** Module: 6 to 70	最高9级 up to wheel quality 9
	**ICI滚刀** 模数：5.5–45 1头和2头 **ICI hob** Module: 6 to 45, One and two-starts	B/C bis AAA/A B/C to AAA/A

蓝帜菲特其他齿轮刀产品范围 Other gear cutting tools LMT Fette product range	
	**倒角刀系统** **ChamferCut**
	**整体滚刀** **Solid hobs**

其它模数可单独询价
Other modules on request.

For the roughing of gears, both gear milling cutters (single tooth method) and ICI hobs can be used. The selection of the best type of tool depends on the lot size to be manufactured and the corresponding number of teeth. Gear hobbing is the most productive method for cutting large-module gears with a high number of teeth. Gear milling cutters are especially to be preferred for low numbers of teeth or small lot sizes. The diagram contains the guide values for the selection of the appropriate tool.

From a cost point of view, gear milling cutters are more economical both in terms of the tool procurement costs and the recurring costs of the indexable inserts than hob cutters with indexable inserts. Gear milling cutters are technically characterized by the possibility of being designed as a roughing cutter and a finishing cutter. The roughing cutters listed in this catalog include the dimension series which are offered by LMT Fette with short delivery times.

对大模数齿轮的加工方式在实践中是不同的。齿轮尺寸和齿数，机床铣削效率，切削性能和齿轮质量这几个要求，都对选择切削刀具有影响。

The machining methods for gears with large modules differ considerably in practice. Number and sizes of the gears, the efficiency of the gear cutting machine as well as machinability and gear quality are only a few of the factors which affect the selection of the cutting tools.

粗加工齿轮铣刀 目录号2667
可转位硬质合金刀片
Gear milling cutter for roughing, Cat.-No. 2667, with indexable carbide inserts

精加工齿轮铣刀 目录号2675
可转位硬质合金刀片，渐开线齿形
Gear finishing cutter, Cat.-No. 2675, with indexable carbide inserts, involute profile

粗齿形铣刀加工 鼓风机轴
2部分，Ø 312 x 260 x Ø 120 mm, 92 片可转位刀片
Profile roughing cutter for rotary pistons (Roots blower) 2-section, 312 mm dia. x 260 x 120 dia., 92 indexable carbide inserts

圆形齿轮齿形铣刀 m 50，压力角20°，11齿，
不带齿顶圆弧整齿范围Ø 295 x 190 x Ø 80 mm, 136片可转位刀片
Circular-type gear profile cutter m 50, 20° p.a., 11 teeth, without roof radius, 295 mm dia. x 190 x 80 dia., 136 indexable carbide inserts

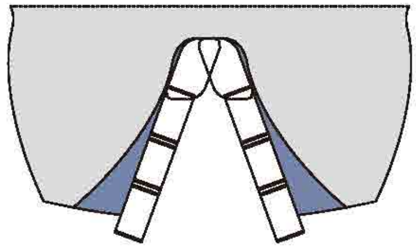
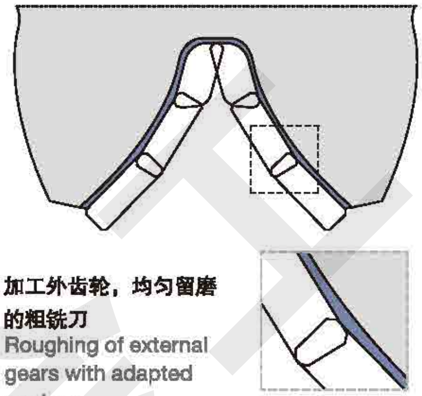
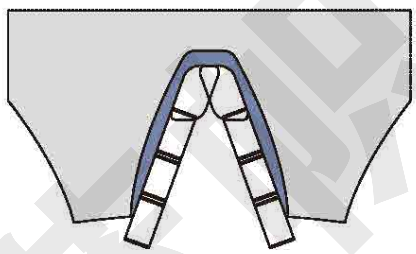
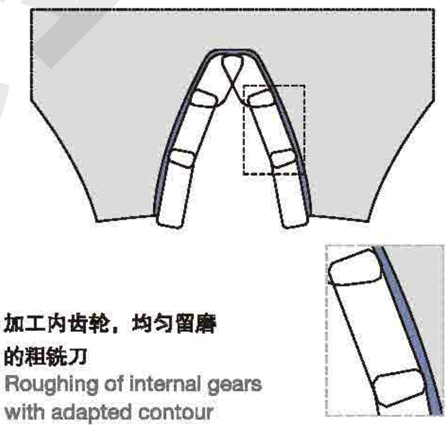
蓝帆菲特在设计这些刀具方面有相当丰富的经验。特别对于粗加工，已开发出适合不同机床的粗加工刀具。整体式用于传统铣齿机。我们提供了端形铣刀用于大模数的，例如在镗铣床加工齿轮段。对于铣床有大功率发电机铣头的，我们生产镶硬质合金块的铣刀（目录号2675和2667）。菲特公司也设计和制造用传统方式设计的齿形刀具加工大量的非标齿形。

我们还可以根据用户的需求，对铣刀的使用和维护提供帮助。

LMT Fette has considerable experience in the design of these tools. For pre-machining, in particular, high-performance roughing cutters have been developed for a very wide range of machine tools. The solid-type designs are intended for use on conventional gear cutting machines. For gear cutting machines with powerful motor milling heads, we manufacture milling cutters with carbide-tipped blades (Cat.-Nos. 2675 and 2667).

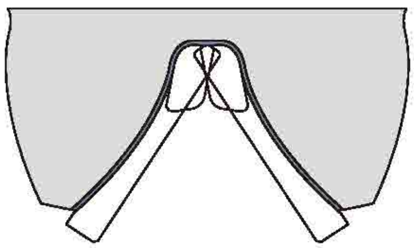
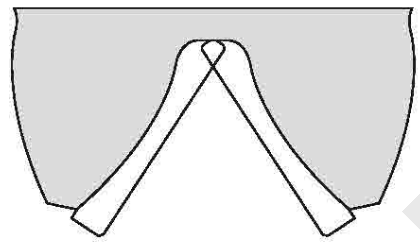
LMT Fette also designs and manufactures custom-designed profile cutters in a range of designs for the production of special forms. In addition, our experience is at our customers' disposal regarding the use and maintenance of these tools.

端型铣刀(粗切)m48，20° 压力角
Ø150 x 180，22片可转位刀片
End mill type gear cutter (roughing cutter) m 48-stub, 20° p.a., 150 dia. x 180 mm length, 22 indexable carbide inserts

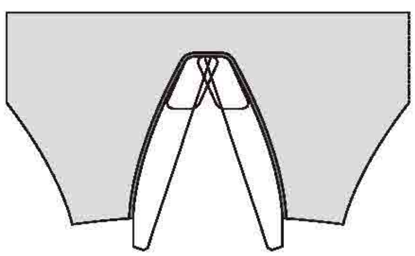
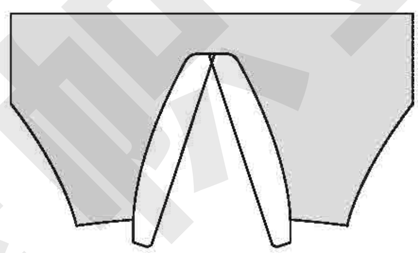
	直线齿形的粗铣刀 Roughing cutter	折线齿形的粗铣刀 Roughing cutter with faceted allowance
外齿轮 External gears 	 用于外齿轮粗开毛坯的粗铣刀 Coarse roughing of external gears	 加工外齿轮，均匀留磨的粗铣刀 Roughing of external gears with adapted contour
内齿轮 Internal gears 	 用于内齿轮粗开毛坯的粗铣刀 Coarse roughing of internal gears	 加工内齿轮，均匀留磨的粗铣刀 Roughing of internal gears with adapted contour

齿轮精度增加 Increasing wheel quality →

加工后的齿轮精度 Attainable wheel quality	+	++
刀片排列形式 Insert arrangement	直线齿形 Straight flank	折线齿形 Adapted profile
刀片形式—顶刃 Insert type - tip	标准化 Standard	标准化/半标准化 Standard/Semi Standard
刀片形式—侧刃 Insert type - flank	标准化 Standard	标准化 Standard
刀体 Body	标准化，见第96–97页 P. 96–97, standard	见第96–97页，LMT Fette优先推荐系列 P. 96–97, LMT Fette preferred series on request
刀具成本 Tool costs	€	€€
交货期 Delivery time	(quarter clock)	(half clock)

渐开线齿形的粗铣刀 Roughing cutter with even allowance	精铣刀 Finishing cutter
	
用于外齿轮半精加工的渐开线齿形粗铣刀 Pre-finishing of external gears with adapted inserts	加工外齿轮的精铣刀 Finishing of external gears

→ 齿轮精度增加 Increasing wheel quality →

	
用于内齿轮半精加工的渐开线齿形粗铣刀 Pre-finishing of internal gears with adapted inserts	加工内齿轮的精铣刀 Finishing of internal gears
+++	+++ / ++++
渐开线齿形 Final profile	渐开线齿形 Final profile
半标准化 Semi Standard	半标准化 Semi Standard
半标准化 Semi Standard	半标准化 Semi Standard
见第96–97页，LMT Fette优先推荐系列 P. 96–97, LMT Fette preferred series on request	见第96–97页，LMT Fette优先推荐系列 P. 96–97, LMT Fette preferred series on request
€€€	€€€€

齿轮的生产是由齿轮类型的不同模数、不同齿形以及不同的批量决定的。为了满足不同齿轮的生产需求，必须根据特定的需求对刀具进行优化设计。
加工内齿轮或外齿轮时，通常刀具的更换是非常复杂和耗时的。可转位刀片通常还没来得及换，刀具就从机床上拆卸下来了。
这时换刀的难易程度及所需时间，取决于机床的设计，特别是机床的驱动连接方式及后续换刀后的安装及刀具找正。

LMT—FETTE最新设计的可拆卸的刀条式齿轮铣刀，可节省您换刀的时间。
这种铣刀的刀体可以保留在机床上，而刀条可以根据您的加工需求相应地更换。
这种可更换的刀条式齿轮铣刀是专为加工大模数齿形设计的，由此可以保证加工过程的灵活性。

优点：

- 换刀时间短，约15分钟
- 刀片可以在机床外更换
- 可设计为内冷方式
- 适用于内齿轮或外齿轮加工
- 可设计齿顶倒角

Gear manufacture is characterized by many different types of gears with different modules, profiles and small batch sizes. For the manufacture of all these gears tools must be used which have been optimized for the individual requirements. For internal and external gears the disassembly of these tools is very time-consuming. And even indexable inserts are often changed after the tool is disassembled. Depending on the design of the machine, tool changes are very time-consuming, in particular, due to the removal of the drive shaft and the time needed for the subsequent set-up.

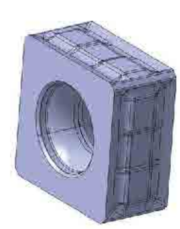
With the newly developed, segmented tooth form cutter by LMT Fette, the time required for a tool change can be reduced dramatically. The base plate can remain on the shaft for all gear cutting tasks and the pre-assembled segments can be replaced quickly. The segmented tooth form cutter is designed for the largest profile to be cut and, therefore, enables flexible manufacture.

Benefits

- Short tool changes, approx. 15 min.
- Changing the indexable inserts can be done outside of the machine
- Internal cooling
- Suitable for internal and external gear
- With optional adjustable chamfer

8个正切削刃的可转位刀片
Indexable insert with 8 Positive cutting edges

新研发有8个正切削刃的刀片对于内和外齿轮铣刀的容屑槽的范围被改进了，现在可以采用正切削刃的刀具来高速进给。硬质合金材料和涂层是根据齿轮切削工厂需要专门做的，这些刀片在粗切时与精切应用一样好。



The range of gashing cutters for internal and external gear cutting is enhanced by the newly developed inserts with 8 positive cutting edges. By the positive design softer cuts at high feed rates are now possible.
The carbide substrate and the coatings are tailored to the requirements of the gear cutting industry. These inserts could be used for roughing cuts as well as finishing cuts.

询价单
Inquiry form

日期
Date

公司
Company

用户编号
Customer No.

名称
Name

街道
Street

邮政编码/城市
Post Code/City

电子信箱
E-Mail

LMT·TOOLS

齿轮铣刀加工内外齿轮
Gear milling cutters for internal and external gear

请发送你的询价单到Please send your inquiry to: Gearcutting@lmt-tools.com

菲特刀具编号：
LMT-Fette-Ident-No.:

工件图纸编号：
Workpiece drawing No.:

刀具图纸编号：
Tool drawing No.:

零件材质：
Part material:

抗拉强度：
Tensile strength:

所询刀具数量(件)： ☐1 ☐2 ☐3
Quantity (pieces) ☐4 ☐

☐ 模数 Module ☐DP ☐CP
☐ 节距 Pitch:

压力角
Pressure angle:

☐ 粗加工铣刀 Roughing cutter
☐ 精加工铣刀 Finishing cutter

基本齿形
Basic profile:

☐„1“ DIN 3972 ☐„2“ DIN 3972
☐„3“ DIN 3972 ☐„4“ DIN 3972
☐DIN 5480 ☐ISO 53
☐BS 2062 ☐特殊齿形
☐AGMA 201.02-1968 Other profile
☐AGMA 201.02-1968 STUB

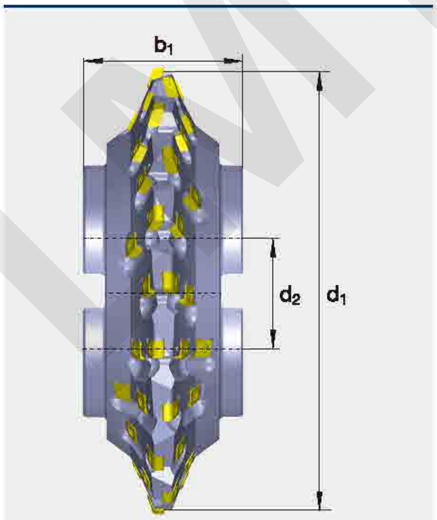
零件齿形部位参数：
From part data:

齿顶倒角 ☐是 yes
Semi topping ☐否 no

齿根挖根 ☐是 yes
Protuberance ☐否 no

齿顶修缘 ☐是 yes
Tip relief ☐否 no

齿底全圆弧 ☐是 yes
Full radius ☐否 no



刀具参数 Tool data

精度等级 ☐AA ☐A
Quality grade ☐B ☐B/C

标准选择 ☐DIN 3968
To standard ☐AGMA ☐BS

非标公差：
Non-standard tolerance:

外径 (d_1):
Outside diameter (d_1):

切削刃长 (l_3):
Cutting length (l_3):

刀具总长(l_1):
Overall length (l_1):

内孔直径 (d_2):
Bore diameter (d_2):

轴肩直径：
Hub diameter:

有效切削齿数 Z_{eff}:
Number of eff. teeth:

涂层 ☐LCP35H
Grade ☐LC630XT

Drive
☐ Keyway DIN 138
☐ One right-hand drive slot DIN 138
☐ One left-hand drive slot DIN 138
☐ Two drive slots
☐ With internal coolant supply

机床参数 Machine data

机床种类：
Type of machine:

最大串刀长度：
max. shift length:

最大刀具外径：
max. tool diameter:

最大刀具长度：
max. length:

☐ 湿式切削 wet cutting
☐ 干式切削 dry cutting

备注 Notes:

零件参数 Part data

☐内齿轮 Internal gear
☐外齿轮 External gear

☐模数 Module ☐DP ☐CP
☐节距 Pitch:

齿数：
Number of teeth:

压力角：
Pressure angle:

螺旋角：
Helix angle:

齿顶圆：
Tip circle diameter:

齿根圆：
Root circle diameter:

有效齿顶圆直径
Effective tip circle dia.:

有效齿根圆直径
Effective root circle dia.:

圆角半径
Fillet radius:

齿顶径向倒角总量：
Radial amount of the tip chamfer:

单面齿厚留量 max.:
Stock per flank min.:

公法线跨齿数：
Number of teeth for checking:

公法线长度 Tooth width:
成品 finished
半成品 milled

球径/棒径：
Ball dia./pin dia.:

球间距
Diametral dimension between balls:
成品 finished
半成品 milled

棒间距
Diametral dimension between pins:
成品 finished
半成品 milled

分度圆弧齿厚 Tooth thickness:
分度圆直径
Pitch line dia.

齿轮精度 ☐DIN
Gear quality ☐AGMA

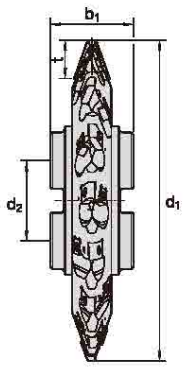
齿幅宽(mm):
Gear width (mm):

工件年产量：
Workpieces p.a.:

LMT Tool Systems GmbH
Heidenheimer Strasse 84 · 73447 Oberkochen
Telefon +49 7364 9579-0 · Telefax +49 7364 9579-8000
lmt.de@lmt-tools.com · www.lmt-tools.com

LMT Fette Werkzeugtechnik GmbH & Co. KG
Grabauer Strasse 24 · 21493 Schwarzenbek
Telefon +49 4151 12-0 · Telefax +49 4151 3797
info@lmt-fette.com · www.lmt-fette.com

齿轮粗铣刀
Gear roughing cutters



							刀刃数 Number of cutting edges		
							N4	N4	N4
									
						LMT-Code	XNHQ251405012	XNHQ251405020	XNHQ191406032
						切削材料编号: Cutting materials Ident. No.	LC630XT 7052952 / LCP35H 7078874	LC630XT 7053699 / LCP35H 7078875	LC630XT 7053725 / LCP35H 7078876
m	d_1	b_1	d_2	Z_{eff}	t	Ident No.			
6	220	70	60	8	17	7078803	16		
6	270	70	60	10	17	7078804	20		
6	350	70	80	12	17	7078805	24		
8	220	70	60	8	17	7078806		16	
8	270	70	60	10	17	7078807		20	
8	350	70	80	12	17	7078808		24	
10	220	70	60	8	23	7078809		16	
10	270	70	60	10	23	7078810		20	
10	350	70	80	12	23	7078811		24	
12	220	70	60	6	34	7078812			12
12	270	70	60	8	34	7078813			16
12	350	90	80	8	34	7078814			16
14	220	70	60	6	43	7078815			12
14	270	70	60	8	43	7078816			16
14	350	90	80	8	43	7078817			16
16	270	90	60	6	43	7078818			12
16	350	90	80	8	43	7078819			16
16	450	90	100	10	43	7078820			20
18	270	90	60	6	52	7078821			
18	350	90	80	8	52	7078822			
18	450	90	100	10	52	7078823			
20	270	90	60	6	56	7078824			
20	350	90	80	8	56	7078825			
20	450	90	100	10	56	7078826			
22	270	90	60	6	56	7078827			
22	350	120	80	8	56	7078828			
22	450	120	100	10	56	7078829			
24	270	120	60	6	62	7078830			
24	350	120	80	8	62	7078831			
24	450	120	100	10	62	7078832			
26	350	120	100	8	63	7078833			
26	450	120	100	10	63	7078834			
28	350	120	100	8	67	7078835			
28	450	120	100	10	67	7078836			
30	350	120	100	8	81	7078837			
30	450	120	100	10	81	7078838			
32	400	120	100	8	81	7078839			
32	500	120	100	10	81	7078840			
36	400	140	100	8	92	7078841			
36	500	140	100	10	92	7078842			

1150-86 1045766	1158-2 T15	1150-84 1045777	1188-3 T20

Vorzugsabmessungen **Preferred dimensions**

您的优势:
- 快速交货
- 节约成本

Your advantages
- faster delivery time
- cost saving

v

	N4		N4		N4		N8		N8	
										
	XNHQ151207044		XNHQ121406048		XNHQ141206060		LNHQ1206		LNKU1206	
	LC630XT	LCP35H	LC630XT	LCP35H	LC630XT	LCP35H	LC630XT	LCP35H	LC630XT	LCP35H
	7053739	7078877	7078881	7078878	7078882	7078879	9203919	7078880	7007153	7062832
							16			
							20			
							24			
							12			
							16			
							16			
							18			
							24			
							24			
							18			
							24			
							30			
	12						24			
	16						32			
	20						40			
	12						30			
	16						40			
	20						50			
	12						30			
	16						40			
	20						50			
			12				36			
			16				48			
			20				60			
			16				48			
			20				60			
			16				56			
			20				70			
					16		64			
					20		80			
					16		64			
					20		80			
					16		72			
					20		90			
										
	1150-80A 2217211	1158-2 T15	1150-84 1045777				1158-3 T20			

Zahnformfräser mit Wendeplatten
Gear milling cutters with inserts

Car-bide

Katalog-Nr. Cat.-No.	2695

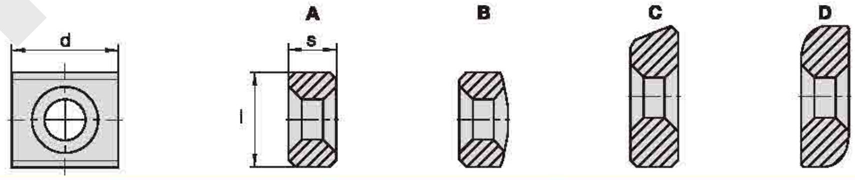
转子外廓尺寸 Rotor measurements			铣刀外廓尺寸(可变化) Cutter measurements (var.)			
外径 Outside diameter	齿高 Profile height	型式 Type	d_1	b_1	d_2	
100	22	HL	220	60	60	25– 36
100	22	NL	220	60	60	
127,5	27,5	HL	250	70	80	32– 45
127,5	27,5	NL	250	70	80	
163,2	35,5	HL	250	80	80	40– 56
163,2	35,5	NL	250	80	80	
204	44	HL	300	100	100	50– 70
204	44	NL	300	100	100	
255	55	HL	320	125	100	63– 85
255	55	NL	320	100	100	
318	70	HL	350	160	100	70–100
318	70	NL	350	125	100	

HL = Hauptläufer Male rotor (MALE), NL = Nebenläufer Female rotor (FEMALE)

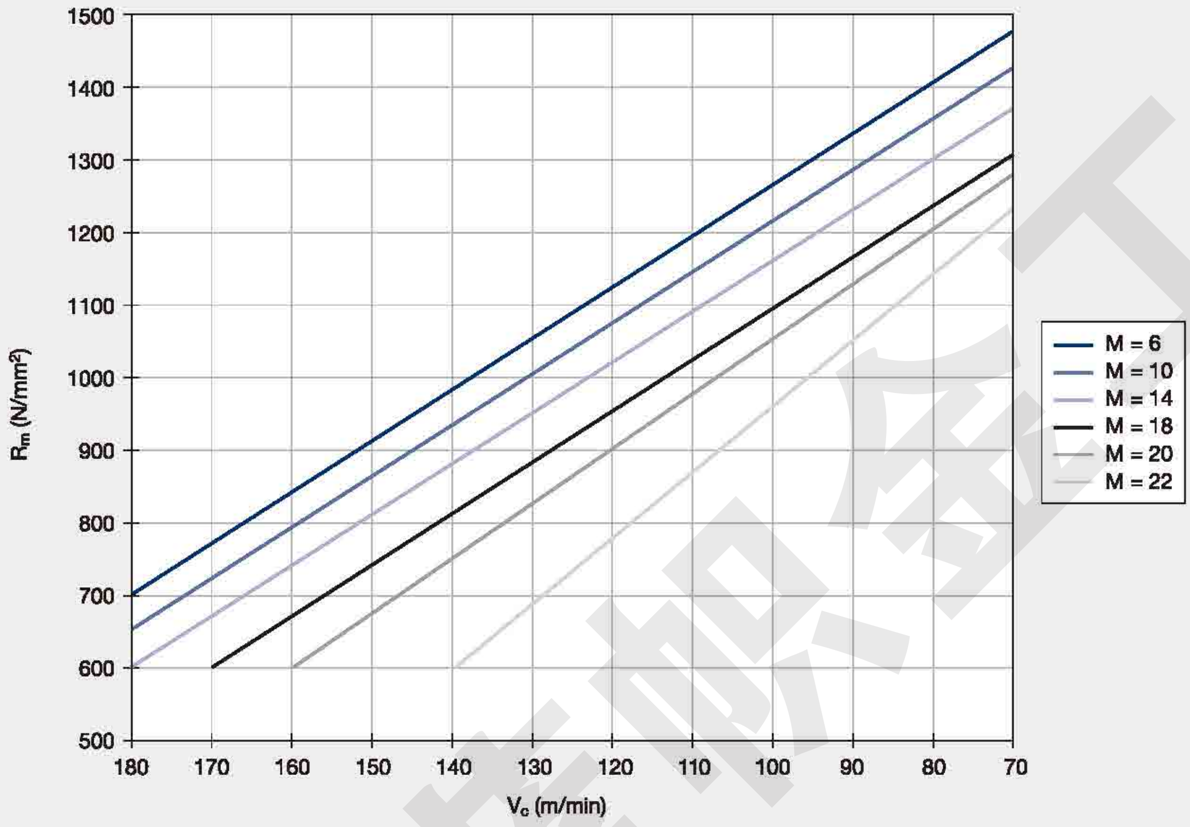
这些刀具由于切削速度高和免维护所以非常经济。齿廓由多边形直线部分形成，包含供精铣或磨削的最小余量。
为了获得尽可能平行的精加工余量，在标准转位刀片进行修改。
增加倒角和圆角处理。

These tools are, because of their high cutting rates and trouble-free maintenance, particularly economical.
The profile is formed polygonally form straight sections and contains a minimum allowance for finish milling or grinding.
To achieve finishing allowances which are as parallel as possible, modified forms are used in addition to the standard indexable inserts. These are provided with chamfers or rounded edges.

可转位刀片形式
Indexable insert forms



型式	l	s	d	目录号 Designation	夹紧螺钉 Clamping screw
A	12,70	6,35	14,29	1185-11	1150-80
	12,70	7,94	15,88	1185-15	
	15,88	7,94	15,88	M4-21764	
	19,05	6,35	14,29	1185-31	
B	12,70	6,35	14,29	M4-20859	
	12,70	7,94	15,88	M4-19730-2	
C	19,05	6,35	14,29	M4-21045	
D	25,40	6,35	14,29	M4-20924	
	19,05	6,35	14,29	1185-35	



渐开线粗加工动力需求推荐值：

R_m = 抗弯强度 (N/mm²)
V_c = 切削速度 (m/min)
h_{m1} = 顶刃切屑厚度 (mm) Wert ≈ 0,1 mm
z = 容屑槽数
f_z = 每齿进给量(mm)
a = 切深 (mm) (Schnittiefe)
D = 刀具直径
v_f = 进给量 (mm/min)
$Q_{spez.}$ = 动力系数 (cm³ min · kW) (Wert aus Tabelle)

全齿深的可用公式：

$$P_{(kW)} = \frac{3{,}19 \cdot Mod.^2 \cdot v_f}{1000 \cdot Q_{spez.}}$$

$$v_f = f_z \cdot n \cdot z$$

$$f_z = \frac{h_{m1}}{\sqrt{\frac{a}{D}}}$$

Recommended values for the power requirement for involute roughing:

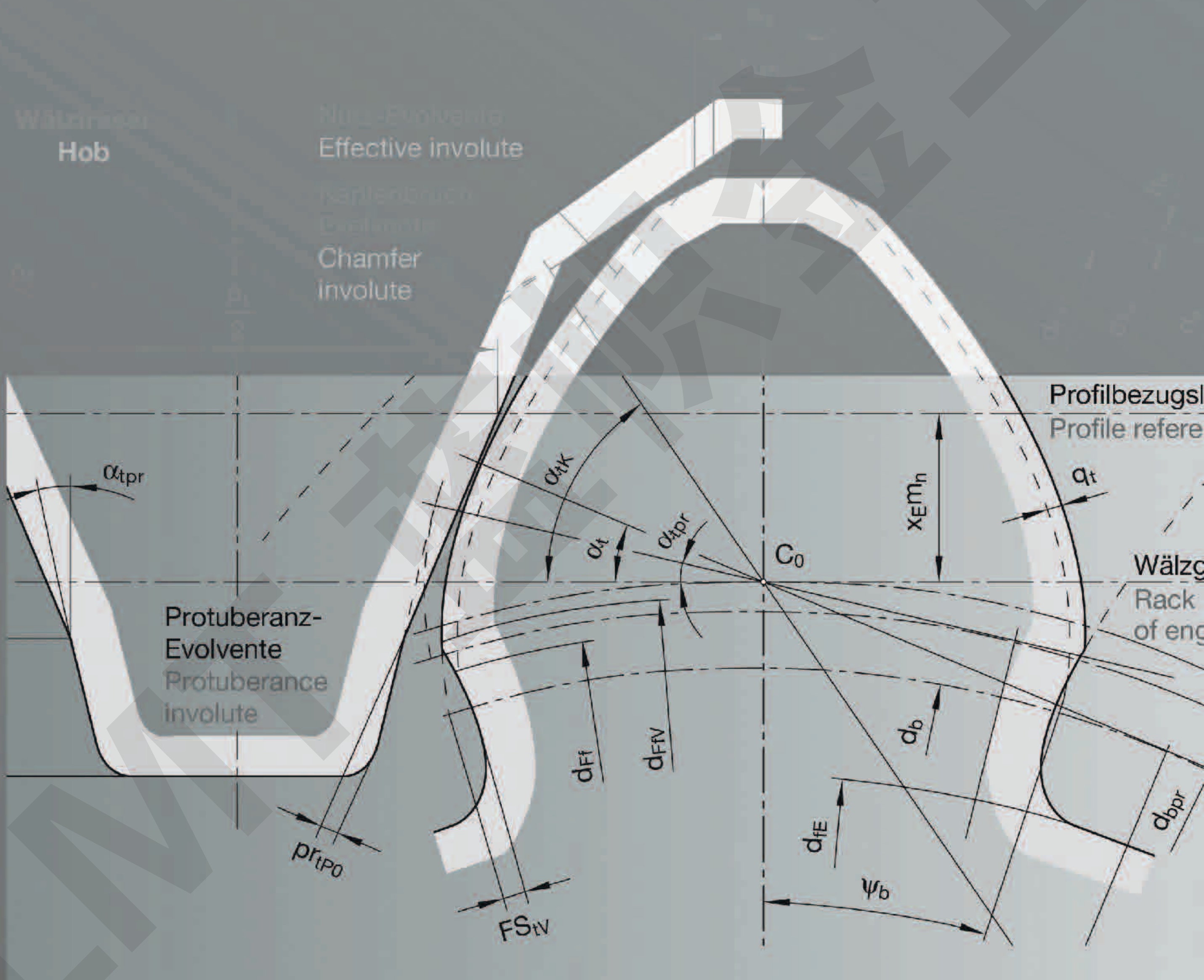
R_m = Tensile strength (N/mm²)
V_c = Cutting speed (m/min)
h_{m1} = Mean tip chip thickness (mm) Value ≈ 0.1 mm
z = Number of gashes / 2
f_z = Tooth feed (mm)
a = Radial feed (mm) (cutting depth)
D = Tool diameter
v_f = Feed (mm/min)
$Q_{spez.}$ = Power factor (cm³ min · kW) (Value taken from table)

Formula applicable for full profile depth:

$$P_{(kW)} = \frac{3.19 \cdot Mod.^2 \cdot v_f}{1000 \cdot Q_{spez.}}$$

$$v_f = f_z \cdot n \cdot z$$

$$f_z = \frac{h_{m1}}{\sqrt{\frac{a}{D}}}$$



ANHANG 技术说明

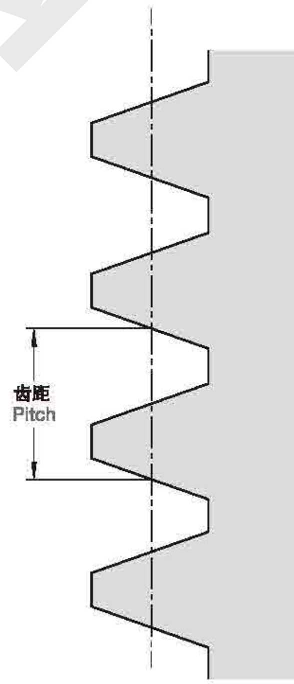
ATTACHMENT

技术说明与列表
Attachment

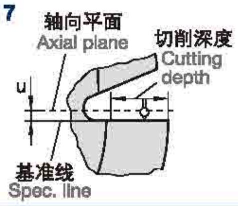
LMT • FETTE

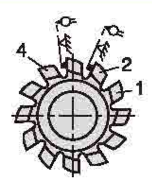
模数	径节	周节
$m = \frac{25,4}{DP}$ $m = \frac{25 \cdot 4}{\pi} \times CP$	$DP = \frac{\pi}{CP}$ $DP = \frac{25,4}{m}$	$CP = \frac{\pi}{DP}$ $CP = \frac{m \cdot \pi}{25 \cdot 4}$

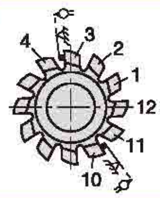
齿距 Pitch mm	模数 Module	DP	CP	齿距 Pitch mm	模数 Module	DP	CP	齿距 Pitch mm	模数 Module	DP	CP
0,31416	0,1			2,84987		28		22,22500			7/8
0,34558	0,11			2,98451	0,95			22,79899		3 1/2	
0,37699	0,12			3,06909		26		23,81250			1 5/16
0,39898		200		3,14159	1			25,13274	8		
0,43982	0,14			3,17500			1/8	25,40000			1
0,44331		180		3,32485		24		26,59892		3	
0,45598		175		3,62711		22		26,98750			1 1/16
0,49873		160		3,92699	1,25			28,27433	9		
0,50265	0,16			3,98982		20		28,57500			1 1/8
0,53198		150		4,43314		18		29,01689		2 3/4	
0,56549	0,18			4,71239	1,5			30,16250			1 3/16
0,62831	0,20			4,76250			3/16	31,41593	10		
0,62832		127		4,98728		16		31,75000			1 1/4
0,66497		120		5,49779	1,75			31,91858		2 1/2	
0,69115	0,22			5,69975		14		33,33750			1 5/16
0,75997		105		6,28319	2			34,55752	11		
0,78540	0,25			6,35000			1/4	34,92500			1 3/8
0,79796		100		6,64970		12		35,46509		2 1/4	
0,83121		96		7,06858	2,25			36,51250			1 7/16
0,87965	0,28			7,85398	2,5			37,69911	12		
0,90678		88		7,93750			5/16	38,10000			1 1/2
0,94248	0,30			7,97965		10		39,89823		2	
0,99746		80		8,63938	2,75			41,27500			1 5/8
1,09557	0,35			8,86627		9		43,98230	14		
1,10828		72		9,42478	3			44,45000			1 3/4
1,24682		64		9,52500			3/8	45,59797		1 3/4	
1,25664	0,40			9,97456		8		47,62500			1 7/8
1,32994		60		10,21018	3,25			50,26548	16		
1,41372	0,45			10,99557	3,5			50,80000			2
1,57080	0,50			11,11250			7/16	53,19764		1 1/2	
1,58750			1/16	11,39949		7		56,54867	18		
1,59593		50		11,78097	3,75			62,83185	20		
1,66243		48		12,56637	4			63,83716		1 1/4	
1,72788	0,55			12,70000			1/2	69,11504	22		
1,73471		46		13,29941		6		75,39822	24		
1,81356		44		14,13717	4,5			78,53982	25		
1,88496	0,60			14,28750			9/16	79,79645		1	
1,89992		42		14,50845		5 1/2		81,68141	26		
1,99491		40		15,70796	5			87,96459	28		
2,04204	0,65			15,87500			5/8	91,19595		7/8	
2,09991		38		15,95930		5		94,24778	30		
2,19911	0,70			17,27876	5,5			100,53096	32		
2,21657		36		17,46250			11/16	106,39527		3/4	
2,34695		34		17,73255		4 1/2		109,95574	35		
2,35619	0,75			18,84956	6			113,09734	36		
2,49364		32		19,05000			3/4	125,66371	40		
2,51327	0,80			19,94911		4		127,67432		5/8	
2,65988		30		20,42035	6,5			141,37167	45		
2,67035	0,85			20,63750			13/16	157,07963	50		
2,82743	0,90			21,99115	7			159,59290		1/2	

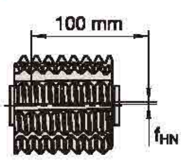


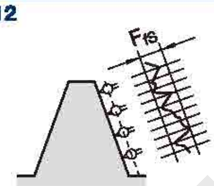
单头滚刀公差：
DIN3968标准适用于渐开线直齿轮
Tolerances for single-start hobs for spur gears with involute teeth to DIN 3968 in µm

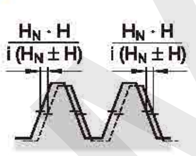
7


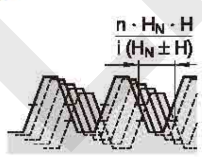
8


10


11


12


14


15


16, 17


项目号 Item no.[1]	检测项目 Measurement	符号 Symbol		精度等级 Quality grade	模数范围 For module range 大于 above 0,63–1	1–1,6	1,6–2,5	2,5–4	4–6,3	6,3–10	10–16	16–25	25–40
1	内孔直径 Diameter of the bore			AA	H 5								
				A	H 5								
				B	H 6[2]								
				C	H 6								
				D	H 7								
4	径向圆跳动 Radial runout at the indicator hubs	f_{rp}		AA	5	5	5	5	5	5	6	6	8
				A	5	5	5	6	8	10	12	16	20
				B	6	6	6	8	10	12	16	20	25
				C	10	10	10	12	16	20	25	32	40
5	夹紧端面轴向圆跳动 Axial runout at the clamping face	f_{ps}		AA	3	3	3	3	3	4	5	5	6
				A	3	3	3	5	5	8	8	10	10
				B	4	4	4	6	6	10	10	12	12
				C	6	6	6	10	10	16	16	20	20
				D	10	10	10	16	16	25	25	32	32
6	刀齿径向圆跳动 Radial runout at the tooth tips	f_{rk}		AA	10	10	12	16	20	25	32	40	50
				A	12	16	20	25	32	40	50	63	80
				B	25	32	40	50	63	80	100	125	160
				C	50	63	80	100	125	160	200	250	315
				D	100	125	160	200	250	315	400	500	630
7	前刀面形状和位置误差 Form- and position deviation of the cutting face	F_{fN}		AA	10	10	12	16	20	25	32	40	50
				A	12	16	20	25	32	40	50	63	80
				B	25	32	40	50	63	80	100	125	160
				C	50	63	80	100	125	160	200	250	315
				D	100	125	160	200	250	315	400	500	630
8	容屑槽相邻周节误差 Individual pitch of the gashes	f_{tN}	+	AA	10	10	12	16	20	25	32	40	50
			–	A	12	16	20	25	32	40	50	63	80
				B	25	32	40	50	63	80	100	125	160
				C	50	63	80	100	125	160	200	250	315
				D	100	125	160	200	250	315	400	500	630
10	容屑槽的周节累积 Cumulative pitch of the gashes	F_{tN}		AA	20	20	25	32	40	50	63	80	100
				A	25	32	40	50	63	80	100	125	160
				B	50	63	80	100	125	160	200	250	315
				C	100	125	160	200	250	315	400	500	630
				D	200	250	315	400	500	630	800	1000	1250
11	在100mm长度上容屑槽导程 Gash lead over 100 mm hob length	f_{HN}	+	AA	50								
			–	A	70								
				B	100								
				C	140								
				D	200								
12	切削刃误差形式 Form deviation of the cutting edge	F_{fS}		AA	6	6	6	8	10	12	14	18	22
				A	10	11	12	14	16	20	25	32	40
				B	20	22	25	28	32	40	50	63	80
				C	40	45	50	56	63	80	100	125	160
13	基准圆柱上的齿厚 Tooth thickness on the reference cylinder	f_s	–	AA	16	16	16	20	25	32	40	50	63
				A	25	28	32	36	40	50	63	80	100
				B	50	56	63	71	80	100	125	160	200
				C	100	112	125	140	160	200	250	320	400
				D	100	112	125	140	160	200	250	320	400
14	在螺旋线方向切削刃之间的滚刀导程 Hob lead from cutting edge to cutting edge in the direction of spiral	f_{HF}	+	AA	4	4	4	5	6	8	10	12	16
			–	A	6	7	8	9	10	12	16	20	25
				B	12	14	16	18	20	25	32	40	50
				C	25	28	32	36	40	50	63	80	100
				D	50	56	63	71	80	100	125	160	200
15	一转内切削刃在螺旋线方向的滚刀导程 Hob lead in the direction of spiral between any cutting edges of a turn	F_{HF}		AA	6	6	6	8	10	12	14	18	22
				A	10	11	12	14	16	20	25	32	40
				B	20	22	25	28	32	40	50	63	80
				C	40	45	50	56	63	80	100	125	160
				D	80	90	100	112	125	160	200	250	320
16	切削刃之间节距基本剖面 Base pitch section from cutting edge to cutting edge	f_e	+	AA	4	4	4	5	6	8	10	12	16
			–	A	6	7	8	9	10	12	16	20	25
				B	12	14	16	18	20	25	32	40	50
				C	25	28	32	36	40	50	63	80	100
17	啮合区域上的基本节距 Base pitch within an engagement area	F_e		AA	8	8	8	10	12	16	20	25	32
				A	12	14	16	18	20	25	32	40	50
				B	25	28	32	36	40	50	63	80	100
				C	50	56	63	71	80	100	125	160	200

[1] 项目号是对应于DIN3968标准中的检测项目
Item no. of the measurement points to DIN 3968

[2] 为了标准的一致性，菲特生产的B级滚刀内孔采用H5公差
In accordance with the works standard, LMT Fette Hobs of quality grade B are made with bore tolerance H 5.

LMT·FETTE

项目号 Item no.	检测项目 Measurement	符号 Symbol		精度等级 Quality grade	模数范围 For module range 大于 above 0,63–1	1–1,6	1,6–2,5	2,5–4	4–6,3	6,3–10	10–16	16–25	25–40
1	内孔直径 Diameter of the bore			AA					H 5				
				A					H 5				
				B					H 6				
					公差单位 μm Tolerances in μm								
4	径向圆跳动 Radial runout at the indicator hubs	f_{rp}		AA	5	5	5	5	5	5	6	6	8
				A	5	5	5	6	8	10	12	16	20
				B	6	6	6	8	10	12	16	20	25
5	夹紧端面轴向跳动 Axial runout at the clamping faces	f_{ps}		AA	3	3	3	3	3	4	5	5	6
				A	3	3	3	5	5	8	8	10	10
				B	4	4	4	6	6	10	10	12	12
6	刀齿径向圆跳动 Radial runout at the tooth tips	f_{rk}	2–4 头数 2–4 start	AA	10	12	16	20	25	32	40	50	63
				A	16	20	25	32	40	50	63	80	100
				B	32	40	50	63	80	100	125	160	200
			5–7 头数 5–7 start	AA	12	16	20	25	32	40	50	63	80
				A	20	25	32	40	50	63	80	100	125
				B	40	50	63	80	100	125	160	200	250
7	前刀面形状和位置误差 Form- and position deviation of the cutting face	F_{fN}		AA	10	10	12	16	20	25	32	40	50
				A	12	16	20	25	32	40	50	63	80
				B	25	32	40	50	63	80	100	125	160
8	前刀面形状和位置误差 Individual pitch of the gashes	f_{tN} ±		AA	10	10	12	16	20	25	32	40	50
				A	12	16	20	25	32	40	50	63	80
				B	25	32	40	50	63	80	100	125	160
10	容屑槽节距累计误差 Cumulative pitch of the gashes	F_{tN}		AA	20	20	25	32	40	50	63	80	100
				A	25	32	40	50	63	80	100	125	160
				B	50	63	80	100	125	160	200	250	315
11	在100mm长度上容屑槽导程 Gash lead over 100 mm hob length	f_{HN} ±		AA					50				
				A					70				
				B					100				
12	切削刃形状误差 Form deviation of the cutting edge	F_{fS}	2 头数 2 start	AA	6	6	8	10	12	14	18	22	28
				A	11	12	14	16	20	25	32	40	50
				B	22	25	28	32	40	50	63	80	100
			3–4 头数 3–4 start	AA	6	8	10	12	14	18	22	28	36
				A	12	14	16	20	25	32	40	50	63
				B	25	28	32	40	50	63	80	100	125
			5–6 头数 5–6 start	AA	8	10	12	14	18	22	28	36	45
				A	14	16	20	25	32	40	50	63	80
				B	28	32	40	50	63	80	100	125	160

项目号 Item no.	检测项目 Measurement	符号 Symbol		精度等级 Quality grade	模数范围 For module range 大于 above 0,63–1	1–1,6	1,6–2,5	2,5–4	4–6,3	6,3–10	10–16	16–25	25–40
				公差单位 µm Tolerances in µm									
13	基准圆柱的齿厚 Tooth thickness on the reference cylinder	f_s –		AA	–25	–28	–32	–36	–40	–50	–63	–80	–100
				A	–25	–28	–32	–36	–40	–50	–63	–80	–100
				B	–50	–56	–63	–71	–80	–100	–125	–160	–200
14	在螺旋线方向切削刃之间的滚刀导程 Hob lead from cutting edge to cutting edge in the direction of spiral	f_{HF} ±	2 头数 2 start	AA	4	4	5	6	8	10	12	16	20
				A	7	8	9	10	12	16	20	25	32
				B	14	16	18	20	25	32	40	50	63
			3–4 头数 3–4 start	AA	4	5	6	8	10	12	16	20	25
				A	8	9	10	12	16	20	25	32	40
				B	16	18	20	25	32	40	50	63	80
			5–6 头数 5–6 start	AA	5	6	8	10	12	16	20	25	32
				A	9	10	12	16	20	25	32	40	50
				B	18	20	25	32	40	50	63	80	100
15	在螺旋线方向一个轴向节距上任意切削刃之间滚刀导程 Hob lead in the direction of spiral between any cutting edges in one axial pitch	F_{HF}	2 头数 2 start	AA	6	6	8	10	12	14	18	22	28
				A	11	12	14	16	20	25	32	40	50
				B	22	25	28	32	40	50	63	80	100
			3–4 头数 3–4 start	AA	6	8	10	12	14	18	22	28	36
				A	12	14	16	20	25	32	40	50	63
				B	25	28	32	40	50	63	80	100	125
			5–6 头数 5–6 start	AA	8	10	12	14	18	22	28	36	45
				A	14	16	20	25	32	40	50	63	80
				B	28	32	40	50	63	80	100	125	160
18	一段牙形上相邻螺纹的节距误差 Pitch deviation between adjacent threads of a tooth segment	f_{px} ±	2–3 头数 2–3 start	AA	5	5	6	7	8	11	13	16	20
				A	7	8	9	10	12	16	20	25	32
				B	14	16	18	20	25	32	40	50	63
			4–6 头数 4–6 start	AA	6	7	8	11	13	16	20	25	32
				A	9	10	12	16	20	25	32	40	50
				B	18	20	25	32	40	50	63	80	100
19	滚刀导程内牙形刃带上任意两条螺旋线的节距误差 Pitch deviation between any two spirals of a tooth land within the hob lead	F_{px}	2–3 头数 2–3 start	AA	8	8	8	11	14	17	20	25	31
				A	14	15	17	20	22	28	35	45	56
				B	28	31	35	39	45	56	70	88	112
			4–6 头数 4–6 start	AA	10	10	10	13	16	19	22	29	35
				A	16	18	19	22	26	32	40	51	64
				B	32	35	40	45	51	64	80	101	128

LMT · FETTE

加工渐开线直齿轮的单头滚刀公差按DIN3968标准计算，用于精密机械的滚刀公差按DIN58413标准计算。
多头滚刀的公差值以及特殊齿形的滚刀可根据制造商与用户之间的协商制定标准进行加工。

The tolerances of single-start hobs for spur gears with involute teeth are laid down in DIN 3968 and the tolerances for the hobs used in precision engineering in DIN 58413.
The tolerances for multi-start hobs and for hobs with special profiles are defined in works standards or by agreement between manufacturer and customer.

滚刀按等级高低可分为A，B，C，D以及特级AA等级。对于具有特殊要求的滚刀，其公差质量比AA等级有更严格的要求时，其对应的质量等级可参考AAA级标准。

The hobs are classified into grades A, B, C, D and the special grade AA. For extreme requirements it is usual to agree further restrictions of the tolerances of quality grade AA, which is then referred to as quality grade AAA.

订单号： Ident No.:		齿顶圆直径： Tip circle diameter:	58.979	导程角： Lead angle:	02° 43'33"
滚刀号： Hob No.:	E1305	切削刃宽度： Cutting edge width:	150	导程： Lead:	7.8314
模数： Module:	2.49	内孔径： Bore diameter:	–	基本外形： Basic profile:	–
压力角： Pressure angle:	20° 00'00"	刀头： Handing/nbr. of starts:	R1	外形修整： Profile modification:	–
齿顶高 Tooth addendum:	3.82	容屑槽数： Number of gashes:	14	切削深度： Cutting depth:	–
轴向齿厚： Axial tooth thickness:	3.9154	切削面偏移量： Cutting face offset:	0	材料： Material:	–
齿高： Tooth height:	6.6	齿槽导程： Gash lead:	1.E + 100	硬度： Hardness:	HRC –

(4) 右侧径向跳动
(4) Right-hand radial runout

	预计值 Intend. value		实际 Actual value	
f_{rp}	5	AA	2	AAA

(5) 右侧轴向跳动
(5) Right-hand axial runout

	预计值 Intend. value		实际 Actual value	
f_{ps}	3	AA	2	AAA

(5) 左侧轴台轴向跳动
(5) Left-hand axial runout

	预计值 Intend. value		实际 Actual value	
f_{ps}	3	AA	2	AAA

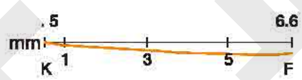
(4) 左侧轴台径向跳动
(4) Left-hand radial runout

	预计值 Intend. value		实际 Actual value	
f_{rp}	5	AA	2	AAA

(6) 齿顶圆径向跳动
(6) Radial runout at the tooth tip

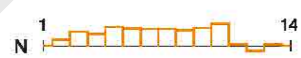
	预计值 Intend. value		实际 Actual value	
f_{rk}	12	AA	7	AAA

(7) 前刀面的形式和位置
(7) Form and location of the cutting face



	预计值 Intend. value		实际 Actual value	
F_{fn}	12	AA	5	AAA

(8, 10) 容屑槽的节距
(8, 10) Pitch of the gashes



	预计值 Intend. value		实际 Actual value	
F_{tN}	25	AA	11	AAA
f_{tN}	12	AA	8	AAA

(11) 容屑槽导程
(11) Gash lead

	预计值 Intend. value		实际 Actual value	
f_{HN}	50	AA	5	AAA

(14, 15) 右侧螺旋线误差
(14, 15) Right-hand lead

	预计值 Intend. value		实际 Actual value	
F_{HF}	6	AA	3	AAA
f_{HF}	4	AA	1	AAA

(14, 15) 左侧螺旋线误差
(14, 15) Left-hand lead

	预计值 Intend. value		实际 Actual value	
F_{HF}	6	AA	2	AAA
f_{HF}	4	AA	1	AAA

(16, 17) 右侧基本节距
(16, 17) Right-hand base pitch

	预计值 Intend. value		实际 Actual value	
F_e	8	AA	4	AAA
f_e	4	AA	2	AAA

(16, 17) 左侧基本节距
(16, 17) Left-hand base pitch

	预计值 Intend. value		实际 Actual value	
F_e	8	AA	3	AAA
f_e	4	AA	2	AAA

右侧轴向齿距误差
Right-hand axial pitch

	预计值 Intend. value			
F_{px}	2			
f_{px}	1			

左侧轴向齿距误差
Left-hand axial pitch

	预计值 Intend. value			
F_{px}	4			
f_{px}	2			

公差标准：
DIN 3968 AAA
Tolerances to:
DIN 3968 AAA

LMT · FETTE
滚刀测量
HOB MEASUREMENT

20 my

日期：
校核：
制图号：61574
文件：E1305 05M

R
W
F

检测误差可以手工记录、机械标记以及录入计算机内。在一份检测报告中，测量误差是AA或AAA级精度是很正常的。检测报告在检测滚刀整个维护周期中均可使用。

检测报告记录清晰信息完整。当在基本间距或切削刃形状误差或滚刀导程出现偏差时及时显示在图表中。

这些图表可以直接用来与加工过程中的齿轮外形轨迹加以对比。

这里的测试报告的尺寸为简化尺寸；

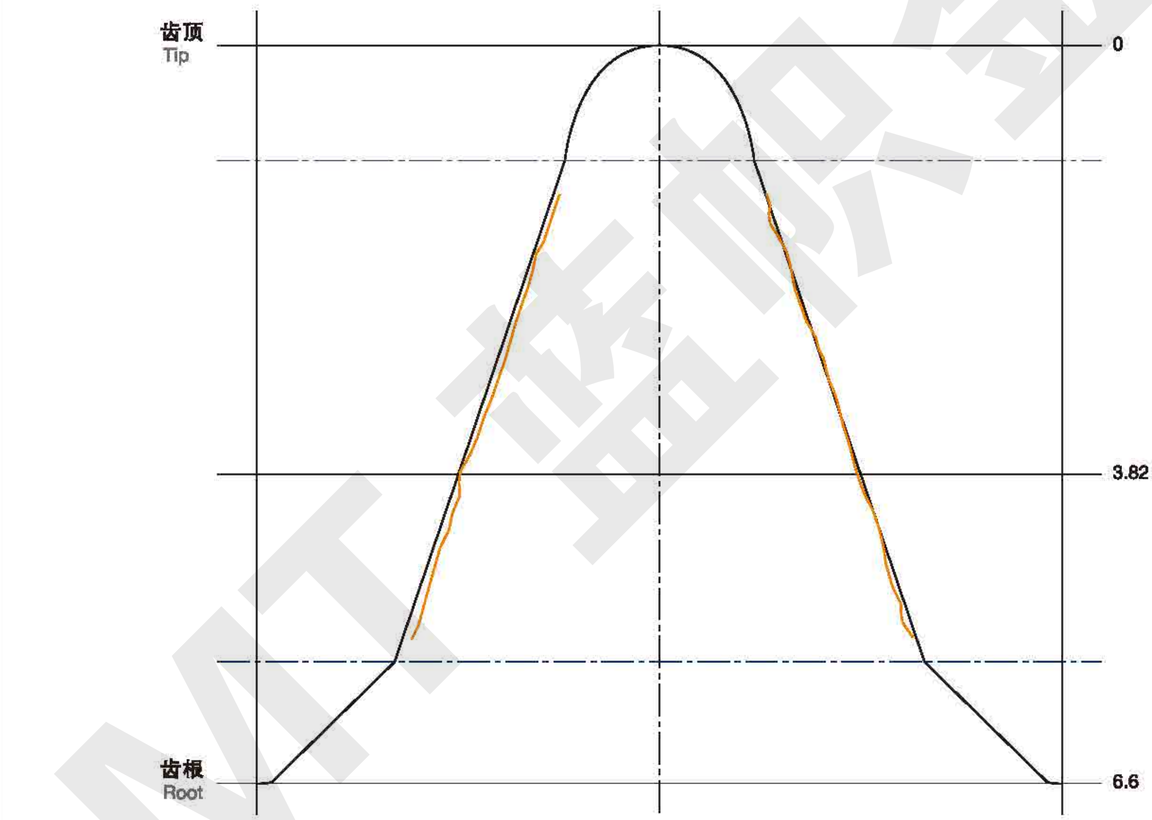
原始的尺寸为DINA4。

The deviations of the measured values can be written, marked down by hand, mechanically recorded or stored in a computer.
In the case of quality grades AA or AAA it is usual to record the deviations of the measured values in an inspection report. The inspection report is used for monitoring the hob throughout its entire service life.

The inspection report becomes particularly clear and informative when the base pitch or the form deviation of the cutting edge and the deviation of the hob lead are represented in the form of diagrams.
These diagrams can then be directly compared with the profile traces of the machined gears and interpreted.

The test report is shown in DIN A4.

(12) 切削刃形状误差
(12) Form deviation of the cutting edge



(LF)	预计值 Intended value		实际 Actual value		(13) 齿厚 f_s (13) Tooth thickness f_s	预计值 Intend. value		实际 Actual value			(RF)	预计值 Intended value		实际 Actual value	
F_{fs}	6	AA	3	AAA		–16	AA	–3	AAA		F_{fs}	6	AA	2	AAA

评价 Remarks:

LMT • FETTE

滚刀测量
HOB MEASUREMENT

20 my

日期：
校核：
制图号：61574
文件： E1305 05M

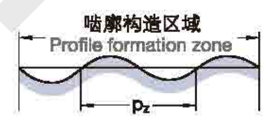
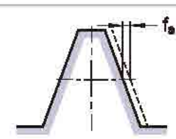
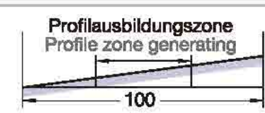
R
W
F

刀具误差和刀具装夹误差对齿轮加工的影响
(压力角20度的单刀头滚刀，铲制后角约10度)

The effect of cutter deviations and cutter clamping errors on the gear
(for single-start hobs with 20° pressure angle and relief rake angle of approx. 10°)

滚齿加工的齿轮质量是各种参数和生产条件综合作用的结果。滚刀设计外形的误差和加工设备上夹具的误差对齿轮质量有重要影响。在滚齿加工过程中，刀具包络螺旋线的误差以及刀具切削面的误差之间具有较大差别。单头滚刀主要是在齿形误差上影响齿轮的精度。因此了解滚刀误差和刀具夹具误差对齿轮质量大小的影响情况非常重要。

The quality of a hobbed gear is the product of the interaction of various components and production conditions.
The deviations from the intended geometry of the hob and the clamping errors of the cutter on the hobbing machine play an important part in this.
In hobbing, a distinction is made between the deviations on the enveloping helix of the cutter and the deviations on the cutting faces of the cutter.
The deviations of single-start hobs affect the quality of the gear mainly in the form of profile deviations.
It is here important to know in which order of magnitude the deviation on the hob and clamping errors of the cutter affect gear quality.

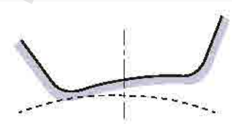
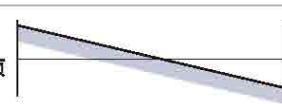
滚刀 Hobs			
造成误差的原因 Nature of the deviation	**偏差设计和符号 (依据VDI2606)** Designation and symbols of the deviation acc. to VDI 2606	**编号&偏差符号 依据DIN 3968(09–1960)** Item no. & symbol of the deviation acc. to DIN 3968 (09-1960)	**误差描述** Representation of the deviation
滚刀包络啮合线的误差 Deviations on the enveloping helix of the hob	**啮合区域的基本节距总误差值F_{pe}** Total base pitch deviation F_{pe} within an engagement area	Nr. 17 No. 17 F_e	
	单次回转中切削刃方向的啮合线最大误差F_{HF} Cutter lead height deviation in the direction of start F_{HF} between any cutting edges in one convolution	Nr. 15 No. 15 F_{HF}	
	齿顶圆径向跳动值f_{ra} Radial runout f_{ra} on the tooth tip	Nr. 6 No. 6 f_{rk}	
	基本参考圆柱上的齿厚误差f8 Tooth thickness deviation f_s on the basic reference cylinder	Nr. 13 No. 13 f_s	
	切削刃的形状误差F_{fS} Form deviation F_{fS} of the cutting edge	Nr. 12 No. 12 F_{fS}	
滚刀前刀面的误差 Deviations on the cutting faces of the hob	**前刃面形状和位置误差F_{fN}** Form- and position-deviation F_{fN} of the cutting faces	Nr. 7 No. 7 F_{fN}	
	前刃面累积误差F_{pN} Cumulative pitch deviation F_{pN} of the gashes (cutting faces)	Nr. 10 No. 10 F_{tN}	
	切削长度超过100mm时的前刃面导程误差f_{HN} Gash lead deviation f_{HN} over 100 mm cutter length	Nr. 11 No. 11 f_{HN}	
滚齿设备上滚刀夹具的误差 Clamping errors of the hob on the hobbing machine	**两个轴台上的径向圆跳动f_{rP}** Radial runout f_{rP} on the two indicator hubs	Nr. 4 No. 4 f_{rP}	
	轴台上的轴向圆跳动f_{rx} Axial runout f_{rx} on the clamping faces	Nr. 5 No. 5 f_{ps}	

它们之间的相互关系如表中所示。必须记住的一点是滚刀的加工精度主要受错误重磨削的影响。因此在每次重磨削操作完成后，务必对滚刀切削面的误差进行检查。

有关滚刀正确的检测步骤，必需的设备和测量结果评估等详细情况可参见VDI / VDE的2606建议内容。

These relationships are shown in the table. It must be remembered that the working accuracy of the hob can be considerably affected by faulty regrinding. A check of the deviations on the cutting faces of the hob should therefore be made obligatory after each regrind.
The correct inspection procedure for hobs, the necessary equipment and the evaluation of the measurement results are described in detail in VDI/VDE Recommendation 2606.

齿轮 Gear

误差影响 Effect of the deviation	影响大小排列次序 Order of magnitude of the effect	误差注释典型过程 Representation of the deviation
齿形误差 Profile deviation	≈ 100 %	
齿形误差 (仅对形状构成的问题区域有效) Profile deviation (only the deviation of the profile formation zone in question is effective)	≈ 100 %	
齿牙底部区域的形状误差 (仅对构成齿根圆的切削刃误差有效) Form deviation in the bottom of the tooth space (only the deviation of the tip cutting edges forming the root cylinder is effective)	≈ 20 %	
(齿厚误差) (Tooth thickness deviation)	(≈ 100 %)	刀具的齿厚误差通常通过调整滚齿机中心矩实现。因此对齿轮的齿厚误差没有影响。通过这种修整，会对下面齿轮直径产生影响：齿根圆和有效齿根圆，齿顶圆（如果采用顶切滚刀修整），有效齿顶圆（如果采用非顶切滚刀修整）。 The tooth thickness deviation of the cutter is generally compensated by a correction of the centre distance of the hobbing machine and is therefore not effective as a tooth thickness deviation on the gear. From this correction, changes result on the following diameters of the gear: root circle and effective root circle, tip circle in the case of topping cutters, effective tip circle in the case of cutters with semi-topping.
直径误差 Diameter deviations	> 100 %	(see above)
齿形误差 Profile deviation	≈ 100 %	
齿形误差 Profile deviation	≈ 10 %	
齿形误差 Profile deviation	≈ 10 %	
齿形误差 (仅对齿廓构成区域的误差有效) Profile deviation (only the deviation of the profile forming zone is effective	≈ 10 %	
齿形误差 Profile deviation	≈ 30 %	
齿形误差 Profile deviation	≈ 100 %	

滚刀质量等级对齿轮质量的影响

Effect of the quality grades of the hob on gear quality

对于直齿轮，其规格系数的公差由DIN3962到DIN3967标准给出。滚齿的质量分为十二个等级，分别用数字1到12标出。标记为1的齿轮精度最高。

For **spur gears**, the tolerances of their specification factors are given in DIN 3962 to DIN 3967. The tooth quality is subdivided into twelve quality stages, which are identified by the numbers 1 to 12. Gear quality 1 is the most accurate.

单头滚刀的许用公差符合D1N3968标准的要求。根据其精度不同，共分为五个等级，即质量等级A，B，C，D和特级AA。

The permissible deviations for single start **hobs** are laid down in DIN 3968. Depending on the accuracy, a distinction is made between five quality grades, namely the quality grades A, B, C, D and the special grade AA.

滚刀的基本齿距为齿轮齿廓总误差提供了参考。因此将滚刀啮合区域的基本齿距误差Fe与齿轮总齿形误差Ff相比较是有一定意义的。

The base pitch on the hob provides some guidance about the total profile deviation on the gear. It therefore makes sense to compare the base pitch deviation F_e within an engagement area of the hob with the total profile deviation F_f of the gear.

然而必须考虑到，总轮廓误差不仅可能是由滚刀本身的误差造成的，也可能是由滚齿加工设备，工件夹具和滚刀误差以及切削应力造成的。

It must be considered however that the total profile deviation may be caused not only by deviations on the hob itself, but also by the hobbing machine, errors in hob and workpiece clamping, and the cutting forces.

“可获得的齿轮质量”表是在假设齿轮总误差的2／3是由于滚刀造成的前提下得到的。而其他的影响因素如上述内容所述。

The table of “Attainable gear qualities” is based upon the assumption that $^2/_3$ of the total profile deviation on the tooth is caused by the hob, and the remainder by the influencing factors stated above.

单头滚刀质量等级 DIN 3968 Quality grade to DIN 3968 for single-start hobs		可获得的齿轮质量 DIN 3962第1–8.78部分 Attainable gear qualities to DIN 3962 part 1 – 8.78 (F_f) 模数范围 Module ranges über from										
		1–1,6	1,6–2	2–2,5	2,5–3,55	3,55–4	4–6	6–6,3	6,3–10	10–16	16–25	25–40
F_e	AA	7	7	7	8	7	7	7	8	8	7	7
	A	9	10	9	9	9	9	8	9	9	9	9
	B	11	11	11	11	10	11	10	11	11	10	10
	C	12	1)	12	12	12	12	12	12	12	12	12

1) 低于质量等级12
Inferior to gear quality 12

单刀头滚刀的许用公差等级符合D1N3968标准。

The permissible deviations for single-start hobs are laid down in DIN 3968.

总共有16种不同的公差类别，它们部分互相依赖，且属于累积误差。

There are 16 individual deviations, which are partly interdependent, and one cumulative deviation.

啮合区域的接触比率误差Fe作为整体误差，对于评估滚刀质量具有重要参考作用。在限制条件下，该参考值也可用来对齿轮齿面形状进行预测。

The contact ratio deviation F_e within an engagement area, as a collective deviation, is the most informative value when assessing hob quality. It also allows, within limits, to forecast the flank form of the gear.

为了保证滚刀的质量，必须在每次磨刃后对前刀面的形状和位置：齿距和方向允许偏差进行检查。

To maintain hob quality, it is necessary to check the permissible deviations after each sharpening operation for form and position, pitch and direction of the cutting faces (item nos. 7 to 11, page 108).

滚齿设备的滚刀夹紧装置
Tool holding of hobs in the hobbing machine

刀具夹紧装置有两个基本作用：首先是传递力矩，其次是对加工设备中的刀具进行定位。当然在滚齿设备与滚刀/刀杆之间的安装位置也有相同的应用。其连接处的几何形状主要由设备制造商确定。

Tool holding has two essential functions: firstly to transmit the torque, and secondly to locate the tool in the machine. The same applies of course to the interface between the hobbing machine and the hob/cutter arbor. The geometrical arrangement of this connection is largely determined by the hobbing machine manufacturer.

滚刀与滚齿机/刀杆之间的连接形式主要有两种：孔式和杆式滚刀。

The following two chief arrangements are employed at the interface between the hob and the hobbing machine/cutter arbor: the **bore-type** and the **shank-type hob**.

孔式滚刀包括以下几种：
- 正向力矩传递的带键槽的孔
- 一端或两端实现正向力矩传递的带驱动槽的孔
- 在滚刀面实现摩擦力矩传递的孔

The **bore-type hob** has the following sub-categories:
- Bore with keyway for positive torque transmission
- Bore with drive slot on one or both ends for positive torque transmission
- Bore with frictional torque transmission on the hob face

杆式滚刀包括以下几种；
- 两端带有短圆柱柄实现正向力矩传递
- 两端带有锥形柄实现正向力矩传递
- 不同类型的复合型，在驱动和支撑端具有圆柱柄和锥形柄的类型
- 内凹锥形柄
- 驱动端具有大锥度和支撑端具有圆柱柄或锥形柄的类型

The **shank-type hob** has the following sub-categories:
- Short cylindrical shanks at each end with positive torque transmission
- Tapered shank at each end with positive torque transmission
- Different types, cylindrical and tapered, on the drive and support ends
- Hollow shank taper type
- Steep-angle taper on the drive end and cylindrical or taper type on the support end

参数描述之一符合设计任务要求或功能要求后，设备制造商便会推荐购买这种类型的滚齿设备。要注意到不同刀具头部设计的区别，从而认识到各种滚齿加工设备对夹紧装置的设计区别。使用转换头实现刀具的夹紧应视为最后的选择方案。因为选用转换头实现夹紧很可能会导致加工工件的质量有所降低。因此，在购买滚齿设备之前必须考虑刀具连接接口的兼容性。如果滚齿机配有不同的刀具夹持方式，就需要大量的滚刀。

One of the variants described above, adapted to the function and the task in question, is generally recommended by the machine manufacturer upon purchase of a hobbing machine. Note that there are differences in cutter head design and therefore in tool holding arrangement from one hobbing machine manufacturer to the next. The use of adapters for holding equivalent tools should be regarded only as a last resort, as in the majority of cases it results in a loss in quality on the machined workpiece. For this reason, the compatibility of the interface must be clarified prior to purchase of a hobbing machine. A large number of hobs is required if hobbing machines are employed with different tool holding arrangements.

上述使用最为广泛的滚刀是带有键槽的孔形滚刀。这是由一定的历史原因造成的。只有在对几何约束有特殊要求或需要更高的加工精度时才会使用柄式滚刀。孔形滚刀在加工小型产品以及对工件加工精度不是很高的情况下是一种很好的选择，滚刀通常是采用高速钢制造而成的，其键槽符合DIN138标准。几何设计要求允许的情况下，一端或两端的驱动槽符合DIN138标准（短型的滚刀当然也符合该标准）。硬质合金滚刀往往在一端或两端带有驱动槽，并通常设计成短系列（根据D1N138标准要求，驱动槽深度减半）。孔形滚刀则可以没有键槽或驱动槽。

The most widely used hob type is the bore-type hob with keyway. Bore-type hobs are a good choice for small production runs and where requirements on the workpiece accuracy are not particularly stringent. Hobs are generally manufactured from high-speed steel, with a keyway to DIN 138. Geometric requirements permit designs with a drive slot on one or both ends to DIN 138 (and also in shortened versions). Carbide hobs are always manufactured with drive slots on one or both ends, and almost always in the shortened design (½ drive slot depth according to DIN 138). Bore-type hobs may also be manufactured without keyway or drive slot.

现在，两端带有短圆柱柄的滚刀使用的越来越多了，特别在大批量生产。其优点在于换刀速度快，装在机床上滚刀跳动小。不需要对刀柄进行预校正。没有接口元件（刀柄）。在购买加工设备时：必须注意滚刀在不同制造商生产的滚齿机的兼容性。

Hobs with short cylindrical shanks at both ends are increasingly being used, particularly for large production runs. The advantages are fast tool changing and very low runout of the hob in the machine. Prealignment on the cutter arbor is not required. There is no interface element (cutter arbor). When hobbing machines are purchased, attention must be given to the compatibility of hobs on hobbing machines from different manufacturers.

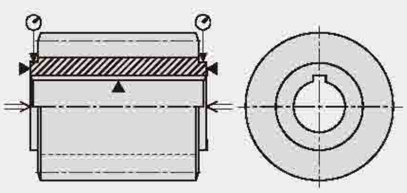
上述的其他类型滚刀为其他加工提供了解决方法，但在使用时必须考虑其能否满足用户规定的加工要求。

The other hob types described above represent further possible solutions which should however be regarded as special cases for the fulfilment of specific customer requirements.

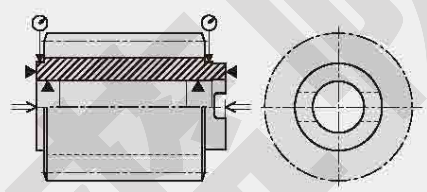
如有加工需要，也可制造配备安装接口的蜗轮滚刀(请参考蜗轮滚刀转换头)。

If required, worm gear hobs are manfactured with an interface geometry that has been adapted to the hobbing machine (refer to Worm gear hobs chapter).

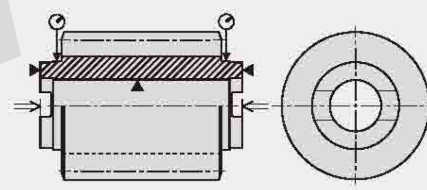
滚刀夹紧示意图
键槽
Hob clamping
Keyway



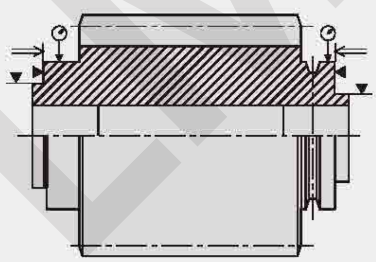
滚刀夹紧示意图
一端带驱动槽
Hob clamping
Drive slot at one end



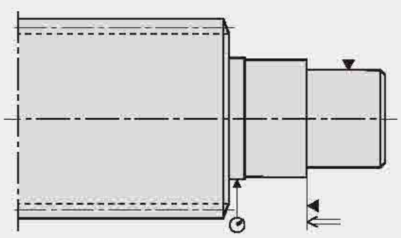
滚刀夹紧示意图
两端带驱动槽
Hob clamping
Drive slots at both ends



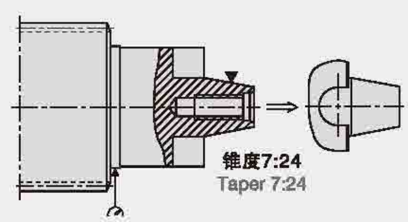
滚刀夹紧示意图
摩擦力矩传递
Hob clamping
frictional torque transmission



滚刀夹紧示意图
圆柱柄式
Hob clamping
cylindrical shank

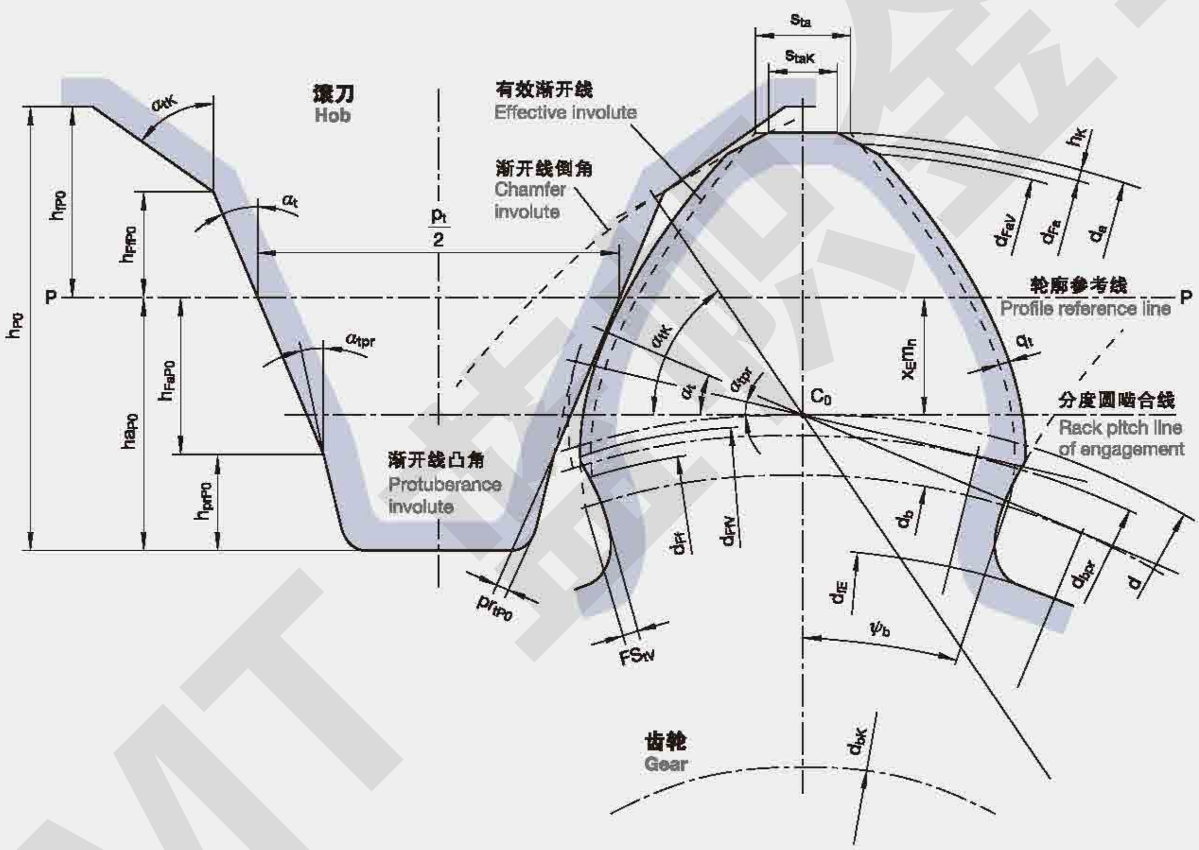


滚刀夹紧示意图
锥形柄式
Hob clamping
tapered shank



⊘ = 表面圆跳动指示器 Runout indicator surface
▼ = 安装接口 Mounting surface
⟹ = 夹紧力 Clamping force

带倒角和齿根清根的斜齿轮轮廓的预加工模型，
以及预加工刀具的相关基本轮廓。
Pre-formed helical spur gear face profile with chamfer and root clearance cut,
with corresponding basic profile of the pre-forming tool (Protuberance)



渐开线直齿圆柱齿轮的基本齿廓
Basic profiles for spur gears with involute teeth

渐开线直齿圆柱齿轮的侧齿面轮廓线位于渐开线的圆弧面上（与齿轮轴线垂直的截面）。

渐开线的形状取决于齿轮的齿数。随着齿数的增加，渐开线的曲率会逐渐减小。当齿数增至无穷数量时，齿轮的齿将变成具有垂直齿面的直边齿。因此我们可以使用直齿轮代替渐开线齿轮并确保与配合齿轮相互啮合完成运动传递时保持平稳。

由于直边齿的齿廓形状比渐开线齿轮更易于描述，建议采用直边齿的轮廓值确定齿廓的“参考（基本）齿廓”，并以渐开线齿廓值作为基本齿廓。

基本齿廓的定义如下：

> 直齿圆柱齿轮的基本齿廓是指基本齿条的齿的法向齿廓，当增加齿数到无穷数量后得到齿顶圆基本齿条的极限直径，此时外齿轮齿成为基本齿条。

渐开线啮合体系的基本齿廓的侧面是直线。参考齿廓值则由附加参数P确定。

测量基本齿廓的基本参数是模数m。模数是长度纲量(单位：mm)。它是由齿距p与π相除得到的。我们通常采用模数的比值定义基本齿廓的测量值。

齿廓参考线与基本齿廓相交，从而使齿厚与齿槽宽等于齿距的一半。

齿顶高值通常为1・m。

由于配合齿轮的齿顶不得与齿槽的底部相接触，因此基本齿廓中的齿根值h_{fp}要比齿高值略大出一个齿顶间隙的数值。这基本齿廓长度要比增加的C_P值大。

基本齿廓的齿形角。α p等于对应齿轮的法向压力角。

有关直齿圆柱齿轮基本齿廓的详细标准可参见：

DIN867
DIN56400
ISO53

The flank profiles of spur gears with involute teeth are in the face section (plane of section perpendicular to the gear axis) circular involutes.

The form of the involute depends among others on the number of teeth on the gears. With an increasing number of teeth the curvature of the involute becomes progressively weaker. At an infinite number of teeth the spur gear becomes a tooth rack with straight flanks. The tooth rack can therefore take the place of a spur gear and ensures an even and trouble-free transmission of motion when meshing with a companion gear.

Since the form of a rack is easier to describe than that of a spur gear, it suggested itself to apply the tooth values of spur gears to the ‘reference (basic) tooth rack’ and to refer to the latter as the basic profile.

The definition of the basic profile is as follows:

> The basic profile of a spur gear is the normal section through the teeth of the basic tooth rack, which is created from the external gear teeth by increasing the number of teeth up to infinity and thus arriving at an infinite diameter.
> The flanks of the basic profile of an involute tooth system are straight lines. Values of the reference profile are identified by the additional index P.

The basis for the measurements on the basic profile is the module m. The module is a length measurement in mm. It is obtained as the quotient from the pitch p and the number π. It is usual to define the measurements of the basic profile in proportion to the module.

The profile reference line intersects the basic profile so that the tooth thickness and the tooth space width correspond to half the pitch.

The addendum is generally 1 · m.

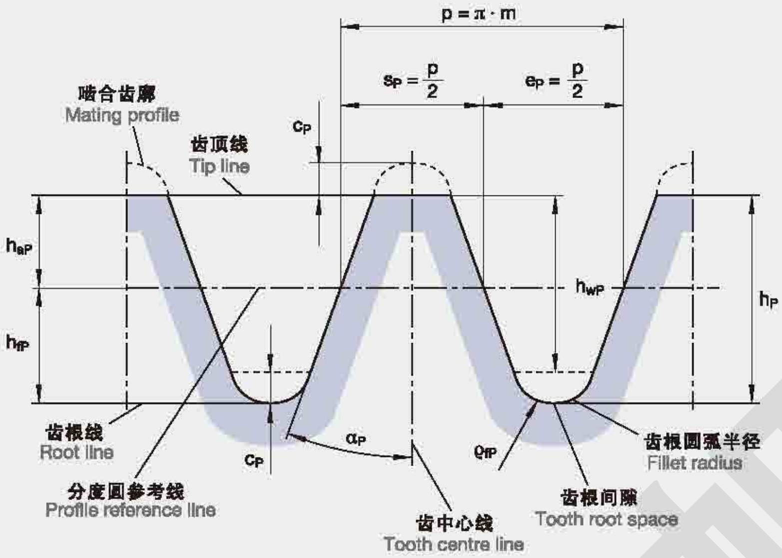
Since the tooth tips of a companion gear must not touch the bottom of the space between the teeth of the gear, the dedendum h_{fP}, of the basic profile is larger than its addendum by the amount of the tip clearance c_P.

The profile angle α_P, on the basic profile is equal to the normal pressure angle of the corresponding gear.

Details of standardized basic profile for spur gears are found in:

DIN 867
DIN 58400
ISO 53

直齿轮的基本齿廓
Basic profile of a spur gear



$p = m \cdot \pi$ = 齿距
Pitch

e_P = 齿廓参考线上的齿间隙宽度
Tooth space width on the profile reference line

s_P = 齿廓参考线上的齿厚
Tooth thickness on the profile reference line

h_P = 齿高
Profile height

h_{aP} = 齿顶高
Addendum

h_{fP} = 齿根高
Dedendum

α_P = 齿廓角
Profile angle

ϱ_{fP} = 齿根圆弧半径
Root fillet radius

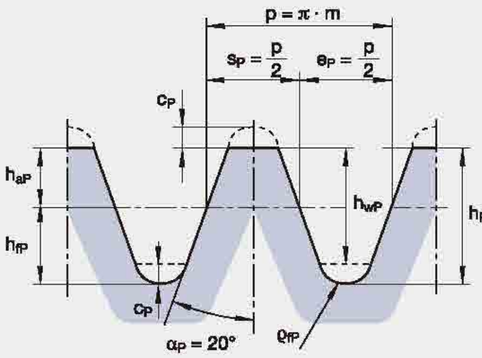
h_{wP} = 基本齿廓和啮合齿廓的啮合齿高
Common tooth height of basic profile and mating profile

c_P = 基本齿廓与啮合齿廓之间的齿顶间隙
Tip clearance between basic profile and mating profile

直齿轮的基本齿廓用参数P表示。
The basic profiles of spur gears are denoted by the index p.

渐开线齿的基本齿廓
Basic profiles for involute teeth

1

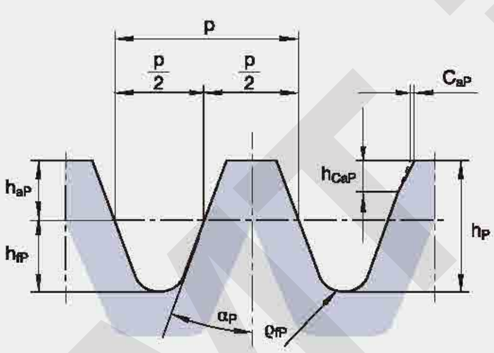


DIN 867—直齿轮基本齿廓
(渐开线圆柱齿轮)
DIN 867 – Basic profile for spur gears
(cylindrical gears with involute teeth)

h_{aP} = m
h_{fP} = m + c
c_P = 0,1 · m bis to 0,3 · m
= 0,4 · m in 特别情况 in special cases
h_{wP} = 2 · m
$\varrho_{fP max.}$ = 0,25 · m 当 at c_P = 0,17 · m
= 0,38 · m 当 at c_P = 0,25 · m
= 0,45 · m 当 at c_P = 0,3 · m

p = 齿距
Pitch
e_P = 齿廓参考线上的齿槽宽度
Tooth space width on the profile reference line
s_P = 齿廓参考线上的齿厚
Tooth thickness on the profile reference line
h_P = 全齿高
Profile height
h_{aP} = 齿顶高
Addendum
h_{fP} = 齿根高
Dedendum
α_P = 齿形角
Profile angle
ϱ_{fP} = 齿根圆弧半径
Root fillet radius
h_{wP} = 基本齿廓和啮合齿廓的啮合齿高
Common tooth heigt of basic basic profile and mating profile
c_P = 基本齿廓与配合齿廓之间的齿顶间隙
Tip clearance between basic profile and mating profile
m = 模数
Module
C_{aP} = 齿顶铲背补偿
Addendum tip relief
h_{CaP} = 齿顶铲背高度
Height of the addendum tip relief

2



ISO53—渐开线直齿圆柱齿轮的基本齿廓
ISO 53 – Basic profile for spur gears with involute flanks

p = m · π
$s_P = \frac{p}{2}$
h_{aP} = m
h_{fP} = 1,25 · m
h_P = 2,25 · m
α_P = 20°
ϱ_{fP} = 0,38 · m
C_{aP} = 0,02 · m
h_{CaP} = 0,6 · m

LMT • FETTE

滚刀基本轮廓定义

滚刀基本轮廓的定义是依据直齿轮基本齿廓得到的。该定义仅适用于具有一定限制的直齿轮齿牙，而且不能在特别的齿廓中采用，因为没有适合这类齿轮的齿廓。

一般情况下滚刀的基本轮廓定义如下：

滚刀的基本轮廓是一个虚构齿条的在法向截面的轮廓，并在以下条件下与工件相互啮合：

- 齿条上的基本轮廓线在工件的分度圆直径上滚动。
- 齿条齿距等于分度圆上的齿距。
- 工件的啮合在以下情况时发生：

  根据齿轮传动的基本规则，当共有垂线经过与分度圆的交叉点以及当齿轮参考线（转动点）与齿轮面和齿条齿面产生交叉点时。

  经过加工工件的齿条轮廓线部分的相关路径时。

  判断基本齿廓的计算和设计取决于加工工件的基本齿形。最简单的判断方法是渐开线直齿轮的基本齿廓。

渐开线直齿轮的基本加工齿廓

滚刀或刀具齿形是与直齿轮的啮合齿廓。基本滚刀的齿廓参考线与直齿轮的齿廓是一致的，例如齿厚S_{p0}等于齿距的一半。齿顶高h_{aP0}。与基本直齿轮的齿底高h_{fP}相对应，齿顶圆弧半径ϱ_{aP0}。等于基本直齿轮的齿根圆弧半径ϱ_{fP}。

如果基本滚刀的齿廓没有任何齿形修整，比如倒角，齿形修正，凸角等，那么相同的滚刀可以用来生产任意齿数，螺旋角度和齿廓补偿的直齿轮和斜齿轮。

标准化的基本滚刀齿廓在以下标准中给出：
DIN3972
DIN58412

基本滚刀齿廓和滚刀齿廓

基本滚刀齿廓不一定清晰体现滚刀齿廓，尽管基本滚刀齿廓是计算滚刀齿廓、滚刀直径、刀头数目的基础依据，而且对滚刀齿廓的形状有一定的影响，其详细情况与滚刀制造商有关。制造商必须确保具有相同基本齿廓的滚刀能够加工出符合滚刀许可公差范围内的齿形。

Defination of the basic hob profiles

The definition of the basic hob profile is generally derived from the basic profile of the spur gear teeth. This procedure applies to spur gear teeth only within limits and cannot be used for special tooth systems, since no basic profiles exist for these.

The basic hob profile can generally be defined as follows:

The basic hob profile is the normal sectional profile of an imaginary tooth rack, which meshes with the workpiece teeth under the following conditions:

- The basic profile line of the rack rolls on a defined pitch circle diameter of the workpiece.
- The pitch of the rack is equal to the pitch on the pitch circle diameter.
- Meshing with the workpiece takes place:
  - according to the basic law of the tooth system, the common perpendicular passing through the contact point of pitch circle and reference line (rolling point) in the contact point of gear flank and tooth rack flank, or
  - through relative paths of parts of the tooth rack profile on the workpiece.

The computing and design effort for determining the basic profile depends on the nature of the workpiece teeth. The simplest is the determination of the basic hob profile for spur gears with involute flanks.

Basic hob profile for spur gears with involute flanks

The hob or tool profile is the mating profile of the spur gear teeth. The profile reference lines of the basic hob- and spur gear profile coincide, i. e. the tooth thickness s_{P0} equals half the pitch. The addendum h_{aP0} corresponds to the dedendum h_{fP}, on the basic spur gear profile and the addendum radius ϱ_{aP0} is equal to the dedendum radius ϱ_{fP} on the basic spur gear profile.

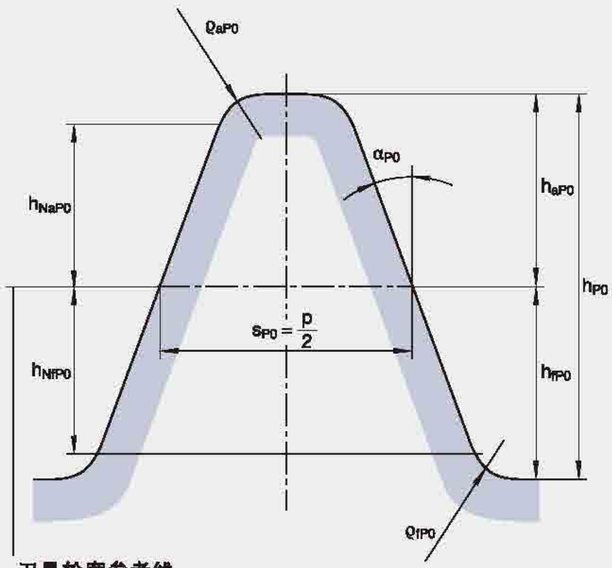
The same hob can be used for producing spur- and helical gears with any number of teeth, helix angles and profile displacements, if the basic hob profile does not contain any profile modifications such as chamfer, tooth profile corrections, protuberance etc.

Standardized basic hob profiles are shown in:
DIN 3972
DIN 58412

Basic hob profile and hob profile

The basic hob profile must not be confused with the hob profile. Although the basic profile forms the basis for the calculation of the hob profile, the diameter and the number of starts of the hob also affect the hob profile. The details concern the hob manufacturer. He has to ensure that hobs with the same basic profile produce identical teeth within the scope of the permissible hob tolerances.

滚刀基本齿廓
Basic cutter profile



$p = m \cdot \pi$ = 齿距
Pitch

s_{P0} = 齿厚
Tooth thickness

h_{P0} = 齿廓高度
Profile height

h_{aP0} = 齿顶高
Addendum

h_{fP0} = 齿根高
Dedendum

α_{P0} = 齿形角（即压力角）
Flank angle (pressure angle)

ϱ_{aP0} = 齿顶圆弧半径
Tip radius

ϱ_{fP0} = 齿根圆弧半径
Root fillet radius

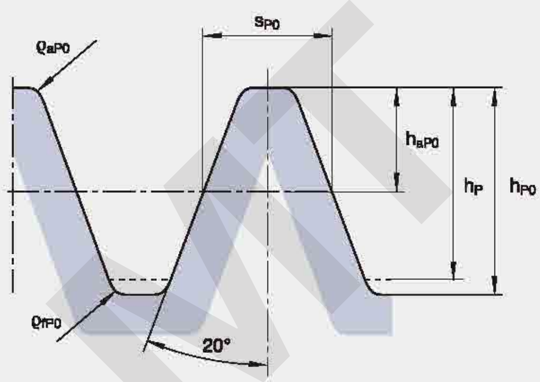
h_{NaP0} = 有效齿顶高
Effective addendum height

h_{NfP0} = 有效齿根高
Effective dedendum height

基本刀具轮廓值用附加参数P0确定。
Values of the basic tool profile are identified by the addition of P0 indexes.

DIN3972标准的滚刀基本齿廓
Basic hob profiles to DIN 3972

1



h_{aP0} = 基本转廓齿顶高
Addendum of the basic profile

h_P = 齿轮齿廓高度=切削深度
Profile height of the gear = cutting depth

h_{P0} = 基本轮廓齿高
Profile height of the basic profile

s_{P0} = 齿厚
Tooth thickness

ϱ_{aP0} = 齿顶圆弧半径
Tip radius

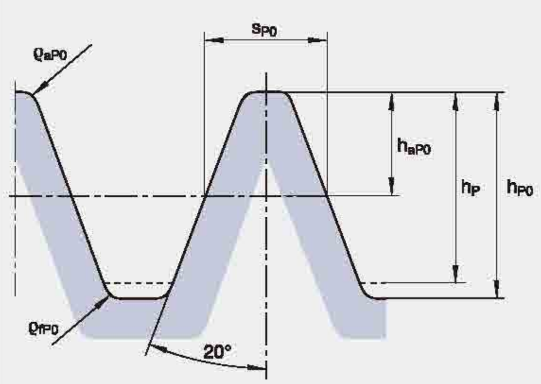
ϱ_{fP0} = 齿根圆弧半径
Root fillet radius

DIN3972——基本齿廓
I–压力角20度
DIN 3972 – Basic profile I
20° Pressure angle

$h_{aP0} = 1{,}167 \cdot m$
$h_P = 2{,}167 \cdot m$
$h_{P0} = 2{,}367 \cdot m$
$\varrho_{aP0} \approx 0{,}2 \cdot m$
$\varrho_{fP0} \approx 0{,}2 \cdot m$
$s_{P0} = \frac{\pi}{2} \cdot m$

精加工
for finishing

2

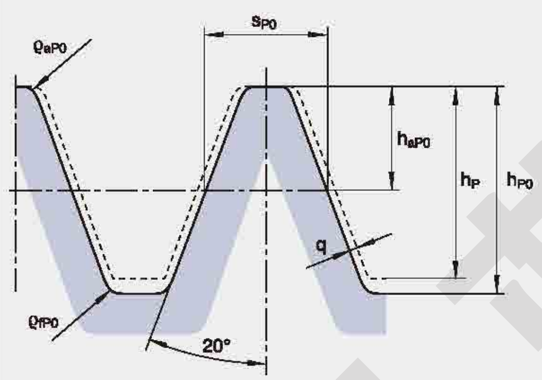


DIN3972——基本齿廓 II
—压力角20度
DIN 3972 – Basic profile II
20° Pressure angle

$h_{aP0} = 1{,}250 \cdot m$
$h_P = 2{,}250 \cdot m$
$h_{P0} = 2{,}450 \cdot m$
$\varrho_{aP0} \approx 0{,}2 \cdot m$
$\varrho_{fP0} \approx 0{,}2 \cdot m$
$s_{P0} = \frac{\pi}{2} \cdot m$

精加工
for finishing

3

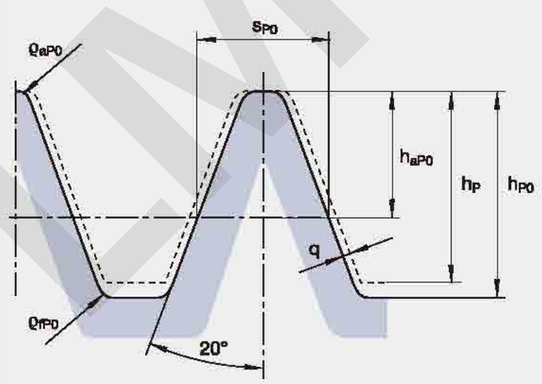


DIN3972——基本齿廓 III
—压力角20度
DIN 3972 – Basic profile III
20° Pressure angle

$h_{aP0} = 1{,}25 \cdot m + 0{,}25 \sqrt[3]{m}$
$h_P = 2{,}250 \cdot m$
$h_{P0} = 2{,}450 \cdot m$
$\varrho_{aP0} \approx 0{,}2 \cdot m$
$\varrho_{fP0} \approx 0{,}2 \cdot m$
$s_{P0} = \frac{\pi}{2} \cdot m$
$q = 0{,}25 \sqrt[3]{m} \cdot \sin 20°$

磨削或刮削之前加工
for machining prior to grinding or shaving

4



DIN3972——基本齿廓IV
—压力角20度
DIN 3972 – Basic profile IV
20° Pressure angle

$h_{aP0} = 1{,}25 \cdot m + 0{,}60 \sqrt[3]{m}$
$h_P = 2{,}250 \cdot m$
$h_{P0} = 2{,}450 \cdot m$
$\varrho_{aP0} \approx 0{,}2 \cdot m$
$\varrho_{fP0} \approx 0{,}2 \cdot m$
$s_{P0} = \frac{\pi}{2} \cdot m$
$q = 0{,}6 \sqrt[3]{m} \cdot \sin 20°$

精加工前进行加工
for machining prior to finishing

LMT · FETTE

DIN58412基本滚刀齿廓
Basic hob profiles to DIN 58412

h_{fP0} = **基本轮廓齿根高**
Dedendum of the basic profile

h_{Pw} = **齿根与基本齿廓直齿面之间的距离**
Distance beween the tooth root and the end of the straight flank of the basic profile

h_{P0} = **基本轮廓齿高**
Profile height of the basic profile

h_P = **齿轮齿廓高度 = 切削深度**
Profile height of the gear = cutting depth

$s_{P0} = \frac{\pi}{2} \cdot m$ = **齿厚** Tooth thickness

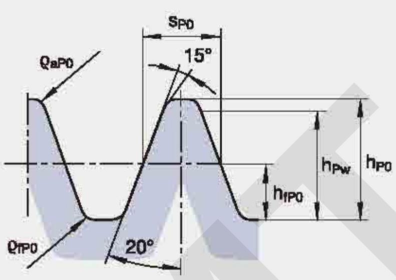
ϱ_{aP0} = **齿顶圆弧半径**
Tip radius

ϱ_{fP0} = **齿根圆弧半径**
Root fillet radius

U_1, N_1, V_1 } **加工DIN58400标准齿轮的基本刀具轮廓**
For gears with basic cutter profile to DIN 58 400

U_2, N_2, V_2 } **加工DIN867标准齿轮的基本刀具轮廓**
For gears with basic cutter profile to DIN 867

5

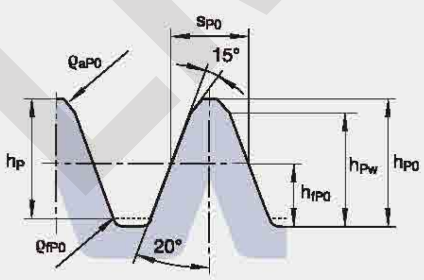


DIN58412—基本齿廓UI
–顶切–压力角20度
DIN 58 412 – Basic profile U I
topping – 20° Pressure angle

h_{fP0} = 1,1 · m
h_{Pw} = 2,2 · m
h_{Pw} = 2,2 · m
h_P = h_{P0} = 2,6 · m **模数为** 0.1~0.6
h_P = h_{P0} = 2,45 · m **模数大于** 0.6~1.0
ϱ_{aP0} ≈ 0,2 · m
ϱ_{fP0} ≈ 0,2 · m **最大尺寸** max. size

精加工
for finishing

6

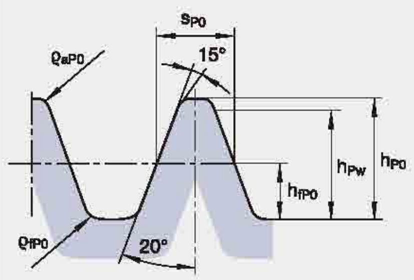


DIN58412——基本齿廓N1
–非顶切–压力角20度
DIN 58 412 – Basic profile N 1
non-topping – 20° Pressure angle

h_{fP0} = 1,3 · m
h_{Pw} = 2,4 · m
h_P = 2,6 · m **模数为** 0.1~0.6
h_P = 2,45 · m **模数大于** 0.6~1.0
h_{P0} = 2,8 · m **模数为** 0.1~0.6
h_{P0} = 2,65 · m **模数大于** 0.6~1.0
ϱ_{aP0} ≈ 0,2 · m
ϱ_{fP0} ≈ 0,2 · m **最大尺寸** max. size

精加工
for finishing

7

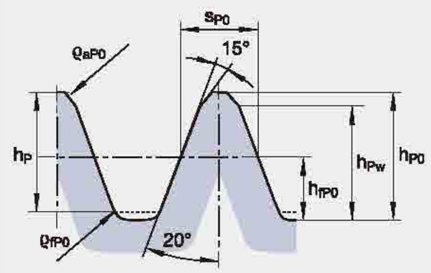


DIN58412—基本齿廓U2
–顶切–压力角20度
DIN 58412 – Basic profile U 2
topping – 20° Pressure angle

$h_{fP0} = 1 \cdot m$
$h_{Pw} = 2 \cdot m$
$h_P = h_{P0} = 2{,}25 \cdot m$
$\varrho_{aP0} = 0{,}2 \cdot m$
$\varrho_{fP0} = 0{,}2 \cdot m$ 最大尺寸 max. size

精加工
for finishing

8

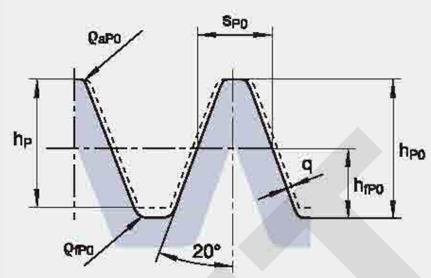


DIN58412—基本齿廓N2
–非顶切–压力角20度
DIN 58412 – Basic profile N 2
non-topping – 20° Pressure angle

$h_{fP0} = 1{,}2 \cdot m$
$h_{Pw} = 2{,}2 \cdot m$
$h_P = 2{,}25 \cdot m$
$h_{P0} = 2{,}45 \cdot m$
$\varrho_{aP0} = 0{,}2 \cdot m$
$\varrho_{fP0} = 0{,}2 \cdot m$ 最大尺寸 max. size

精加工
for finishing

9

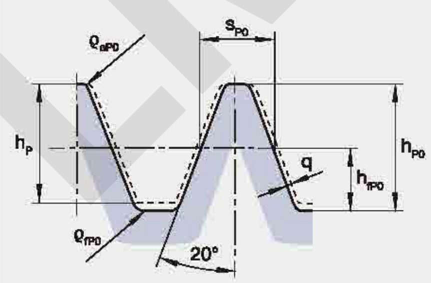


DIN58412—基本齿廓V1
–非顶切–压力角20度
DIN 58412 – Basic profile V 1
non-topping – 20° Pressure angle

$h_{fP0} = 1{,}3 \cdot m$
$h_P = 2{,}6 \cdot m$ 模数为 0.3~0.6
$h_P = 2{,}45 \cdot m$ 模数大于 0.6~1.0
$h_{P0} = 2{,}8 \cdot m$ 模数为 0.3~0.6
$h_{P0} = 2{,}65 \cdot m$ 模数大于 0.6~1.0
$s_{P0} = \frac{\pi}{2} \cdot m - \frac{2q}{\cos\alpha}$
$\varrho_{aP0} = 0{,}1 \cdot m$
$\varrho_{fP0} = 0{,}2 \cdot m$ 最大尺寸 max. size
$q = 0{,}05 \cdot m + 0{,}03$

粗加工
for pre-machining

10



DIN58412—基本齿廓V2
–非顶切–压力角20度
DIN 58412 – Basic profile V 2
non-topping – 20° Pressure angle

$h_{fP0} = 1{,}2 \cdot m$
$h_P = 2{,}25 \cdot m$
$h_{P0} = 2{,}45 \cdot m$
$s_{P0} = \frac{\pi}{2} \cdot m - \frac{2q}{\cos\alpha}$
$\varrho_{aP0} = 0{,}1 \cdot m$
$\varrho_{fP0} = 0{,}2 \cdot m$ 最大尺寸 max. size
$q = 0{,}05 \cdot m + 0{,}03$

粗加工
for pre-machining

径节制滚刀基本齿廓
Basic hob profiles for diametral pitch teeth

h_{aP0} = 基本转廓齿顶高
Addendum of the basic profile

h_P = 齿轮齿廓高度 = 切削深度
Profile height of the gear = cutting depth

h_{P0} = 基本轮廓齿高
Profile height of the basic profile

s_{P0} = 齿厚
Tooth thickness

h_{CP0} = 修整高度
Height of the correction

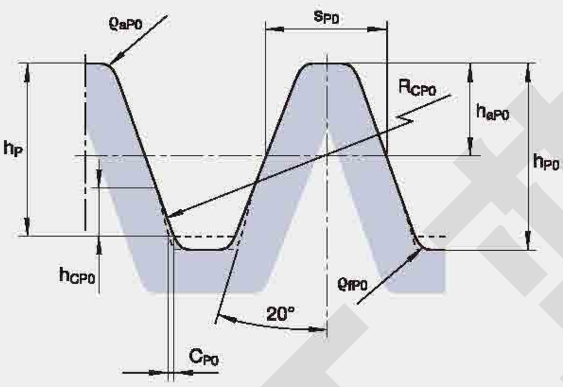
C_{P0} = 修整宽度
Width of the correction

R_{CP0} = 修整半径
Radius of the correction

ϱ_{aP0} = 齿顶圆弧半径
Tip radius

ϱ_{fP0} = 齿根圆弧半径
Root fillet radius

11



适用于1959年BS2062
第一部分的齿形DP1~DP20
压力角20度
For teeth to BS 2062,
Part 1, 1959, for DP 1 ~ DP 20
20° Pressure angle

$h_{aP0} = \frac{1,25}{DP}\ 25,4$

$h_P = \frac{2,25}{DP}\ 25,4$

$h_{P0} = \frac{2,45}{DP}\ 25,4$

$s_{P0} = \frac{1,5708}{DP}\ 25,4$

$h_{CP0} = \frac{0,63}{DP}\ 25,4$

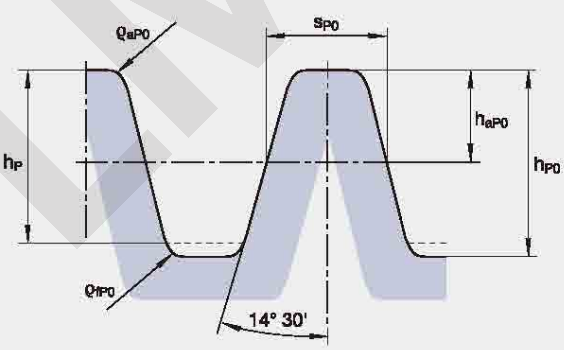
$C_{P0} = \frac{0,019}{DP}\ 25,4$

$R_{CP0} = \frac{12,9}{DP}\ 25,4$

$\varrho_{aP0} = \frac{0,3}{DP}\ 25,4$

$\varrho_{fP0} = \frac{0,2}{DP}\ 25,4$

12



适用于1968年AGmA201.02
的齿形DP1~DP19.99
压力角14度30分
For teeth to AGMA 201.02 – 1968
for DP 1 ~ DP 19.99
14° 30' Pressure angle

$h_{aP0} = \frac{1,157}{DP}\ 25,4$

$h_P = \frac{2,157}{DP}\ 25,4$

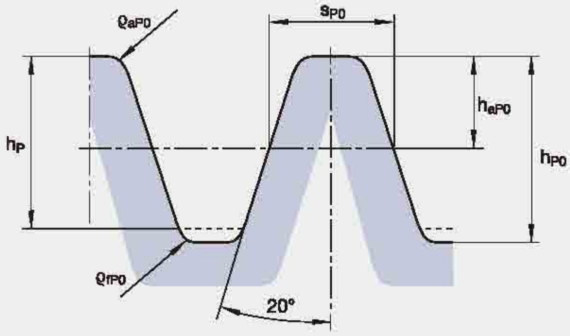
$h_{P0} = \frac{2,357}{DP}\ 25,4$

$s_{P0} = \frac{1,5708}{DP}\ 25,4$

$\varrho_{aP0} = \frac{0,209}{DP}\ 25,4$

$\varrho_{fP0} = \frac{0,2}{DP}\ 25,4$

13



适用于1968年AGMA201.02
的齿形DP1~DP19.99
压力角20度
For teeth to AGMA 201.02 – 1968
for DP 1 – DP 19.99
20° Pressure angle

$h_{aP0} = \frac{1,25}{DP} 25,4$

$h_P = \frac{2,25}{DP} 25,4$

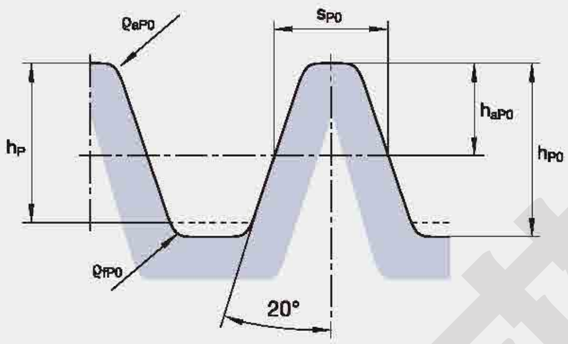
$h_{P0} = \frac{2,45}{DP} 25,4$

$s_{P0} = \frac{1,5708}{DP} 25,4$

$\varrho_{aP0} = \frac{0,3}{DP} 25,4$

$\varrho_{fP0} = \frac{0,2}{DP} 25,4$

14



适用于1968年AGMA201.02
的齿形DP1~DP19.99
压力角20度 短齿
Stub-Verzahnung
For teeth to AGMA 201.02 – 1968
for DP 1 – DP 19.99
20° Pressure angle
stub-tooth

$h_{aP0} = \frac{1}{DP} 25,4$

$h_P = \frac{1,8}{DP} 25,4$

$h_{P0} = \frac{2}{DP} 25,4$

$s_{P0} = \frac{1,5708}{DP} 25,4$

$\varrho_{aP0} = \varrho_{fP0} = \frac{0,2}{DP} 25,4$

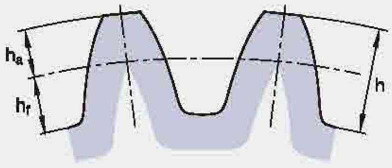
渐开线直齿轮和斜齿轮，基本刀具轮廓，如DIN3972I–Ⅳ。

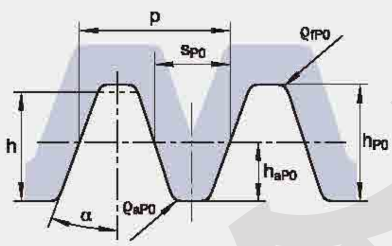
如需订货请提供以下参数：模数，压力角。齿的基本齿形或滚刀基本齿形

Involute teeth for spur- and helical gears, basic cutter profile e.g. DIN 3972 I–IV.

When ordering please quote:
Module, pressure angle, basic profile of the teeth or basic hob profile.

1





工件
Workpiece

h = 齿廓高度=切削深度
Profile height = Cutting depth

h_a = 齿顶高
Addendum

h_f = 齿根高
Dedendum

滚刀基本齿廓
Basic cutter profile

h_{P0} = 齿廓高度
Profile height

h_{aP0} = 齿顶高
Addendum

α = 压力角
Pressure angle

$\frac{p}{\pi}$ = m = 模数
m = Module

带齿顶圆铲背的渐开线直齿轮和斜齿轮。这种齿廓的齿形可以防止啮合时发生干涉。

如需订货请提供以下参数：模数，压力角，齿数，斜齿轮螺旋角，齿形位移以及齿轮的齿顶圆直径，齿的基本形状齿顶铲背的高度和宽度或滚刀基本齿廓。

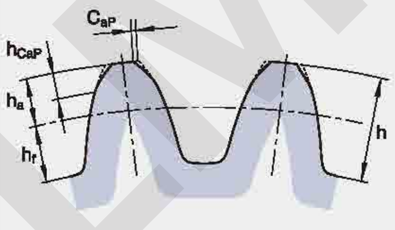
高速齿轮为减少噪音，需对齿顶作修正。在修正时，必须考虑到弹性齿变形刀具修正后可以与被切齿轮的齿相配。

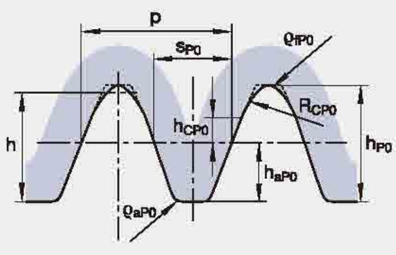
Involute teeth for spur- and helical gears with addendum tip relief. This profile shape is used to avoid interference when the gears roll into mesh.

When ordering please quote:
Module, pressure angle, number of teeth, helix angle, profile displacement and tip circle dia. of the gear, basic profile of the teeth, height and width of the tip relief or basic hob profile.

Gears of high-speed transmissions are corrected in the tooth tips to reduce noise. In this correction the elastic tooth deflection has been taken into account. The cutter correction is then matched to the number of teeth to be cut on the gear.

2





工件
Workpiece

h_{CaP} = 齿顶铲背高度
Height of the tip relief

C_{aP} = 齿顶铲背
Tip relief

滚刀基本齿廓
Basic cutter profile

h_{CP0} = 参考线以上的修整高度
Height of the correction over the reference line

R_{CP0} = 修整半径
Radius of the correction

带倒角的渐开线直齿轮和斜齿轮。

Involute teeth for spur- and helical gears with tip chamfer.

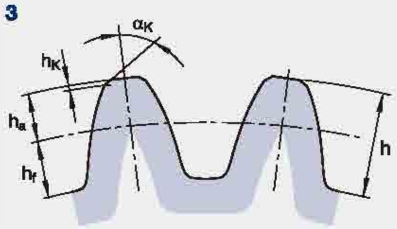
如需订货请提供以下参数：模数，压力角，齿数，斜齿轮螺旋角，齿形位移以及齿轮的齿顶圆直径，齿的基本形状，圆弧半径和倒角角度或滚刀的基本齿廓。

When ordering please quote:
Module, pressure angle, number of teeth, helix angle, profile displacement and tip circle diameter of the gear, basic profile of the teeth, radial amount and angle of the chamfer or basic hob profile.

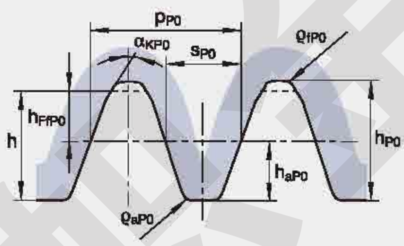
齿顶倒角可以视为保护性倒角，用来保护齿顶边缘免受损坏和产生毛刺。从产品长期使用的角度来看，建议在对齿轮齿顶边缘进行倒角处理的同时对滚刀边缘也作相同的处理。因为倒角的尺寸会随着齿轮齿数的增加而增加，或随着齿数的减少而减少，于是使用一个滚刀就可以完成齿轮所有齿的倒角加工。

The tip chamfer can be regarded as a protective chamfer, which protects the tooth tip edge against damage and burring. For long production runs it is advisable to chamfer the gear tip edge simultaneously with the hob. The number of teeth range which can be cut with one hob is in that case limited, since the size of the chamfer would be reduced with fewer teeth/gear and greater with more teeth/gear.

3



工件
Workpiece
h_K = 齿顶倒角的圆弧半径
Radial amount of the tip chamfer
α_K = 倒角角度
Angle of the chamfer



滚刀基本齿廓
Basic cutter profile
h_{FfP0} = 滚刀基本齿廓的有效齿根高
Effective dedendum of the basic cutter profile
α_{KP0} = 倒角面的角度值
Profile angle of the chamfer flank

带齿根清根(挖根)渐开线直齿轮和斜齿轮机构。所选齿轮的齿形是取决于剃、磨、刮前的要求。

Involute tooth system, for spur- and helical gears with root (protuberance) clearance. This profile formation is chosen for gears which are pre-machined for shaving, grinding or skiving.

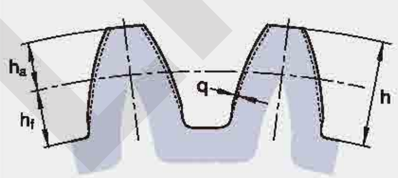
如需订货请提供以下参数：模数，压力角，基本齿形、加工余量和滚刀基本齿廓或滚齿挖根量。

When ordering please quote:
Module, pressure angle, basic profile of the tooth system, machining allowance and root clearance or basic hob profile.

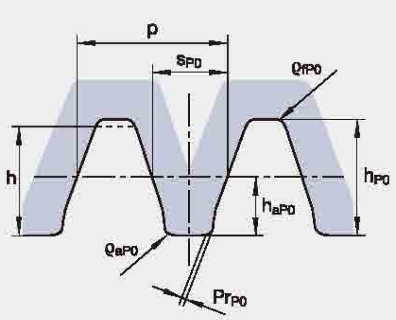
使用带凸角滚刀加工磨削或剃削前的齿轮是最佳的。这种齿根清根可以提高剃刀的使用寿命，并改善剃削或磨削加工齿轮的质量。

Gears which are cut with shaving- or grinding allowance are best made with a protuberance cutter. The tooth root clearance obtained with this increases the service life of the shaving tool and improves the quality of the shaved or ground gear.

4



工件
Workpiece
q = 加工余量
Machining allowance



滚刀基本齿廓
Basic cutter profile
Pr_{P0} = 凸角量
Amount of protuberance

带齿根清根（挖根）和齿顶倒角的渐开线直齿轮和斜齿轮机构。

这种滚刀齿形用来对齿轮进行剃削或磨削预加工，并在精加工条件下加工齿顶倒角。

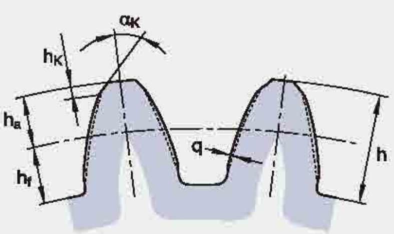
如需订货请提供以下参数：模数，压力角，齿数，斜齿轮螺旋角，齿形变位以及齿轮的齿顶圆直径，齿轮机构的基本形状，倒角角度和圆弧半径或滚刀基本齿廓。

Involute tooth system for spur- and helical gears with root (protuberance) clearance and tip chamfer.

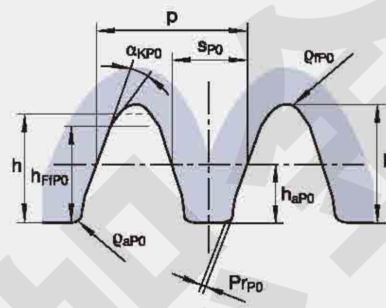
This profile is used for gears which are pre-machined for shaving or grinding and which are to exhibit a tip chamfer in the finished condition.

When ordering please quote:
Module, pressure angle, number of teeth, helix angle, profile displacement and tip circle diameter of the gear, basic profile of the tooth system, radial amount and angle of the chamfer or basic hob profile.

5



工件
Workpiece



滚刀基本齿廓
Basic cutter profile

齿顶圆直径需顶切（顶切滚刀）的渐开线直齿轮和斜齿轮。这种齿廓也可以用上述图1–5的齿廓。

如需订货请提供以下参数："顶切加工滚刀"和根据1至5的详细轮廓。

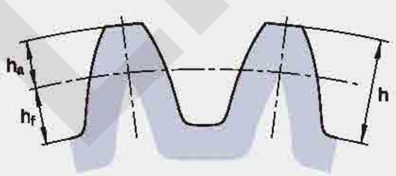
顶切滚刀主要用来加工尺寸相对较小的齿轮，从而获得对孔很高的同心度。特别地，所加工的齿在精加工时使用齿顶加工刀具，能使内孔与外圆的同轴度更高。当把齿顶部分用夹具夹紧后，可以保证齿轮孔和齿之间的同轴度。

Involute teeth for spur- and helical gears for the simultaneous topping of the outside diameter (topping cutter). This profile type can also be used for all the previous profiles under 1 to 5.

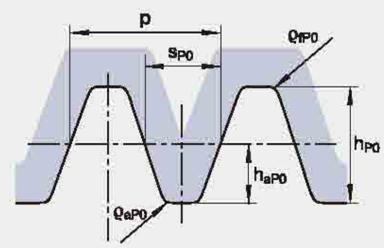
When ordering please quote:
"Topping cutter" and the details according to the pofiles 1 to 5.

Topping cutters are mainly used for relatively small gears, to achieve good concentricity of the tooth system in relation to the bore. In particular, topping cutters are used when the bore is only finish machined after the teeth have been cut. When the parts are clamped over the tooth tips, accurate concentricity of the bore in relation to the teeth is guaranteed.

6



工件
Workpiece



滚刀基本齿廓
Basic cutter profile
$h_{P0} = h$

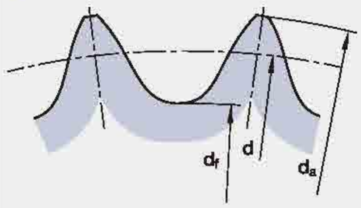
用于辊子和传动链的链轮机构符合DIN8187和8188标准，链轮的齿轮机构符合DIN8196标准，滚刀的基本齿廓符合DIN8197标准。

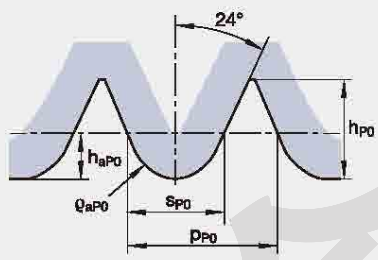
如需订货请提供以下参数：
链节距，辊子直径，链轮的DIN标准要求。

Sprocket tooth system for roller- and sleevetype chains to DIN 8187 and 8188, tooth system of the sprockets to DIN 8196, basic hob profile to DIN 8197.

When ordering please quote:
Chain pitch, roller diameter, DIN standard of the chain.

7





工件
Workpiece
p = 链节距 Chain pitch
d_1 = 辊子直径 Roller diameter
d = 节圆直径 Pitch circle diameter
d_f = d−d1=齿根圆直径 Root circle diameter
d_a = 齿顶圆直径 Tip circle diameter

滚刀基本齿廓
Basic cutter profile
$p_{P0} = 1{,}005 \cdot p$ = 基本齿廓节距 Pitch of the basic profile
$h_{aP0} = 0{,}5 \cdot d_1$

摩擦式链轮机构（重载）符合DIN8150标准。

如需订货请提供以下参数：

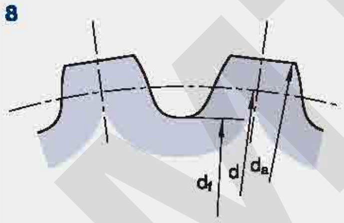
链节距，辊子直径，链轮的DIN标准要求。重型摩擦式链轮的刀具基本齿廓符合DIN8150标准，但并没有标准化，我们制造时使用的压力角值为20度。

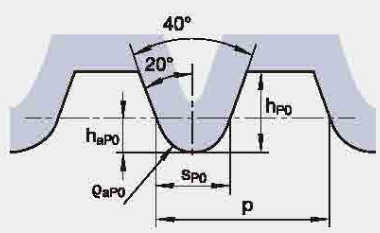
Sprocket tooth system for Gall's chains (heavy) to DIN 8150.

When ordering please quote:
Chain pitch, roller diameter, DIN standard of the chain.

The basic cutter profile for heavy Gall's chains to DIN 8150 is not standardized and is made by us with a pressure angle of 20°.

8





工件
Workpiece
$d_f = d - d_1$

滚刀基本齿廓
Basic cutter profile
$\varrho_{aP0} = 0{,}54 \cdot d_1$
$h_{aP0} = 0{,}5 \cdot d_1$
$h_{P0} = d_1 + 2$ bis to $d_1 = 5$
$h_{P0} = d_1 + 2{,}5$ für for $d_1 > 5$

辊筒式链轮机构符合DIN8164标准。

如需订货请提供以下参数；

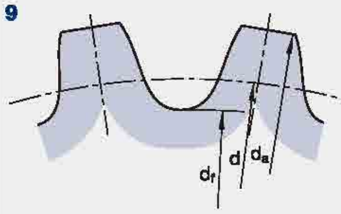
链节距，辊子直径，链轮的DIN标准要求。辊筒式链轮的刀具基本齿廓符合DIN8164标准，但并没有标准化，我们制造时使用的压力角值为20度。

Sprocket tooth system for barrel chains to DIN 8164.

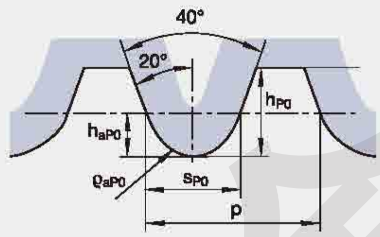
When ordering please quote:
Chain pitch, roller diameter, DIN standard of the chain.

The basic cutter profile for barrel chains to DIN 8164 is not standardized and is made by us with a pressure angle of 20°.

9



工件
Workpiece
$d_f = d - d_1$



滚刀基本齿廓
Basic cutter profile
$\varrho_{aP0} = 0{,}54 \cdot d_1$
$h_{aP0} = 0{,}5 \cdot d_1$
$h_{aP0} = d_1 + 1{,}5$

矩型花键轴机构：不带凸肩和倒角（键侧定心）的刀具基本齿廓。

如需订货请提供以下参数：
内径di，外径da，花键宽度b，键数，以及da，di和b的公差。如有条件还可以提供花键轴的DIN制造标准。设计要求：“无凸肩，无倒角”。

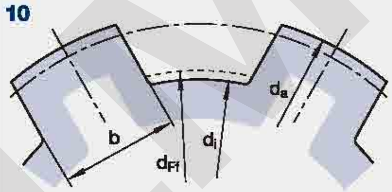
键侧定心的花键轴都是采用没有凸肩和倒角的滚刀加工而成，因此键槽处的内外直径有足够的间隙。必须注意的是从技术角度来说，没有锋利边缘传递的花键传动，其作用力会作用在键侧上。圆形曲线的尺寸取决于轴的直径大小。应确保轴面和键槽之间不会发生重叠现象。并在加工时退刀留下一定的齿底间隙余量。

Spline shaft tooth system; basic cutter profile without clearance lug, without chamfer (flank centred).

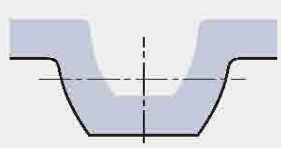
When ordering please quote:
Inside diameter d_i, outside diameter d_a, spline width b, number of splines, tolerances for d_a, d_i, b. Possibly also DIN standard of the splines shaft.
Designation: "Without clearance lug, without chamfer"

Flank centred spline shafts which find sufficient clearance for the internal and the external diameter in the splineway, are produced with hobs without lug and without chamfer. It must be noted that for technical reasons inherent in hobbing no sharp-edged transition can occur from the spline flank to the inside diameter of the spline shaft. The size of the rounding curve depends on the spline shaft dimensions. It must be ensured that no overlapping occurs between the rounding curve and the splineway. It may be necessary to fall back on a tool with clearance lug.

10



工件
Workpiece
d_i = **内直径** Inside diameter
d_a = **外直径** Outside diameter
b = **花键宽度** Spline width
d_{Ff} = **直线起始圆直径** Form circle diameter
花键面d_{Ff}以上为直面，d_{Ff}以下为圆面。
Above d_{Ff} the spline flanks are straight, below d_{Ff} the rounding curve starts



滚刀基本齿廓
Basic cutter profile

矩型花键轴机构；带凸肩和倒角的刀具基本齿廓。如需订货请提供以下参数：

内直径di，外直径da，花键宽度b，花键数，倒角尺寸g,内外直径da,di和花键宽度b的公差。如有条件还可以提供花键轴的DIN制造标准。设计要求：“带凸肩，带倒角”。

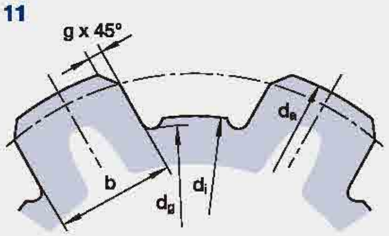
为保证通过内定心花键轴获得花键轴对轴的底径产生合适的向下作用力，滚刀通常带有凸肩。键槽槽角处的间隙通过倒角实现。

Spline shaft tooth system; basic cutter profile with clearance lug and chamfer.

When ordering please quote:
Inside diameter d_i, outside diameter d_a, spline width b, number of splines size of the chamfer g, tolerances for d_a, d_i, b.
Possibly also DIN designation of the spline shaft.
Designation: "With lug and chamfer"

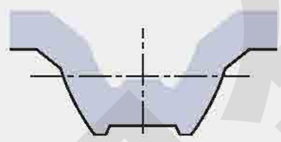
In order to achieve with internally centred spline shafts a correct bearing down on to the spline shaft base, the hob is generally made with lug. The necessary clearance in the slot corners of the splineway is achieved by the chamfer.

11



工件
Workpiece

d_i = 内直径 Inside diameter
d_a = 外直径 Outside diameter
d_g = 底径 Base diameter
b = 花键宽度 Spline width
g = 顶部倒角宽度 Width of the tip relief



滚刀基本齿廓
Basic cutter profile

矩型花键轴机构：带凸肩无倒角的刀具基本齿廓（底部配合）。

如需订货请提供以下参数：
内直径di，外直径da，花键宽度b，花键数，da，di和b的公差。如有条件还可以提供花键轴的DIN制造标准。设计要求；“带凸肩，无倒角”。

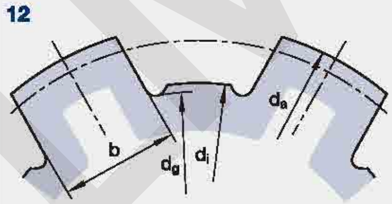
凸肩的详细设计如图所示。如果花键轴外圆直径与相应键槽外圆直径之间的间隙足够大，则不需要制造倒角。

Spline shaft tooth system; basic cutter profile with lug without chamfer (bottom fitting).

When ordering please quote:
Inside diameter d_i, outside diameter d_a spline width b, number of splines, tolerances for d_a, d_i, b. Possibly also DIN standard of the spline shaft.
Designation: "With lug without chamfer"

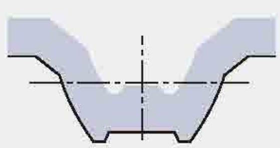
The details under fig. 11 apply to the lug. A chamfer is not necessary if sufficient clearance exists between the spline shaft outside diameter and the corresponding splineway outside diameter.

12



工件
Workpiece

d_i = 内直径 Inside diameter
d_a = 外直径 Outside diameter
d_g = 底径 Base diameter
b = 花键宽度 Spline width



滚刀基本齿廓
Basic cutter profile

矩型花键轴机构：无凸肩带倒角的刀具基本齿廓(底部配合)。

如需订货请提供以下参数：
内直径di，外直径da，花键宽度b，花键数量，da，di和b的公差。如有条件还可以提供花键轴的DIN制造标准。设计要求：“无凸肩，带倒角”：

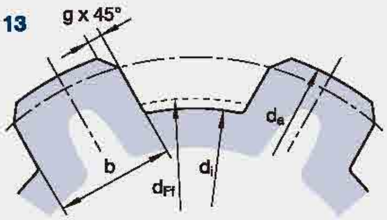
如果内定心花键轴采用不带凸肩滚刀加工，则必须确保键槽上齿的倒角与轴圆弧不会发生干涉现象。

Spline shaft tooth system; basic cutter profile without lug with chamfer (bottom fitting).

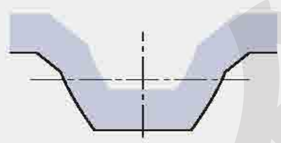
When ordering please quote:
Inside diameter d_i, outside diameter d_a, spline width b, number of splines, tolerances for d_a, d_i, b. Size of the tip chamfer g. Possibly also DIN standard of the spline shaft.
Designation: “Without lug with chamfer”

If internally centred spline shafts are cut with hobs without lug, chamfering on the teeth of the splineway must ensure that interferance with the rounding curve of the shaft are impossible.

13



工件
Workpiece
d_i = 内直径 Inside diameter
d_a = 外直径 Outside diameter
b = 花键宽度 Spline width
g = 顶部倒角宽度 Width of the tip chamfer
d_{Ff} = 形圆直径 Form diameter



滚刀基本齿廓
Basic cutter profile

花键轴齿轮机构：带一个凸肩和倒角的刀具基本齿廓（键侧或外国直径定心）。该齿廓适用于SAE采用花键轴的情况。

如需订货请提供以下参数：内直径di,外直径da，花键宽度b，花键数量，da，di和b的公差。如有条件还可以提供花键轴的DIN或SAE制造标准。设计要求：“带一个凸肩和倒角”。

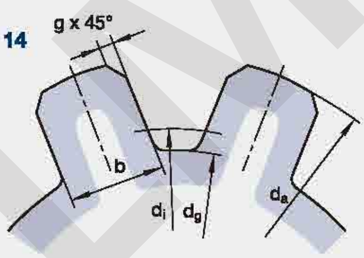
键侧定心的多键花键轴有一个比较深的齿侧通常由滚刀来加工，滚刀只有一个凸起的齿顶。刀具基本齿廓的齿顶非常狭窄以致子只有有限的空间来容纳一个凸肩（对应于凸起的齿顶）。

Spline shaft tooth system; basic cutter profile with one lug with chamfer (Side or major diameter fitting). This profile occurs e.g. in the case of SAE spline shafts.

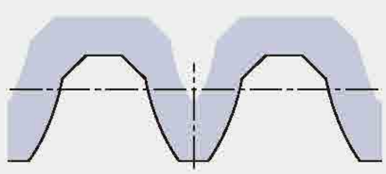
When ordering please quote:
Inside diameter d_i, outside diameter d_a, spline width b, number of splines, tolerances for d_a, d_i, b. Size of the tip relief g. Possibly also DIN- or SAE standard of the spline shaft.
Designation: "With one lug and chamfer"

Flank-centred multi-splined shafts have a very deep spline profile and are generally produced with hobs which only have one raised tooth tip. The tooth tips of the basic cutter profile are so narrow that there is only sufficient space for one lug (equivalent to raised tooth tip).

14



工件
Workpiece
d_i = 内直径 Inside diameter
d_a = 外直径 Outside diameter
d_g = 底径 Base diameter
b = 花键宽度 Spline width
g = 顶部倒角宽度 Width of the tip chamfer



滚刀基本齿廓
Basic cutter profile

矩型花键轴机构；带凸齿贯穿切割台肩的刀具基本齿廓。

Spline shaft tooth system; basic cutter profile with raised tooth for through-cutting a shoulder.

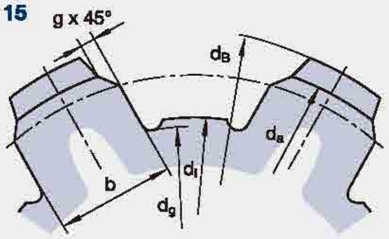
如需订货请提供以下参数：
凸缘直径d_B，以及图中标出的详细尺寸。

When ordering please quote:
Collar dia. d_B and also the details as under profiles 10 to 14.

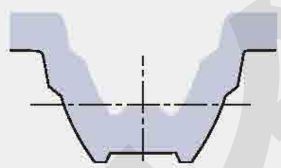
如果使用花键轴，那么花键会推至花键轴的台肩位置，滚刀对台肩进行加工。但台肩外径不能被切削。刀具基本齿廓的齿在制造时必须相应地略高一些。

If in the case of spline shafts the splineway is to be pushed against a shoulder of the spline shaft, the hob cuts into this shoulder. Since, however, the outside diameter of the shoulder must not be machined off, the teeth on the basic cutter profile must be made correspondingly higher.

15



工件
Workpiece
d_i = **内直径** Inside diameter
d_a = **外直径** Outside diameter
d_g = **底键** Base diameter
b = **花键宽度** Spline width
d_B = **台肩直径** Shoulder diameter
g = **顶部倒角宽度** Width of the tip chamfer



滚刀基本齿廓
Basic cutter profile

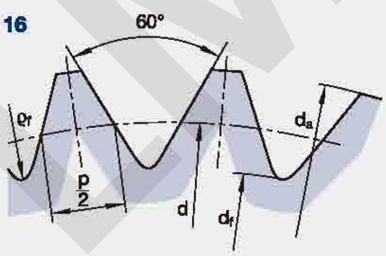
锯齿形齿廓，符合DIN5481标准；名义直径为7×8到55×60。对应于零件的直齿形刀具基本齿廓是凸起的。带直线齿面的刀具也可在上述说明的名义直径范围内使用，如需要采用，则需要预先由客户指定。

Serrations to DIN 5481; nominal diameter 7 x 8 up to 55 x 60. Basic cutter profile with convex flanks for straight workpiece flanks. Cutters with straight flanks can also be used for the nominal diameter range stated above, if this has been arranged with the customer in advance.

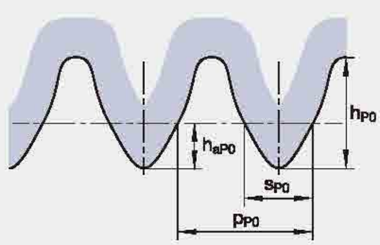
如需订货请指定以下参数：
锯齿形齿和公差的DIN标准。如无特别规定，我们建议用加工凸腹零件的直齿面滚刀齿廓如图所示。
锯齿形细齿用来制造形状匹配的连接插头。

When ordering please quote:
DIN standard of the serration and tolerances. Unless otherwise arranged, we supply the hobs with straight flanks for convex workpiece flanks, as under fig. 17.
Serrations are used for making form-fit plug-on connections.

16



工件
Workpiece
d_f = **根圆直径** Root circle diameter
d = **节圆直径** Pitch circle diameter
d_a = **顶圆直径** Tip circle diameter



滚刀基本齿廓
Basic cutter profile

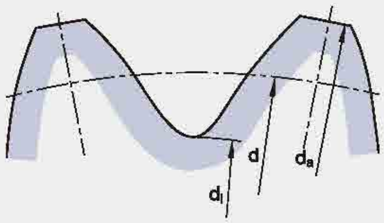
锯齿形齿廓，符合DIN5481标准；名义直径为7×8到55×60和60×65至120x125。对应凸腹的零件采用直线型刀具基本齿廓。名义直径在7×8到55×60的刀具基本齿廓（如图所示）也可以使用。

如需订货请指定以下参数：
适用于锯齿形细齿和对应公差要求的DIN标准。

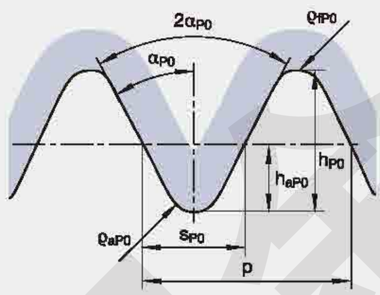
Serrations to DIN 5481; nominal diameter 7 x 8 to 55 x 60 and 60 x 65 to 120 x 125. Basic cutter profile with straight flanks for convex workpiece flanks. For the nom. diameter range 7 x 8 to 55 x 60 basic cutter profiles as under fig. 16 can also be used.

When ordering please quote:
DIN standard of the serrations and tolerances.

17



工件
Workpiece



滚刀基本齿廓
Basic cutter profile

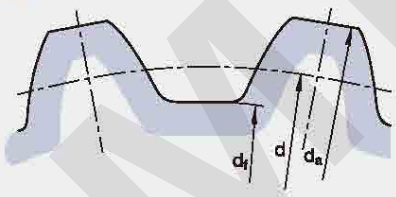
符合DIN5480和其他特定标准的渐开线轮廓齿面的外部花键轮廓。

如需订货请指定以下参数：模数、压力角、齿顶圆直径，齿根圆直径，量棒测量距离、外部花键的DIN标准。

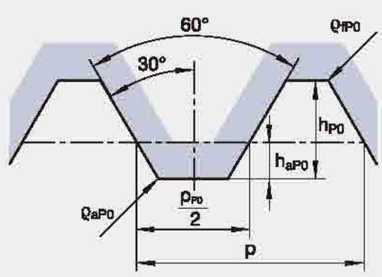
External spline profiles with involute flanks to DIN 5480 and special standards.

When ordering please quote:
Module, pressure angle, tip circle diameter, root circle diameter, diametral two-roll measurement, DIN standard of the external spline.

18



工件
Workpiece



滚刀基本齿廓
Basic cutter profile

$h_{aP0} = 0{,}60 \cdot m$
$h_{P0} = 1{,}25 \cdot m$
$\varrho_{aP0} = 0{,}16 \cdot m$
$\varrho_{fP0} = 0{,}10 \cdot m$

现代切削材料具有优越的机械加工和应用性能。
具体切削材料通常根据应用范围和切削参数来确定。通常制造的含钴合金高速钢当与粉沫冶金高速钢比较时，由于其低的耐磨损和热硬性将被很少使用。

粉沫冶金高速钢的制造方法增加了耐磨损性能的合金元素化合物改善韧性和提高了耐磨损性能。

“速切王”材料是粉沫冶金高速钢连续发展的成果，与粉沫冶金高速钢比较，“速切王”材料在高速切削使用时表现出了明显优异的更高的热硬度和更好的韧性。

常用术语采用粉沫法制造的硬质合金大多数的制作用碳化物和钴基体结合剂。今天市场上典型应用的切削材料在下面表中给出了性能参数。
普通含钴高速钢的切削温度在450℃左右，高钴含量高化合物含量的粉沫冶金高速钢切削温度增加大约到520℃附近。

将粉沫法和游离金属法相结合制作的速切王材料，在韧性与粉沫冶金高速钢相同时，切削温度可达到600℃左右，硬质合金能够达到切削温度在800℃～1000℃。
速切王材料和硬质合金均是高速切削的理想材料，都能干切和湿切。

Modern cutting materials are characterized by the combination of excellent machining and application properties.
Specific cutting materials are used depending on the application spectrum and the cutting parameters. Cobalt alloyed high speed steels (KHSS-E) manufactured in the conventional way are not used much now due to their low wear resistance and hot hardness, when compared to the materials of the powder metallurgical product family. With the power metallurgy method (PM), the percentage of carbides (wear resistance properties) can be increased while improving toughness.

The SpeedCore cutting material represents the continuous development of the PM-HSS cutting materials. Compared to PM-HSS materials, SpeedCore offers an excellent and markedly increased combination of higher hot hardness (= hardness during use) and a higher toughness which results in higher cutting values during use.

The generic term carbide includes materials that were manufactured with the powder-metallurgy method which are mostly made up from tungsten carbide (TC) and the matrix binder material cobalt (Co). A technological comparison between the cutting materials available in the market today is contained in the table below.

The operating temperatures of KHSS-E that has been manufactured in the conventional way are around 480 °C. By using the powder-metallurgy method, a higher cobalt content can be achieved, but also a higher percentage of carbide in the PM-HSS, so that the maximum operating temperatures increase to approx. 520 °C.

The combination of manufacturing with the powder-metallurgy method and the inter-metallic structural composition enables a much higher continuous operating temperature of approx. 600 °C for the SpeedCore cutting material, while maintaining the same toughness as PM-HSS cutting materials. Carbide also enables operating temperatures up to approx. 800–1000 °C.
These properties make SpeedCore and carbide the ideal materials for machining at high cutting speeds, both for wet and dry.

特性值 Characteristics	单位 Unit	 KHSS-E	 PM-HSS	 SpeedCore	 Hartmetall Carbide
23℃硬度 Hardness 23 °C	HV10	800–900	880–960	920–940	1500–1900
600℃硬度 Hardness 600 °C	HV10	400–450	450–540	590–630	1200–1500
密度 Density	g/cm^3	8–8,3	8,1–8,3	8,2	11–15
弹性模量 E-Module	kN/mm^2	210–217	225–241	224	500–660
导热导数 Thermal conductivity (up to 20 °C)	W/(m · °C)	19	17–19	32	30–100
热膨胀系数 Coefficient of thermal expansion	$m \cdot 10^{-6}/(m \cdot K)$	10–13	10–11	10–11	5–7

对齿轮滚刀涂层来说，PVD涂层是经常采用的方法，它是等离子体真空薄涂层的方法，高纯净材料通过电弧或阴极溅射转换成为等离子。通过反应气体，如氧气、氮气或碳的反应，陶瓷材料硬涂层被沉积到刀具上。

硬材料的物理涂层PVD通常由验证熔金属组成，如：铬、钛、钽、铝化合物、镁化合物和非金属（氧、氮、硼和碳）。今天涂层系列化被应用于齿轮切削是氮铝化钛（TiAlN）和氮铬化铝（Alcrn）。高性能的涂层经常采用多层涂层，高弹性和高耐磨性材料相隔涂覆。涂层工艺采用多轴旋转夹具使光滑和同质的涂层涂到刀具表面。

涂层温度在450° 范围之内。

如今，几乎100%的齿轮刀具都要涂层。

For the coating of gear hobs, the PVD (Physical Vapor Deposition) method is used. It is a plasma vacuum thin layer method, during which high-purity materials are transferred into a plasma via an arc or cathode sputtering. By reacting with reactive gases such as oxygen, nitrogen or carbon, ceramic hard material layers are deposited on the tools.

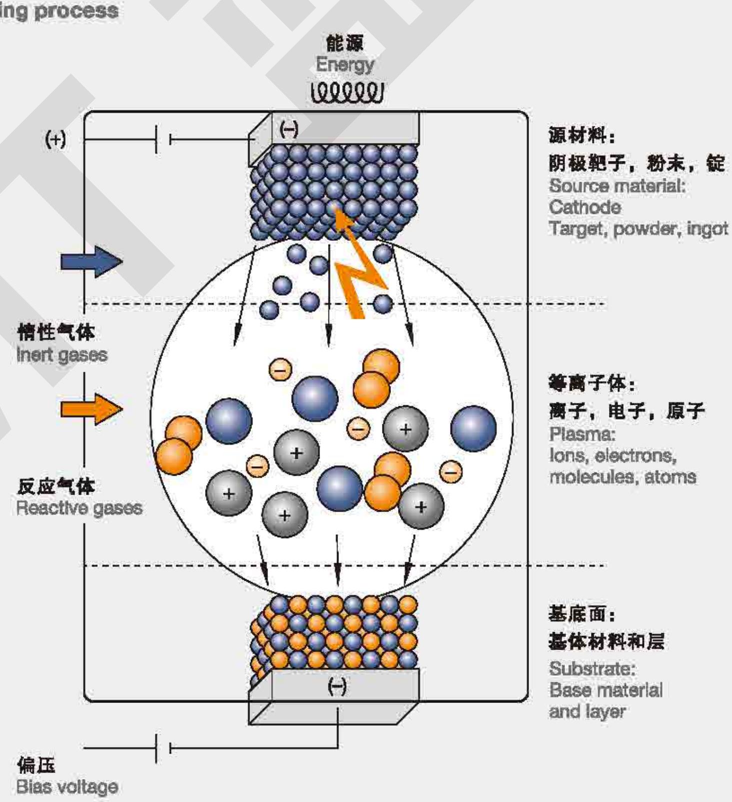
The generated hard material PVD layers normally consist of refractory metals such as chrome, titanium or tantalum, alloyed with aluminum, silicone and a non-metal (oxygen, nitrogen, boron and carbon). Layer systems which are used for gear cutting today are titanium-aluminum-nitrogen (TiAlN) or aluminum-chrome-nitrogen (AlCrN). The high-performance coatings used are made up of several layers which enables both a high elasticity and high wear resistance.

By rotating the tools along multiple axes during the coating process, an even and homogenous thickness of the layers is achieved on the tool surfaces.

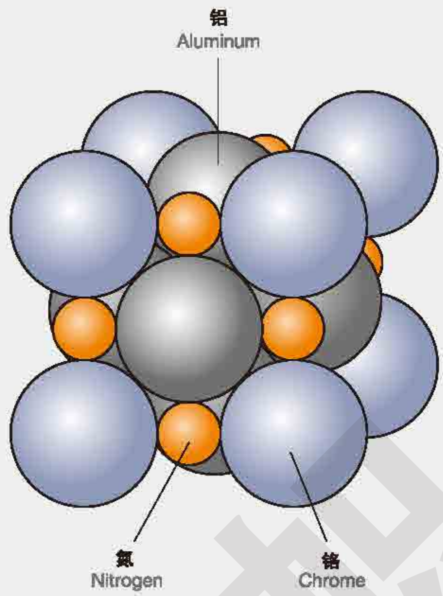
The coating temperatures are in the range of 450 °C. The high-precision coating process management enables the deposition of very thin coatings, to achieve a very sharp and defined cutting edge.

Today, nearly 100 % of gear cutting tools are coated.

PVD涂层工艺示意图
Schematic of the PVD coating process



AlCrN PVD 涂层的示意图
Schematic of the PVD layer system AlCrN



涂层–提高生产率，详见 www.lmt-tools.de, watched us on YouTube
Coatings – increased productivity guaranteed, see www.lmt-tools.de, watched us on YouTube

除了高硬度外、涂层处理的刀具使用寿命的显著增加主要在刀刃部分的物理摩擦和化学特性、低化学反应的涂层对于热钢屑这将导致材料的摩擦力较小，因而使其产生的摩擦热较少，从而减少了刀具的磨损量。

Apart from the high hardness, it is the friction-physical and chemical properties which lead to the extreme tool life increases of coated tools in comparison to uncoated tools. The low chemical affinity of the coating to the hot steel chip results in less friction and, consequently, less friction heat and, therefore, less wear.

涂层本身还保护了涂层下方基质材料免受磨损。

The coatings acts like a barrier that shields the substrate below against wear.

涂层刀具对于高切削速度和高进给的用户是十分有利的。一个主要原因在于刀具使用寿命的延长，另外降低了生产产品时间。因此，经过涂层处理的刀具通过缩短加工时间弥补了涂层处理所花费的费用。

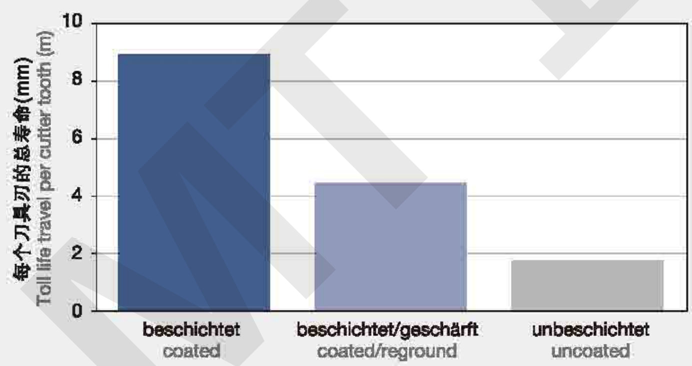
Of particular interest to the user are the greater cutting and feeding speeds that can be achieved with coated tools. However, the focus is not only on longer tool life, but also on the reduction of main manufacturing times. The payback period for the coating costs is, therefore, very low for coated gear hobs.

通过使用涂层材料，加工太阳轮所使用的高速钢材料的滚刀使用寿命从100个工件增加到502个，提高了5倍。经过再磨削后，刀具刀刃处没有涂层，此时只有刀具的侧面位置有涂层。在这种加工条件下刀具的使用寿命平均为251个工件。总共重复22次，无涂层的滚刀所加工的太阳轮总个数可达2300个，带涂层的滚刀加工数目可达6024个，大约是后者的2.6倍。因此，使用涂层的费用比较低，而且对该费用的补偿也比较容易。

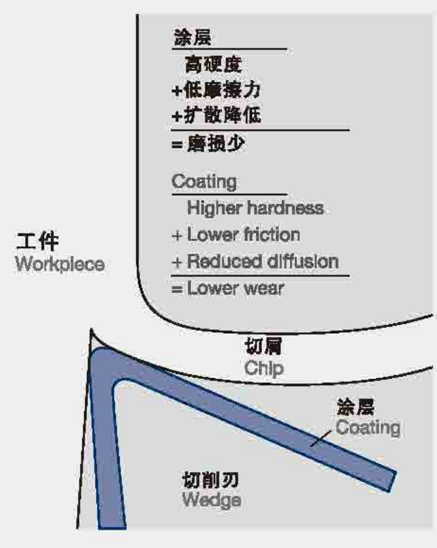
During the manufacture of a sun wheel the tool life of the HSS gear hob increased 5-fold from 100 to 502 gears by adding a coating. After regrinding, the tool was not re-coated and was, therefore, uncoated on the machining surface and coated on the flank only. In this condition, the tool achieved a tool life of an average of 251 manufactured wheels. During a total of 22 grinding cycles, a total of 2300 wheels were manufactured with the uncoated gear hob against a total of 6024 wheels with the uncoated gear hob, i.e. 2.6 times as many. The comparatively small additional cost of the coating therefore easily paid for itself.

对磨损的滚刀重磨后再涂层，花费一定的费用。

Re-coating after grinding the machine surface of the worn gear hob therefore makes sense with regard to costs.



工件 Workpiece:	太阳轮 Sun wheel	切削参数 Cutting data	
材料 Material:	17CrNiMo6	切削深度：Cutting depth:	6,808 mm
刀具 Tool:	高速钢滚刀 KHSS-E hob		
尺寸规格 Dimensions:	d 90 x 80 mm	切削速度：Cutting speed:	65 m/min
模数 Module:	3 mm		
头数：Number of starts:	1	轴向进给：Axial feed:	3 mm/WU
切屑槽数 Number of gashes:	12	顶刃切屑厚度：Tip chip thickness:	0,224 mm
质量等级 Quality grade:	AA	位移长度：Shift length:	54,3 mm



刀具切削刃在使用过程中会受到各种外部因素的影响，这些影响都将促成刀具的磨损。其中加工温度对磨损的影响最大。加工热量的主要来源以及对刀具整体温度的影响包括：

- 刀具切削刃位置的塑性变形：60%
- 切屑和刀具切削刃表面之间的摩擦现象：20%
- 加工工件和刀具后刀面之间的摩擦现象：20%

其中一部分热量（大约占总热量的5–10%）传递到刀具上，并使切削材料发生软化。加工温度越高，切削材料就会变得越软，因而对刀刃产生的耐磨性就越小。加工过程中大约75–80%的热量通过切屑散发掉了。

随着温度的不断上升，机构摩擦（氧化）比率和热扩散开始显著上升。随着温度迅速上升到某个指定温度后，刀具的使用寿命会急剧降低，以致最终超出其经济上的使用极限。

因此，每一种切削材料在进行不同的加工任务时都具有一个最佳的切削速度范围。被加工的材料，加工要求的公差值，特定的加工条件例如系统的刚性，冷却效率以及切削材料的热稳定性等都对确定该材料的切削速度范围有重要的影响。

The cutting edge of the tool that is being used is subject to external influences which, collectively, result in tool wear. The machine temperature plays a major part in this. The main machining process temperature sources and their approximate contribution to the total temperature are as follows:

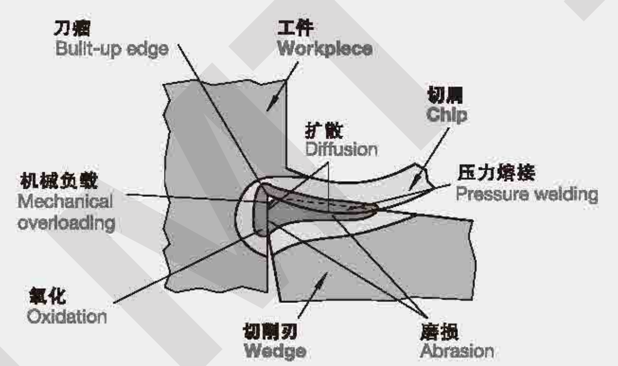
- Plastic deformation in the workpiece just before the cutting edge ... 60 %
- Friction effects between chip and tool machining surface ... 20 %
- Friction effects between workpiece and tool flank ... 20 %

A part of this heat (approx. 5–10 %) flows into the tool and leads to a softening of the cutting material. The higher the operating temperature, the softer the cutting material becomes and the less resistance it has against abrasive friction wear.

Approx. 70–80 % of the heat is dissipated via the chip. With high cutting values, in particular, which coincide with high machining temperatures there will be overlaps of the wear mechanisms of scaling (or oxidation) and diffusion. Their dramatic increase with rising temperatures defines a critical operating temperature limit above which tool lives decrease dramatically, even to the extent of being uneconomical.

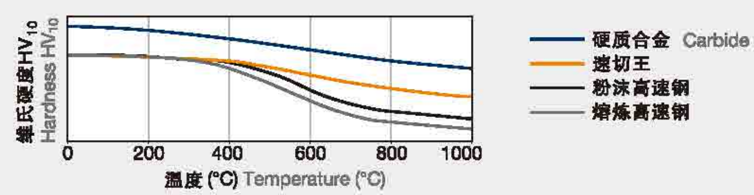
Depending on the application, there is a range of optimum speeds for each cutting material. The material to be machined, the required manufacturing tolerances, the machine conditions such as system rigidities, machining conditions, e. g. wet or dry machining and the high temperature strength of the material play an important part in this.

切削刃磨损原因
Causes of wear on the cutting edge



滚刀刀齿的磨损形式
Typical signs of wear on the cutting edge

熔炼高速钢，粉沫高速钢，速切王，硬质合金的红硬值
Hot hardness of KHSS-E, PM-HSS, SpeedCore and carbide



滚齿还有一个现象，即刀齿应力作用位置的剧烈振动现象。其原因在于切削刀具向着工件上待加工齿形位置旋转进刀过程中数个切削齿连续切削造成的。金属的切削量主要是由滚齿的齿顶刃实现的，它在切削过程中生成大量的较厚的金属碎屑和相应的热量。相比之下，滚刀齿面部分所产生的金属碎屑就薄得多；特定的结合条件也使刀具后角相对较小，因而该位置在切削时生成热量的部件的加工磨擦力也相对较大。与此同时，其产生的碎屑相对较薄，较小，而且吸热容量也比较低。于是会有更多的热量传递到刀具上。

Hobbing has the additional phenomenon of strong local variations in stress upon the cutter teeth. This is a consequence of the tooth profile to be manufactured on the workpiece arising only with successive cuts of a number of cutter teeth engaging in turn. The metal removal capacity is provided principally by the tooth tips, which generate relatively large-volume chips capable of sinking a corresponding quantity of heat. By contrast, much thinner chips are generated in the region of the tooth flanks of the hob; the particular engagement conditions mean that the effective relief angle is also relatively small there, and the cut is characterized by a comparatively high frictional component which generates heat. At the same time, relatively thin, low-volume chips with a low heat-sinking capacity are generated. Consequently, a correspondingly high quantity of energy flows into the tool.

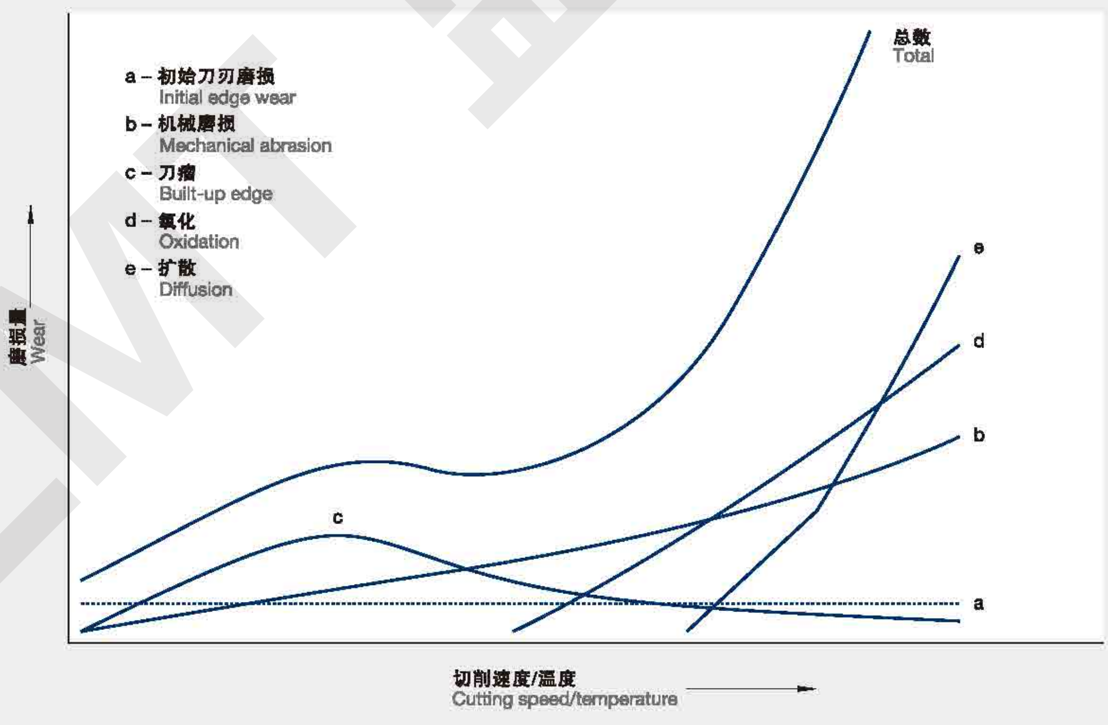
通过刀具移位来补偿刀具的局部磨损。刀具移位会使刀具的应力分布更均匀，以致分布到整个刀具和每个滚齿上。因热量产生磨损而产生的热量则会均匀分布到整个刀具上。

The resulting locally exaggerated wear is compensated for by shifting. Shifting produces a more even tool stress distribution, with regard both to the hob as a whole, and to the individual cutter tooth. Both the abrasive and the thermally generated wear mechanisms are distributed more evenly over the tool.

在刀具粗移位过程中，刀具区域暂时没有参与加工过程，因此有足够的时间进行冷却处理。

During coarse shifting, in particular, cutter regions temporarily uninvolved in the machining process have sufficient opportunity to cool down.

温度导致的磨损(根据Viergge)
Causes of wear against temperature (according to Vieregge)



滚削加工的切削条件主要包括切削速度和进给量。

“滚削加工的切削条件”章节中的切削速度和进给量必须视为推荐值。一般情况下用户应该根据这些建议的参数值指导其齿轮的加工。切削参数的优化目前只能在工作现场上获得，该参数的优化从各个相关方面对切削参数的选取加以考虑。

优化的目标可能有所不同。例如：

- 缩短加工时间；
- 提高刀具使用寿命；
- 降低刀具或齿轮的成本；
- 改善加工齿轮的质量。

只有综合考虑了加工工件，滚刀和滚齿机之间的相互作用关系才能正确选择合理的加工参数。

滚削加工过程中的切削参数主要受以下因素影响：

- 齿轮的材料：化学分析，热处理，拉伸强度，微观机构，可加工性能；
- 刀具的切削材料：速切王高速钢，硬质合金钢，化学分析，工作硬度，红硬性，涂层类型；
- 滚削设备的工况：稳定性，加工精度；
- 工件夹具：径跳动，轴向跳动，对变形和振动的预防能力；
- 滚刀的装夹：径跳动，轴向跳动，滚刀轴向轴承的最小可能间隙。
- 齿轮尺寸：模数，切深
- 刀具使用寿命和刀具质量寿命；
- 规定的齿轮质量

最后，决定切削条件的重要因素还包括对粗加工和精加工的不同要求。

对于粗加工，选择可能的最大进给量是为了获得最大的金属切除率。而对齿面的表面质量要求则是其次要求。

在精加工过程中，选择切削条件时必须保证齿轮的质量和表面加工精度。

当然，在选择不同的切削条件时还必须考虑到经济性方面。为了确定切削参数的最佳组合方案，计算刀具和设备的使用费用以及加工所需的时间是很有必要的。

The cutting conditions applicable to hobbing are principally the **cutting speeds** and the **feeds**.

The cutting speeds and feeds quoted in these “cutting conditions in hobbing” must be regarded as recommendations. The user will in normal cases be able to cut his gears properly with these recommended values. An optimization of the cutting values is only possible on the site, taking into account all the peripheral aspects.

The objectives of optimization may differ.
Examples:

- Short machining times
- High tool life quality
- Low tool or gear costs
- Improvement of the gear quality

A correct choice of cutting conditions is only possible if the interrelation of the workpiece, the hob and the hobbing machine is taken into account.

The cutting conditions in hobbing are mainly affected by:

- Gear material: chemical analysis, heat treatment, tensile strength, microstructure, machineability
- Cutting material of the cutter: SpeedCore, KHSS-E, carbide, chemical analysis, working hardness, red hardness, coating type
- Condition of the hobbing machine: stability, accuracy
- Workpiece clamping: radial runout, axial runout, avoidance of deformation and vibration
- Clamping of the hob: radial runout, axial runout, smallest possible hob spindle bearing clearance
- Gear size: module, cutting depth
- Tool life and tool life quality
- Requisite gear quality

Important for determining the cutting conditions are not least the varying demands made on the roughing and finishing operations.

For **roughing**, the highest possible feeds are selected in order for a high rate of metal removal to be attained. The surface quality of the flank which can be attained is of secondary importance.

The cutting conditions during **finishing** must be chosen so that the required gear quality and surface finish are achieved.

Attention must of course be paid to economic aspects during selection of the cutting conditions. It may be necessary to calculate the tool and machine costs and the machining times in order to ascertain the most favourable combination of cutting parameters.

滚刀使用的切削材料

齿轮滚刀采用KHSS（含钴高性能高速钢）和硬质合金制造。最常用的切削刀具材料是粉末冶金高速钢HSS-PM，它可以采用有或无冷却滚削。对无冷却滚削，滚刀必须涂层。

Speedcore材料制造的滚刀保持了高速钢材料的韧性，这种切削材料在高速切削时，可以实现与粉末高速钢HSS-PM类似的韧性，但硬质合金滚刀却不适合这种工艺。

使用整体硬质合金制造的滚刀可以加工模数达到3的齿轮，其切削速度可达到KHSS滚刀的三倍。这些滚刀一般也会使用涂层。

Cutting materials for gear hobs

Gear hobs are manufactured from both KHSS-E (cobalt alloyed high-performance high-speed steels) and carbides. The most commonly used cutting material is HSS-PM which is made with the power metallurgy method. It can be used both with and without cooling. For applications without cooling, the tool must be fully coated.

Gear hobs made from SpeedCore can be hardened more without losing toughness. This cutting material is used if higher cutting speeds need to be achieved when compared to HSS-PM, but carbides are not suitable due to the process.

If carbide gear hobs are used for the machining of gears up to approx. module 3 from the solid, the cutting speed is higher by a factor of 3 compared to gear hobs made from KHSS-E. These gear hobs are always coated.

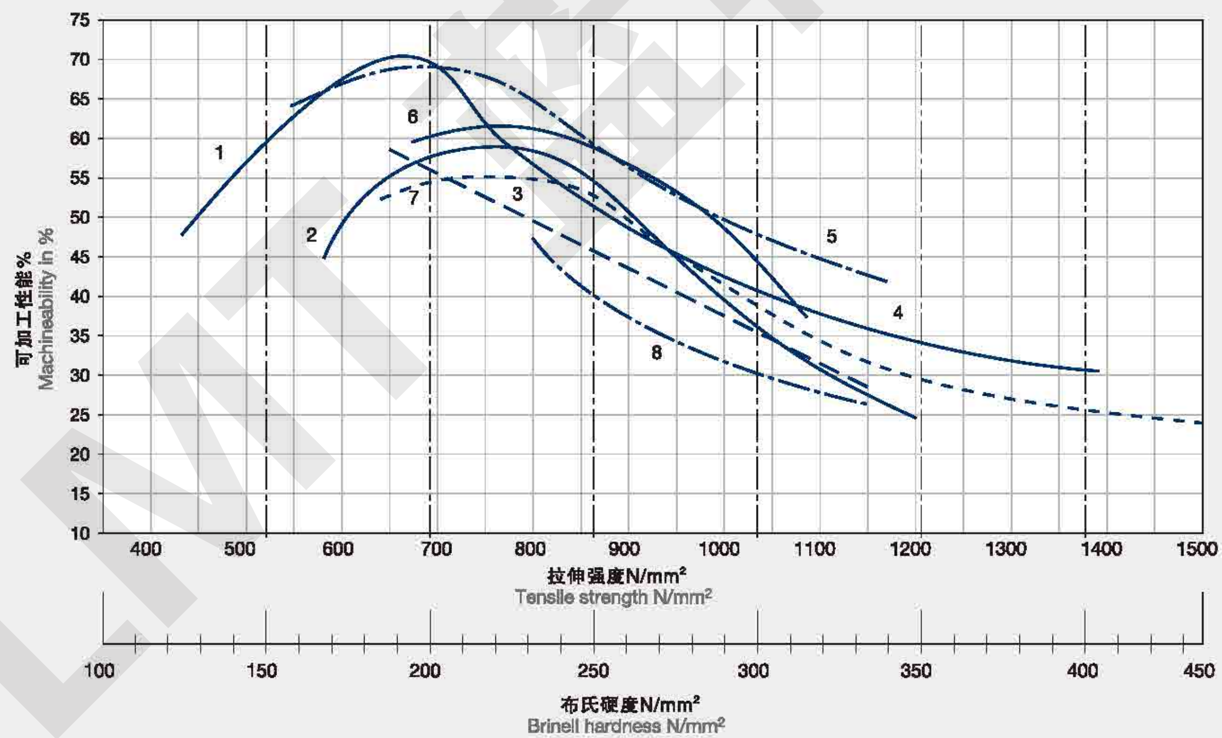
可加工性能

齿轮材料的可加工性能的参考

Machineability

The machineability of a gear material can be referenced to a range of characteristics.

1
齿轮材料的可加工性能
Machineability of the gear materials



1 普通碳钢
Plain carbon steels
2 镍合金钢和铬镍合金（低合金含量）
Nickel steels and chrome/nickel steels (low alloy)
3 铬镍合金钢
Chrome/nickel steels
4 铬镍钼合金钢
Chrome/nickel/molybdenum steels
5 镍钼合金钢
Nickel/molybdenum steels
6 铬钼合金钢
Chrome/molybdenum steels
7 铬合金钢和铬钒合金钢
Chromium steels and chrome/vanadium steels
8 硅锰合金钢
Silicon/manganese steels

一种材料是否便于加工主要取决于其是否能够采用高速切削还是低速切削，以及所能接受的刀具寿命以及磨损标记的宽度。

然而，可加工性也根据切削应力的要求，或加工所能获得的表面质量特性的难易程度进行评估。

在选择滚刀的切削速度时，必须首先确定刀具不能超过磨损标记的宽度(也可参见“滚刀的保养”，第160页)。磨损过大会导致刀具刀齿部位的切削边缘产生变形，从而导致切削应力增大。其结果便会导致加工出来的齿轮质量降低。由于磨损程度会以过大的比例增大，因此从某些经济角度考虑，必须减小磨损标记宽度。

与此同时，从某些经济角度考虑还必须确保刀具的连续磨削。刀具使用寿命过短会导致由于加工刀具的反复更换而使停工时间延长，从而增加再磨削的成本。这时，需要根据可获得合适的刀具寿命质量和磨损标记宽度时的切削速度来评估齿轮材料的可加工性能。齿轮材料的可加工性能作为其化学组成和抗拉强度Rm(单位N/mm2)或布氏硬度HB,的功能参数可以从图表1中查出（原图表如〔1〕，略作更改）。为完全满足该要求，AISI标准(美国钢铁学院)的B1112型钢的可加工性能参数在切削速度为55m/min时是100%；其他钢材等级也可根据该参数值进行分类。机械可加工性能按照百分比进行表示。

应该注意，可加工性能不仅受抗拉强度的影响，也会受到不同的微观结构的影响。相对可加工性能也会因其它切削速度范围的变化而变化，如小模数齿轮的切削速度是所显示的曲线参数中给定速度的两倍。但是对于带有涂层和不带涂层的滚刀，其可加工性能仍然需要分别进行评估，因为碎屑的形成区别很大。

切削速度V_c[m/min]
图表2(142页)表示了切削速度与模数和可加工性能的函数关系。该切削速度针对切削材料s-6-5-2-5[1.3243，EMoSCo5)有关，并适用于粗加工（采用整体式材料）。

精加工时（第二次），切削速度可以按照1.2的倍数增加。

带涂层的KHSS滚刀切削速度可以按照1.25的倍数加倍。

Whether a material can be machined easily or not is determined by whether it can be machined at high or low cutting speeds, and with an acceptable tool life quality and wear mark widths.

The machineability can however also be assessed according to the requisite cutting forces, or the ease or difficulty with which a favourable surface quality can be attained.

For the selection of the cutting speed for hobbing, it must first be assumed that a certain wear mark width must not be exceeded (see also "Maintenance of hobs", page 160). High wear leads to geometric deviations in the cutting edges of the cutter teeth, and to high cutting forces. The result is a reduction in gear quality. Since the wear increases superproportionately beyond a certain magnitude, the wear mark width must also be reduced for economic reasons.

At the same time, however, an economic tool life between successive cutter regrinds must be ensured. Excessively short tool life leads to long down times of the hobbing machine for the purpose of cutter changes, and to high regrinding costs. In this case, the machineability of the gear material is therefore assessed in relation to the cutting speed at an appropriate tool life quality and wear mark width. The machineability of the gear material as a function of its chemical composition and the tensile strength R_m in N/mm^2 or the Brinell Hardness HB can be taken from Diagram 1 (original diagram as [1], with minor modifications). The machineability of B1112 steel to AISI (American Iron and Steel Institute) was specified as 100 % at a cutting speed of 55 m/min for this purpose; all other steel grades were categorized relative to these values. The machineability is indicated in percent.

Note however that the machineability is influenced not only by the tensile strength, but also by the different microstructures. The relative machineability probably also varies for other cutting speed ranges, as gears with small modules are machined at cutting speeds which are around twice as high as those for which the curves shown were produced. It can however be safely assumed that the machineability must be assessed differently for coated and uncoated hobs, as the chip formation differs markedly.

Cutting speed v_c [m/min]
Diagram 2 (page 142) shows the cutting speed as a function of the module and the machineability. This cutting speed relates to the cutting material S-6-5-2-5 (1.3243, EMo5Co5), and applies to the roughing cut (machining from the solid).

For the finishing (second) cut, the cutting speed can be increased by a factor of 1.2.

The cutting speed can be multiplied by a factor of 1.25 for coated KHSS-E hobs.

我们给出了两个表推荐数据，采用粉沫高速钢制造的滚刀根据实践得到的切削速度。

一般的齿轮材料根据其可加工性能的高低分为“好”、“中”、“差”三类。切削速度按照每个齿轮加工模数和精加工和粗加工进行了分类。表1则根据刀具是否带有TiN涂层进行了细分。

使用整体硬质合金滚刀加工模数在3以内的齿轮可以使用或不使用冷却液如下：

齿轮材料：表面硬化或热处理钢材，抗拉强度可达800N/mm²。

切削速度：
带润滑冷却时：
220到250m/min；
不带润滑冷却时：
280到350m/min。

上述滚刀都有涂层处理

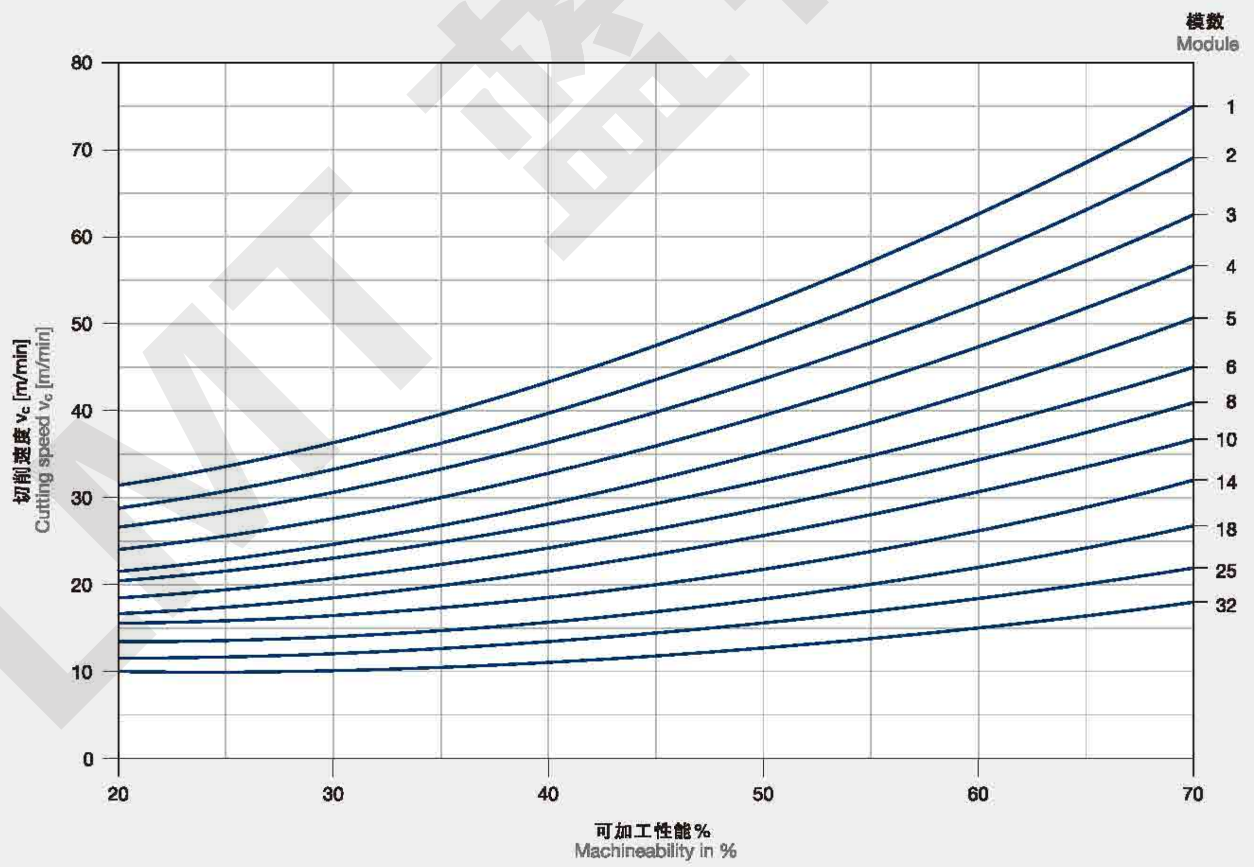
We gave compiled another two tables with reference values for cutting speeds during milling with gear hobs made from HSS-PM, based on practical experience. Commonly used gear materials are classified in the categories “good”, “medium” and “difficult” with regard to their machining properties. The cutting speeds are indicated in relation to the module for roughening cuts and for finishing cuts. The table is subdivided into milling with cooling and without cooling.

Carbide hobs for machining of gears up to approximately module 3 from the solid can be used with or without cooling lubricant as follows:
Gear material: case hardening and heat-treatable steels, tensile strength up to 800 N/mm²

Cutting speed:
220 to 250 m/min
with cooling lubricant;
280 to 350 m/min
without cooling lubricant.

These hobs are all coated.

2
滚削时的切削速度
Cutting speed when hobbing



m	粉沫pm4/14采用AL2Plus 涂层滚刀加工齿轮的推荐切削速度 Reference values for cutting speeds for gear hobbing Gear hob: Cutting material – PM4/14 with Al2Plus coating							
	机械性能 Machineability							
	好 Good		中 Medium				差 Difficult	
	R_m < 700 N/mm²		R_m < 900 N/mm²		R_m < 1000 N/mm²		R_m > 1000 N/mm²	
	16MnCr5, C15, C35 20MnCr5, 15CrNi6		17CrNiMo6, Ck45 C60V		42CrMo4 37MnSi5		30CrMoV9V, 34CrMo5V 40CrNiMo7, 56NiCrMoV7	
	粗加工 Roughing	精加工 Finishing	粗加工 Roughing	精加工 Finishing	粗加工 Roughing	精加工 Finishing	粗加工 Roughing	精加工 Finishing
	m/min							
带冷却 With cooling								
< 2	150	195	113	147	90	120	83	116
2	138	180	104	135	81	113	75	105
2,5	132	173	99	129	75	105	68	98
3	126	165	95	123	68	98	60	90
3,5	120	157	90	117	60	90	53	83
4	114	149	86	111	53	83	45	75
4,5	108	140	81	105	49	79	41	71
5	102	132	77	99	45	75	38	68
5,5	96	129	72	97	44	74	37	66
6	90	126	68	95	44	72	36	64
7	84	117	63	89	42	70	35	60
8	78	110	59	83	41	68	34	56
9	72	101	54	75	40	65	33	53
10	66	93	50	69	39	63	31	49
12	57	80	44	62	35	54	29	42
14	53	74	39	54	33	48	28	39
16	50	69	38	53	31	42	27	36
18	45	63	35	48	29	36	26	33
20	43	57	32	44	26	33	24	30
22	40	51	29	40	25	31	23	28
24	38	47	26	36	24	30	20	25
26	35	42	24	34	24	30	20	24
28	33	35	23	32	23	28	18	23
30	32	34	21	29	21	26	17	21
32	30	33	20	27	20	24	15	19
不带冷却 Without cooling								
< 2	185	241	139	181	111	148	102	142
2	170	222	128	167	100	139	93	130
2,5	163	213	122	159	93	130	83	120
3	155	204	117	152	83	120	74	111
3,5	148	193	111	144	74	111	65	102
4	141	183	105	137	65	102	56	93
4,5	133	173	100	130	60	97	51	88
5	126	163	94	122	56	93	46	83

轴向进给fa(mm/工件转数)

轴向进给可定义为工件每转一圈沿轴向前进的距离，单位mm。

由于在滚齿加工过程中有大量参数会对加工过程产生影响，通过经验可知，轴向进给的最好定义为与刀刃的切屑厚度的函数。

刀刃切屑厚度是滚刀滚齿刃理论上所能切削碎屑的最大厚度。

刀刃切屑厚度被视为滚刀应力的度量标准；切屑厚度越大表示切削应力越大，因而刀具寿命就越短。

随着模数、轴向进给量、切削深度和刀头数量的增加，刀刃切屑的厚度也会随之增加。而随着齿轮齿数、滚刀直径和切屑槽数量的增加，切屑的厚度则会相应减小。

Hoffmeister[1]设计了计算最大刀刃切屑厚度的公式。

通过对公式进行移项计算，可以计算出轴向进给和齿轮其他参数之间的函数关系。实践证明刀刃切屑厚度为0.2至0.25mm是比较实际的数值。

由于经济方面的原因，希望达到尽量高的轴向进给速度，因为可以按比例地增加进给量来缩短加工时间。

Axial feed f_a [mm/workpiece rotation]

The axial feed is specified in mm per workpiece rotation.

Owing to the large number of parameters which influence the machining process during hobbing, experience has shown that the axial feed is best specified as a function of the tip chip thickness.

The tip chip thickness is the theoretical maximum chip thickness removed by the tips of the hob teeth.

The tip chip thickness is regarded as a criterion for the hob stress; high tip chip thicknesses mean high cutting forces and short tool life.

The tip chip thicknesses are increased when the module, axial feed, cutting depth and number of starts are increased. The tip chip thicknesses are reduced when the number of gear teeth, hob diameter and number of gashes are increased.

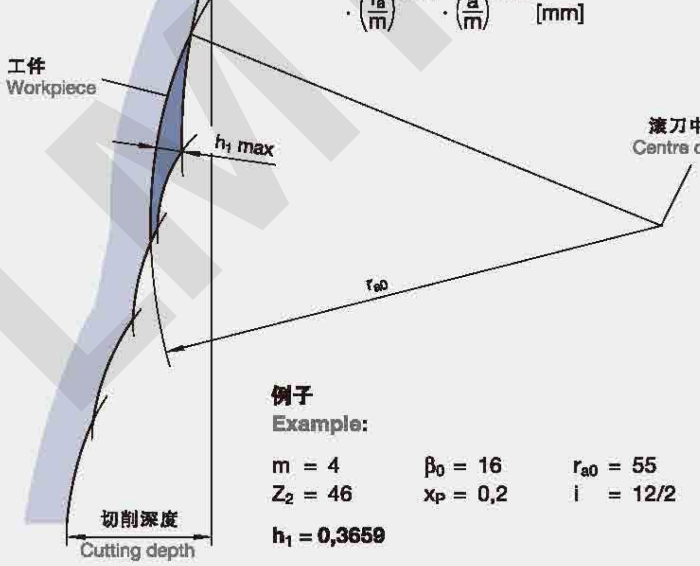
Hoffmeister [1] has devised a formula for the maximum tip chip thickness.

If this formula is transposed, the axial feed can be calculated as a function of the other gear parameters. Experience has shown a tip chip thickness of 0.2 to 0.25 mm to be a realistic value.

For economic reasons, as high an axial feed as possible is aimed for, as the machining time is reduced proportional to the increase in feed.

最大刀刃切屑厚度
Maximum tip chip thickness

$$h_1\,max = 4{,}9 \cdot m \cdot Z_2^{(9{,}25 \cdot 10^{-3} \cdot \beta_0 - 0{,}542)} \cdot e^{-0{,}015 \cdot \beta_0} \cdot e^{-0{,}015 \cdot x_P} \cdot \left(\frac{r_{a0}}{m}\right)^{(-8{,}25 \cdot 10^{-3} \cdot \beta_0 - 0{,}225)} \cdot i^{-0{,}877} \cdot \left(\frac{f_a}{m}\right)^{0{,}511} \cdot \left(\frac{a}{m}\right)^{0{,}319} \text{ [mm]}$$



m = 模数
Module

Z_2 = 齿数
Number of teeth

β_0 = 螺旋角(弧度单位)
Helix angle (radian)

x_P = 齿形移位因数
Profile displacement factor

r_{a0} = 滚刀半径
Half hob diameter

i = 切屑槽数量/刀头数量
Number of gashes/number of starts

f_a = 轴向进给量
Axial feed

a = 切削深度
Cutting depth

e = 2.718282

例子
Example:

$m = 4$	$\beta_0 = 16$	$r_{a0} = 55$	$f_a = 4$
$Z_2 = 46$	$x_P = 0{,}2$	$i = 12/2$	$a = 9$

$h_1 = 0{,}3659$

学术论著：BERND Hoffemister 1970
Dissertation by Bernd Hoffmeister 1970

需要注意的是，虽然进给切痕的深度会随着轴向进给量的平方比增加，一般会根据不同的加工步骤选择不同的最大进给痕迹深度，例如精铣加工，粗滚加工会在刮削加工之前完成，或者粗滚加工会在磨削加工之前进行，这取决于齿轮的质量或公差要求。

Note however that the depth of the feed markings increases quadratically with the axial feed, and that different maximum feed marking depths are permissible according to the machining step such as finish-milling, rough-hobbing prior to shaving, or rough-hobbing prior to grinding, depending upon the gear quality or the allowance.

如果要求使用整体硬质合金滚刀，那么刀刃最大切削碎屑的厚度应保持在0.12mm到0.20mm之间。硬质合金滚刀在不采用润滑液冷却加工时，加工过程中80%的热量必须通过碎屑进行散发。所以需要足够大的碎屑切削断面。由于这个原因，刀刃切削碎屑的厚度不得小于0.12mm。

If carbide hobs are employed for machining from the solid, the maximum tip chip thickness must be between 0.12 and 0.20 mm. For carbide hobbing without cooling lubricant, in particular, 80 % of the heat generated by the cutting process must be dissipated by the chips. Adequate chip cross-sections are therefore required. For this reason, the tip chip thickness should not be less than 0.12 mm.

滚刀头数

除蜗轮滚刀以外，多头滚刀可以提高滚刀的加工效率。

Number of starts of the hob

With the exception of worm gear hobs, multiple start hobs have the function of increasing hobbing performance.

我们都知道，当滚刀头数增加时，轴向进给量必须根据切削碎屑的厚度进行缩减（根据Hoffmeister方程计算刀刃切削碎屑厚度的最大值）。

It is known that the axial feed must be reduced for a given tip chip thickness when the number of starts is increased (formula for the maximum tip chip thickness according to Hoffmeister).

我们还知道，进给标记深度的大小取决于轴向进给量的大小（根据轴向进给标记深度的方程式计算）。

It is also known that the depth of the feed markings is dependent upon the axial feed (formula for the depth of the axial feed markings).

滚刀加工时间

Machining time (production time) for hobbing

$$t_h = \frac{Z_2 \cdot d_{a0} \cdot \pi \cdot (E + b + A)}{Z_0 \cdot f_a \cdot V_c \cdot 1000} \text{ [min]}$$

t_h [min] = 加工时间
Machining time

z_2 = 被加工齿轮的齿数
Number of teeth of the gear to be machined

d_{a0} [mm] = 滚刀齿顶圆直径
Tip circle diameter of the hob

E [mm] = 滚刀主长度
Approach length of the hob

b [mm] = 齿轮厚度
Tooth width of the gear to be machined

A [mm] = 滚刀空移位距离
Idle travel distance of the hob

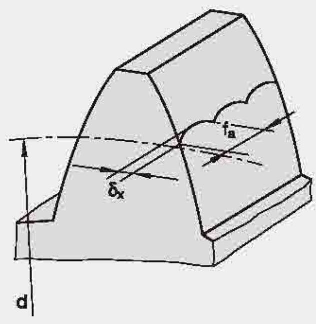
Z_0 = 滚刀刀头数量
Number of starts of the hob

f_a [mm/WU] = 轴向进给量
Axial feed

V_c [m/min] = 切削速度
Cutting speed

进给切痕深度

Depth on the feed markings



$$\delta_x \text{ [mm]} = \left(\frac{f_a}{\cos \beta_0}\right)^2 \cdot \frac{\sin \alpha_n}{4 \cdot d_{a0}}$$

δ_x [mm] = 进给切痕深度
Depth of the feed marking

f_a [mm/WU] = 轴向进给量
Axial feed

β_0 = 螺旋角
Helix angle

α_n = 齿形角
Profile angle

d_{a0} [mm] = 滚刀齿顶圆直径
Tip circle diameter of the hob

多头滚刀的进给量和进给标记深度 Feeds and depth of the feed markings for multiple start hobs							
列 Line/Column	1		2	3	4	5	6
1	模数	Module	2,5	2,5	2,5	2,5	2,5
2	压力角 [°]	Pressure angle [°]	20	20	20	20	20
3	齿数	Number of teeth	29	29	29	29	29
4	螺旋角 [°]	Helix angle [°]	15	15	15	15	15
5	齿形移位因素	Profile displacement factor	0,2	0,2	0,2	0,2	0,2
6	切削深度	Cutting depth	5,63	5,63	5,63	5,63	5,63
7	切削直径	Cutter diameter	110	110	110	110	110
8	切屑槽数量	Number of gashes	24	24	24	24	24
9	刀头数量 z_0	Number of starts z_0	1	2	3	4	5
10	刀刃切削碎屑厚度	Tip chip thickness	0,2	0,2	0,2	0,2	0,2
11	轴向进给量 f_a	Axial feed f_a	15,71	4,78	2,38	1,46	0,99
12	z_0 x f_a	z_0 x f_a	15,71	9,56	7,14	5,84	4,95
13	相对加工时间	Relative machining time	1	1,64	2,2	2,69	3,17
14	进给标记深度	Depth of the feed markings	0,206	0,019	0,005	0,002	0,001

因此刀头数量，刀刃切削碎屑厚度和轴向进给量有一定关系，同时轴向进给量和进给标记的深度之间也存在一定的关系。

There is therefore a relationship between the number of starts, the tip chip thickness and the axial feed, and between the axial feed and the depth of the feed markings.

方程式中加工时间、刀头数目和轴向进给构成了公式中的分母部分，例如当产品的刀头数量和轴向进给量增加时，加工时间就会减少。

In the formula for the machining time, the number of starts and the axial feed form part of the denominator, i.e. the greater the product of the number of starts and the axial feed, the shorter the machining time.

因此，选择产品的目标就是在不使刀刃切削碎屑厚度和进给量标记深度过大的情况下令其刀头数量和轴向进给量保持最大。

The objective is therefore to select a product of the number of starts and the axial feed which is as high as possible without the tip chip thickness and the depth of the feed markings becoming too great.

根据刀刃切削碎屑厚度和进给标记深度确定刀头数量的详细说明

Specification of the number of starts on the basis of the tip chip thickness and the depth of the feed markings

表中以一个齿轮为例列出了刀头数量和轴向进给量的优化值。

The table shows the optimization of the number of starts and the axial feed by way of an example gear.

刀头数量为1–5的刀刃切削碎屑厚度恒定为0.2mm，分别位于第2到6列。

The number of starts 1 to 5 and a constant tip chip thickness of 0.2 mm were entered in columns 2 to 6.

第11行包含刀刃切削厚度为0.2mm时的允许最大进给量。

Line 11 contains the maximum feeds permissible at a tip chip thickness of 0.2 mm.

第12行显示的是产品的刀头数量和轴向进给量。

Line 12 shows the product of the number of starts and the axial feed.

第2列的相对加工时间等于1，其他列的加工时间根据第二列进行计算。

The relative machining time in column 2 is made equal to 1 and the machining times in the following columns calculated in relation to column 2.

第13行清晰列出了给定的刀刃切削碎屑厚度，单头滚刀可以获得最短加工时间。第14行显示出进给标记深度过大，为0.206mm。

Line 13 shows clearly that for a given tip chip thickness, the shortest machining time can be achieved with the single-start hob. Line 14 also shows however that the depth of the feed markings becomes excessive, at 0.206 mm.

对于双头滚刀，其进给量必须减少到单头滚刀的约30%。刀头数量从某种程度上对进给量进行了弥补，如表中的工作台速度是相同切削速度下的两倍。虽然进给标记深度只有0.019mm，但是4.78mm的轴向进给量无论对于刮削或磨削加工前的粗滚加工都还是可以接受的。

With the two-start hob, the feed must be reduced to approximately 30 % of that of the single-start hob. This is however compensated for to some degree by the number of starts, as the table speed is doubled for the same cutting speed. Since the depth of the feed markings is only 0.019 mm, however, the axial feed of 4.78 mm is acceptable, either for rough-hobbing prior to shaving or grinding.

因此，如果假定齿轮在刮削或磨削加工之前进行粗滚加工，那么使用双刀头滚刀，进给量为9.56mm进行加工是最经济的解决方法。

If it is therefore assumed that the gear is being rough-hobbed prior to shaving or grinding, the two-start hob, with a product of feed and number of starts of 9.56, represents the most economic solution.

单刀头滚刀不是可选方案，因为受到进给标记深度和头数的限制，它的允许最大进给量只有4.78mm，而其轴向进给量也只有4.78mm。

The single-start hob is not an option, as it permits a maximum feed of only 4.78 mm even with the single-start hob owing to the depth of the feed markings, and the product of the number of starts and the axial feed would only be 4.78.

三头滚刀也不适用于该加工情况，受到最大刀刃切削碎屑厚度的限制，刀头的轴向进给量只有7.14。

The three-start hob is also unsuitable in this case, as the product of the number of starts and the axial feed is only 7.14, owing to the maximum tip chip thickness.

因此，计算有关刀头的数量必须首先计算允许进给标记深度，然后再计算最大轴向进给量。在选择刀头数量时，应保证该刀头在不超过进给标记深度要求或最大刀刃切削碎屑厚度的前提下，使刀头数量能够最多，并产生最大的轴向进给量(第11行)。

Specification of the number of starts should therefore first entail calculation of the maximum axial feed for the permissible depth of the feed markings. A hob should then be selected with the number of starts which produces the greatest product of number of starts and axial feed without the maximum axial feed being exceeded owing to the depth of the feed markings or the maximum tip chip thickness (line 11).

包络切削误差

尽管多刀头滚削加工具有很多经济方面的优点，但我们仍然不能忽略它在加工精度方面的情况。根据上述描述的情况进行选择时，是否选用多头滚刀还需要根据具体加工情况而定。

Enveloping cut deviations (page 148)

Despite the economic advantages offered by multiple start hobs, the accuracy of the gear must not be ignored. Whether multiple start hobs selected as described above can in fact be used must therefore be considered on a case-by-case basis.

形成齿面的滚刀齿数的多少取决于齿轮的齿数和压力角大小和滚刀的切屑槽数、齿距和头数。

The number of cutter teeth which profile a tooth flank depends upon the number of teeth and the pressure angle of the gear, and the number of gashes, pitch and number of starts of the hob.

如果切屑槽数保持不变，形成齿形的滚刀齿数，如双刀头或三刀头滚刀，会减半或减少至三分之一。此时生成的包络网的密度会有所降低，而包络切削误差会随着齿形所生成的轮廓偏差而增加。当齿轮的齿数较少时，对包络切削误差的计算和检查尤其重要，此时包络切削误差会增加，因为轮廓曲线的曲率很大，每个滚齿切削的工件也会有相当大的扭曲度。

Provided the number of gashes remains unchanged, the number of cutter teeth forming the profile for example on two- or three-start hobs is reduced to half or one-third. The envelope network which is generated is less dense, and the enveloping cut deviations arise in the form of deviations in the profile form. Calculation and examination of the enveloping cut deviations is particularly important when the number of gear teeth is low, as particularly large enveloping cut deviations arise in this case owing to the strong curvature of the profile and the relatively large torsional angle of the workpiece per cutter tooth.

我们可以通过增加切屑槽数来显著地减少包络切削误差。

The enveloping cut deviations can be reduced considerably by increasing the number of gashes.

刀具刀头的数量对齿面形状和齿轮齿距的影响

为了形成齿轮齿面的包络网，对于典型的滚齿加工而言，必须考虑到每个滚齿齿面只能形成一次包络切削，而且包络切削之间的相对位置取决于刀齿面的精度以及滚齿加工设备的分度精度。

单头滚刀对齿轮的分度精度没有影响，因为工件所有的齿都是由一把相同的滚刀切削齿加工完成的。单刀头滚刀的加工误差只会影响加工齿轮的齿面形状。

与单刀头滚刀相比，如果齿轮的齿数按照滚刀刀头数量进行划分的话，多头滚刀对齿轮的分度精度有一定的影响。在这种情况下，齿槽的形状是通过一个滚刀头数加工完成的。这时，刀具齿面齿距的偏差会导致加工工件的齿距产生周期性偏差。由于这种偏差只能通过再次加工进行部分消除（例如剃削），因此应选择具有一定剃削余量的多头滚刀进行加工，此时齿数和刀头数量之比不能是整数。

表面结构

然而，我们仍然应该确定精加工时切屑槽数和刀头的数量之比不是整数。否则所加工的包络切削从刀头到刀头之间的高度会不相同，而且加工好的齿面还会形成蜂窝状结构。

Influence of the number of cutter starts upon the flank form and pitch of the gear

For generation of the gear flanks as an envelope network, as is typical for hobbing, it must also be considered that each cutter tooth flank only generates one enveloping cut, and also that the relative location of the enveloping cuts to each other is dependent upon the accuracy of the cutter lead and the indexing precision of the hobbing machine.

Single-start hobs have no influence upon the indexing precision of the gear, since the same cutter teeth always machine all teeth of the workpiece. Deviations in lead on single-start hobs only influence the flank form of the machined gear.

By contrast, multiple start hobs also have an effect upon the indexing precision of the gear if the number of gear teeth is divisible by the number of starts of the cutter. In this case, the profile of a tooth gap is machined only by the teeth of one cutter start. Under these circumstances, the deviations in pitch of the cutter leads produce periodic deviations in pitch on the workpiece. Since the deviations in pitch can only be eliminated in part for example by shaving, multiple start roughing hobs with a shaving allowance should preferably be selected for which the quotient of the number of gear teeth and the number of cutter leads is not an integer.

Surface structure

However, it should also be ensured that the quotient of the number of gashes and the number of leads during finishing is not an integer. The enveloping cuts will otherwise be generated at different heights from lead to lead, and the tooth flanks will acquire a honeycombed surface structure.

包络切削偏差
Enveloping cut deviations

$$\delta y\ [mm] = \frac{\pi^2 \cdot z_0^2 \cdot m_n \cdot \sin \alpha_n}{4 \cdot z_2 \cdot i^2}$$

δy [mm] = 包络切削误差量
Envelop cut deviation

z_0 = 刀头数量
Number of starts of the hob

m_n = 法向模数
Normal module

α_n = 齿形角
Profile angle

z_2 = 齿数
Number of teeth on the gear

i = 刀具切屑槽数
Number of gashes of the hob

带轴向平行切屑槽的滚刀刀头在数量上的限制

对于带有轴向平行切屑槽的滚刀，应确保随着刀头数量的增加不会导致螺旋倾角超过7.5度，否则由于刀具出口刀刃面的楔入角度过大，齿轮相关的表面质量会下降。

参考:

[1]1970 B.Hoffmeister:学位论文，Aachen

Limitation of the number of leads on the hobs with axially parallel gashes

On hobs with axially parallel gashes, ensure that the increase in the number of leads does not result in a helix angle of 7.5° being exceeded. The surface quality on the corresponding gear flank will otherwise be impaired owing to the excessive wedge angle on the leaving cutter flank.

References

[1] B. Hoffmeister: Dissertation, Aachen 1970

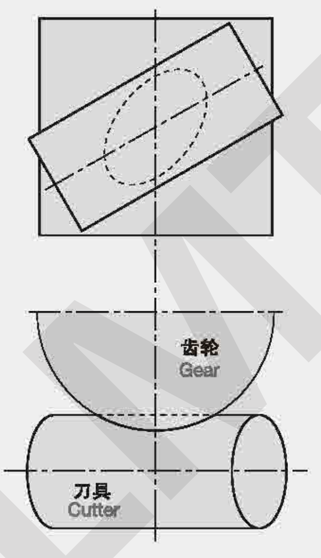
在加工过程中必须对预切割区域与轮廓生成区域加以严格的区分。加工过程中切削体积较大的部分是预切割区域。预切割区域位于滚刀的末尾处，滚刀在沿轴线方向加工时从该位置切入齿轮毛坯。在滚刀完成整个预切割区域之前，必须对滚刀加以定位。刀具长度（即所要求的最小值）是指刀具切削刃的长度。

图1中的齿轮和刀具顶部圆柱体的贯穿曲线是用于计算刀具切削刃长度。根据以下考虑内容，假定加工齿轮为斜齿轮，切削轴线与水平面成绕轴旋转的夹角（$\beta - \gamma_0$）。另外假定螺旋角的值已知，那么该值一定大于滚刀的倾角。贯穿曲线的观察方向是沿着主加工设备向着刀具和齿轮观察的方向。两个圆柱相互重合，它们的贯穿深度等于刀具的切削深度。二者的交叉曲线是一个三维曲线，这个曲线既位于齿轮上，也位于切削圆柱体上。在贯穿曲线下方的参考位置，交叉线的投影线落在平行于刀具轴线的平面上。

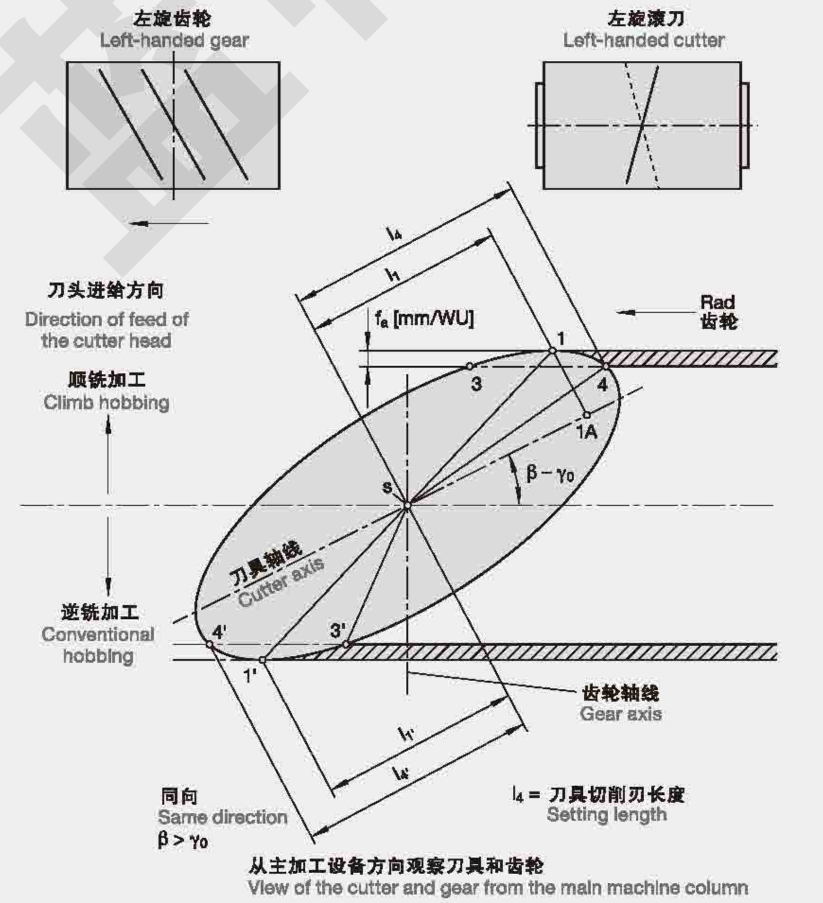
A distinction must be drawn in hobbing between the pre-cutting zone and the profile generating zone. The greater part of the volume to be machined is removed in the pre-cutting zone. The pre-cutting zone is at the end of the hob which first enters the body of the gear during axial machining. The hob must be positioned until it completely covers the pre-cutting zone. This cutter length, the minimum required, is termed the tool cutting edge length.

The penetration curve (fig. 1) of the tip cylinder of the gear and the cutter must be known for calculation of the setting length. For the considerations below, it is assumed that the gear is helical and that the cutting axis is inclined to the horizontal by the pivoting angle ($\beta - \gamma_0$). A further assumption is that where a helix angle is present, it is always greater than the lead angle. **The direction of view of the penetration curve is from the main machine column in the direction of the cutter and the gear.** The two tip cylinders penetrate each other at a depth equivalent to the cutting depth. The intersecting line between the two bodies is a 3-dimensional curve which follows both on the gear and the cutter cylinder. Where reference is made below to the penetration curve, the projection of the intersecting line into a plane axially parallel to the cutter axis is understood.

1
齿轮/刀具的贯穿示意图
Gear/cutter penetration



2
贯穿曲线位置的刀具切削刃确认图
Ascertainment of the setting length from the penetration curve



贯穿曲线的尺寸和形状取决于：

- 齿轮齿顶圆的直径；
- 刀具直径；
- 绕轴线旋转的角度(齿轮的螺旋角 β 刀具的进刀角度γ_0)。
- 切削深度。

贯穿曲线的计算公式可以参见第188页图13的“滚刀的磨损现象”章节的内容。

所有在旋转过程中不穿过贯穿曲线的刀具切削齿不会接触到齿轮。因此就不会形成加工碎屑。关于水平方向穿过齿轮轴“S”和刀具轴的部分，点1为贯穿曲线的最高点，而点1’为贯穿曲线的最低点。

斜齿

顺铣加工，与螺旋角方向相同

顺铣加工过程中，当刀具从齿轮的较高的平面位置移向较低的平面位置时，经过点1位置的刀齿首先与齿轮的齿顶圆柱相交叉。然后刀具的刀齿固定在刀具轴线右倾角所在的平面上，即点1和点1A所在的位置。该点到“S”点的直线正好与刀具的轴线平行，其距离等于点“S”和1A之间的距离。相当于点1与经过轴线“S”的截面之间的刀具长度：

齿轮旋转一周后，刀具沿轴线进给方向向上移动。长度为“fa”的平行线沿水平方向经过点1，并与贯穿曲线相交于点3和点4。穿过点1和点4的平行线形成的阴影区域对应齿轮的毛坯材料部分，该部分将继续向刀具的加工区域推进。贯穿曲线上的点4相当于被切除的材料，并位于轴线交叉点“S”的最远端。所有经过贯穿曲线并远离点“S”的刀具切齿不参与材料的切削加工过程。点4在图2中标记为l_4。这就是使用顺铣加工方法加工斜齿轮时刀具的切削刃长度，它与齿轮进刀方向相同。

由于通常刀具会向着切入侧进行移位操作，入口侧定位在加工工艺的起始位置，它是根据上述说明的方法计算出来的刀刃长度来确定的。如果选择的刀具切削刃长度比较短，那么滚刀在入口区域就无切削齿，接下来的加工齿将承担那些缺齿的功能切除材料。这就会导致第一个进入该加工区域的滚齿产生加工应力过大。如果选择的刀具切削刃过长，那么所使用的刀具就不够经济适用，即刀具前段的刀刃部分无法参与加工并使用。

The form and dimension of the penetration curve are dependent upon:

- The tip circle diameter of the gear
- The cutter diameter
- The pivoting angle
  (helix angle β of the gear, lead angle γ_0 of the cutter)
- The cutting depth

The formulae for calculation of the penetration curve can be found in the Chapter "Wear phenomena in hobbing", page 188, fig. 13).

All cutter teeth which do not pass through the penetration curve (fig. 2) during rotation of the cutter do not make contact with the gear body. They are not therefore involved in chip formation. With respect to the horizontal which passes through the intersection "S" of the gear axis and the cutter axis, Point 1 is the highest and Point 1' the lowest point of the penetration curve.

Helical teeth

Climb hobbing, same lead direction

When the cutter moves from upwards to the lower face of the gear during climb hobbing, the cutter tooth whose path passes through Point 1 is the first to intersect the tip cylinder of the gear. This cutter tooth is then located in a plane at right-angles to the cutter axis, in which Points 1 and 1A are located. The distance to the point "S", measured parallel to the cutter axis, is equal to the path of which "S" and 1A are the end points. It is equivalent to the cutter length for the Point 1 in relation to the section through the axis "S".

Following one rotation of the gear, the cutter has moved upwards by the axial feed. A parallel at a distance "f_a" to the horizontal through Point 1 intersects the penetration curve at Points 3 and 4. The hatched band between the parallels through Points 1 and 4 corresponds to the band of material which is pushed continuously into the working area of the cutter during the machining process. Point 4 is the point on the penetration curve which is still involved in material removal and is located furthest from the axis intersection "S". All cutter teeth whose paths run through the penetration curve but which are located further away from the Point "S" are not involved in the material removal process. The cutter length corresponding to Point 4 is marked "l_4" in fig. 2. This is the tool cutting edge length of the cutter during climb hobbing of a helical-tooth gear with a cutter which has the same direction of lead as the gear.

Since the cutter is generally shifted towards the cutter entering side, the entering side is positioned at the start of the machining process according to the tool cutting edge length calculated as described above. If a shorter tool cutting edge length were to be selected for the cutter teeth would be absent in the entering zone, and the following teeth would have to assume part of the missing teeth's function of material removal. This could lead to overloading of the first teeth in the entering zone. Were an excessively long tool cutting edge length to be selected, the cutter would not be economically viable, as the teeth ahead of the tool cutting edge length would not be used.

顺铣加工，与进刀方向相反

如果使用右旋方向的刀具(与进刀方向相反)替代左旋方向的刀具，那么刀具的切削刃偏角（$\beta + \gamma_0$）会发生改变，齿轮将从左向右进入刀具的加工区域（贯穿曲线）。切除材料的最外端点为点1。

然后点1处的刀具切削刃长度等于刀具的切削刃长度。在使用反进刀方向的刀具进行顺铣加工时，刀具切削刃长度略短于相同进刀方向的刀刃长度。这并不是由进给量的大小确定的。

逆铣加工，与进刀方向相同

如果刀具向下移动到齿轮上表面，经过点1位置的切削齿首先与齿轮毛坯的外圆柱面相交，刀具的切削刃长度等于长度l_1。

两个半贯穿曲线自左至右沿着刀具轴线的法线方向经过点“S”是比较合理的，反向经过点S绕法线和刀具轴线一周，$l_1 = l_1$，$l_4 = l_4$。

组合滚削方式和齿轮与滚刀的进刀方向

表1显示了采用不同滚齿组合加工方法和齿轮与滚刀进刀方向下的进刀末端，绕轴旋转角度以及刀具的切削刃长度。“前端左旋”的意思是指从左自右经过贯穿曲线。”前端左侧l_4上”意思是指刀具切削刃在贯穿曲线上的的长度为l_4。该位置位于齿轮轴的左侧。刀刃切削长度所在的刀面朝上。

再次假设：

观察方向沿主加工设备到刀具和齿轮的方向。对于斜齿轮，螺旋倾角大于刀具的进刀角度。

Climb hobbing, opposite lead direction

If a right-hand (opposite lead direction) cutter is employed in place of the left-handed cutter, the tool cutting edge angle ($\beta + \gamma_0$) changes and the gear runs from left to right into the working area of the cutter (penetration curve). The outmost point involved in material removal is Point 1, page 150.

The cutter length corresponding to Point 1 is then the setting length. The tool cutting edge length is shorter in climb hobbing with a cutter with opposite lead direction than with a cutter with the same lead direction. It is not affected by the magnitude of the feed.

Conventional hobbing, same lead direction

If the cutter moves downwards onto the upper face of the gear, the cutter tooth whose path passes through the point 1 is the first to intersect the tip cylinder of the gear, and the tool cutting edge length is equal to the length l_1.

Since the two halves of the penetration curve to the left and right of the normals on the cutter axis through the point “S” are congruent and are inverted around the normal by “S” and around the cutter axis, $l_1 = l_1$ und $l_4 = l_4$.

Further combinations of hobbing method and direction of lead of gear and hob

The table shows the leading end, pivoting angle and tool cutting edge length for different combinations of hobbing method and direction of lead of gear and hob. “Leading end left” means that the gear runs from left to right into the penetration curve. “Leading end left l_4 up” means that the setting length is equal to the dimension l_4 in the penetration curve. It is located on the left-hand side in relation to the gear axis. The cutter side on which the tool cutting edge length is located is facing upwards.

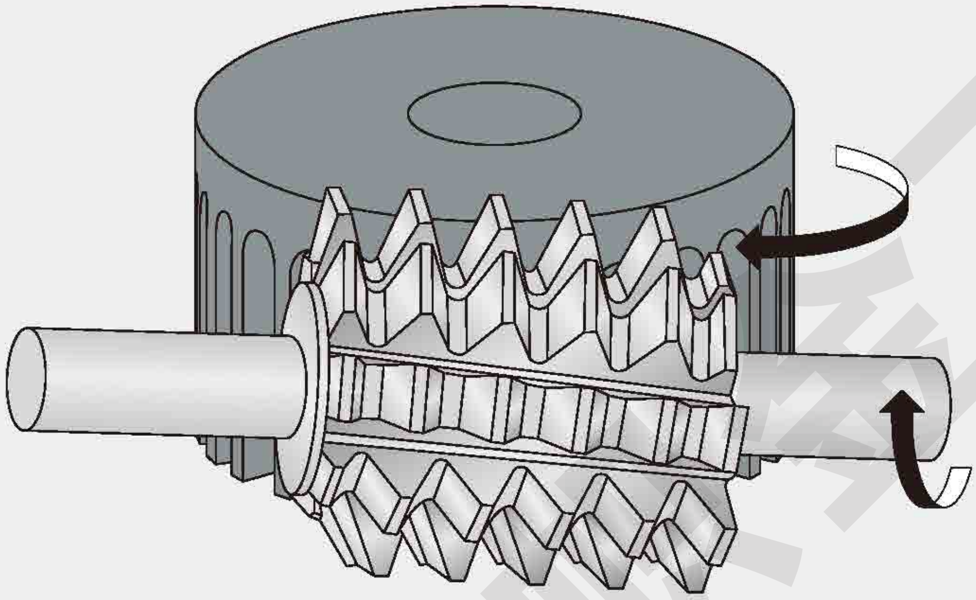
Again the assumptions are:

Direction of view from the main machine column towards the cutter and the gear. On a helical gear, the helix angle is greater than the lead angle of the cutter.

齿轮 Gear		刀具：右旋 Cutter: right-hand start			刀具：左旋 Cutter: left-hand start		
		右侧进刀 right-hand lead	左侧进刀 left-hand lead	直齿 straight teeth	右侧进刀 right-hand lead	左侧进刀 left-hand lead	直齿 straight teeth
顺铣 Climb hobbing	进刀末端 Leading end	左 left			右 right		
	绕轴角度 Pivoting angle	$\beta - \gamma_0$		γ_0	$\beta - \gamma_0$		γ_0
	切削刃长度 Tool cutting edge length	l_4 左，上 left, up	l_1 右，上 right, up	l_1 右，上 right, up	l_1 左，上 left, up	l_4 右，上 right, up	l_1 右，上 left, up
逆铣 Conventional hobbing	进刀末端 Leading end	左 left			右 right		
	绕轴角度 Pivoting angle	$\beta - \gamma_0$		γ_0	$\beta - \gamma_0$		γ_0
	切削刃长度 Tool cutting edge length	l_1 右，下 right, down	l_4 左，下 left, down	l_4 左，下 left, down	l_4 右，下 right, down	l_1 左，下 left, down	l_4 左，下 right, down

从设备主轴位置看刀具和齿轮

View of the cutter and the gear from the main machine column



滚削轮廓啮合长度

齿轮成型大部分位于轮廓形成区域，该区域以齿距位置形成对称结构。在齿轮面内计算的轮廓形成区域用l_{Pa}和l_{pf}表示。

在滚齿过程中，在啮合线上形成齿廓（图3）。轮廓形成发生的区域是由齿轮齿顶圆啮合线的交叉和一根直线连接齿顶半径过渡点到滚刀基本轮廓所在的齿面（齿顶高）决定的。

啮合线末端之间较大的间距，或者滚刀齿顶l_{pa}位置或齿根l_{pf}位置的中较大的间距被称为确定长度。位于滚刀基本齿廓的齿顶区域或齿根区域啮合线的末端是否具有决定性意义取决于齿轮的轮廓移位情况。参看图4和图5：图4表示带正轮廓移位，图5表示带负轮廓移位的情况。

l_{Pa}或l_{pf}两个参数值从滚刀刀面转换到滚刀轴线平面，其中数值较大的一个称为"轮廓形成长度l_{p0}。"

Profile generating length for hobbing

Profiling of the gear takes place exclusively in the profile generating zone, which is arranged symmetrical to the pitch point. The profile generating zone is calculated in the face plane of the gear and is represented there by l_{Pa} and l_{Pf}.

Profile generation takes place during hobbing on the engagement lines (fig. 3). The area in which generation takes place is limited by the intersections of the engagement lines with the tip circle diameter of the gear and by a line connecting the transition points from the tip radii to the flank of the basic hob profile (tip form height).

The greater interval between the end points of the engagement lines, either in the tip region (l_{Pa}) or the root region (l_{Pf}) of the hob profile, is regarded as the definitive length. Whether the end points of the engagement lines in the tip region or in the root region of the basic hob profile are decisive is dependent upon the profile displacement of the gear. Refer here to figs. 4 and 5: fig. 4 represents a gear with positive and fig. 5 a gear with negative profile displacement.

The greater of the two values – l_{Pa} or l_{Pf} – is then converted from the face plane to the axial plane of the hob and termed the "profile generating length l_{P0}".

$\tan \alpha_t = \tan \alpha / \cos \beta$
$l_{Pa} = 2 \cdot (h_{a0} - x \cdot m_n - \varrho_{a0} \cdot (1 - \sin \alpha)) / \tan \alpha_t$
$d_b = z \cdot m_n \cdot \cos \alpha_{at} / \cos \beta$
$\cos \alpha_{at} = d_b / d_a$
$d = z \cdot m_n / \cos \beta$
$l_{Pf} = 2 \cdot (d_a/2 \cdot \cos(\alpha_{at} - \alpha_t) - d/2) / \tan \alpha_t$

如果
$l_{Pa} > l_{Pf}$，那么 $l_{P0} = l_{Pa} \cdot \cos \gamma_0 / \cos \beta$

如果
$l_{Pf} > l_{Pa}$，那么 $l_{P0} = l_{Pf} \cdot \cos \gamma_0 / \cos \beta$

h_{a0} = 滚刀齿顶高
$x \cdot m_n$ = 轮廓移位
ϱ_{a0} = 滚刀齿顶圆弧半径
α = 压力角
β = 螺旋角
z = 齿数
m_n = 法面模数
d_a = 齿轮齿顶圆直径
γ_0 = 滚刀刀刃倾角

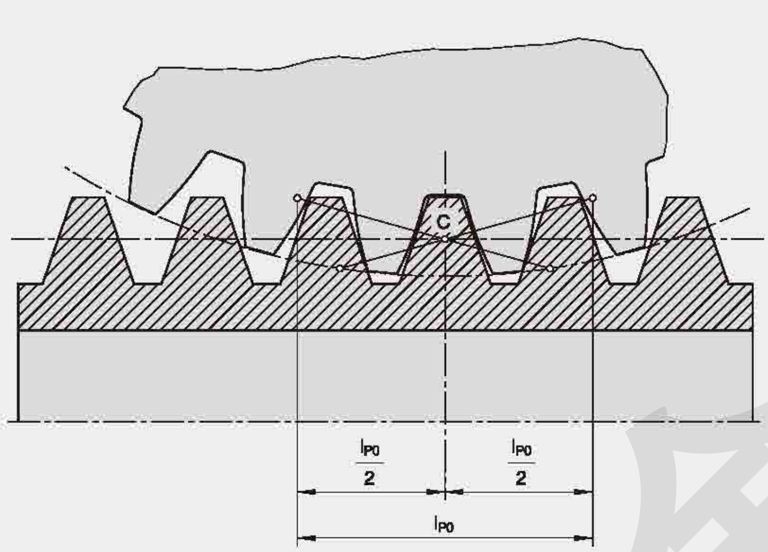
$\tan \alpha_t = \tan \alpha / \cos \beta$
$l_{Pa} = 2 \cdot (h_{a0} - x \cdot m_n - \varrho_{a0} \cdot (1 - \sin \alpha)) / \tan \alpha_t$
$d_b = z \cdot m_n \cdot \cos \alpha_{at} / \cos \beta$
$\cos \alpha_{at} = d_b / d_a$
$d = z \cdot m_n / \cos \beta$
$l_{Pf} = 2 \cdot (d_a/2 \cdot \cos(\alpha_{at} - \alpha_t) - d/2) / \tan \alpha_t$

If
$l_{Pa} > l_{Pf}$, then $l_{P0} = l_{Pa} \cdot \cos \gamma_0 / \cos \beta$

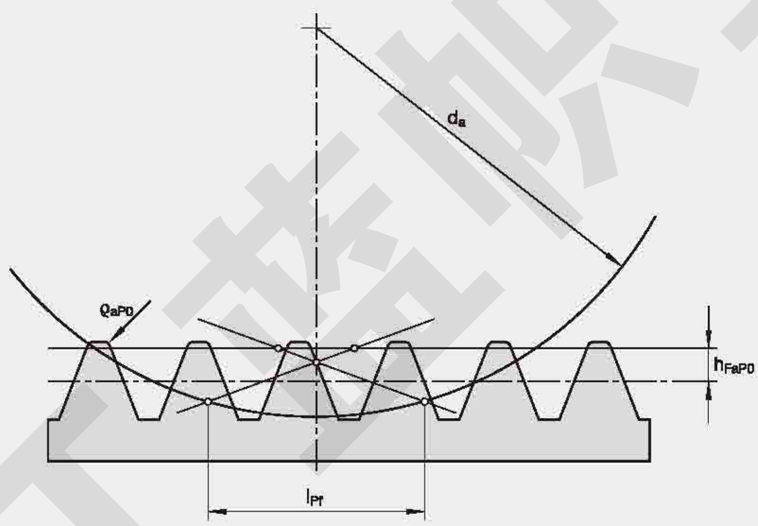
If
$l_{Pf} > l_{Pa}$, then $l_{P0} = l_{Pf} \cdot \cos \gamma_0 / \cos \beta$

h_{a0} = Addendum on the hob
$x \cdot m_n$ = Profile displacement
ϱ_{a0} = Tooth tip radius on the hob
α = Pressure angle
β = Helix angle
z = Number of teeth
m_n = Normal module
d_a = Tip circle diameter of the gear
γ_0 = Lead angle of the hob

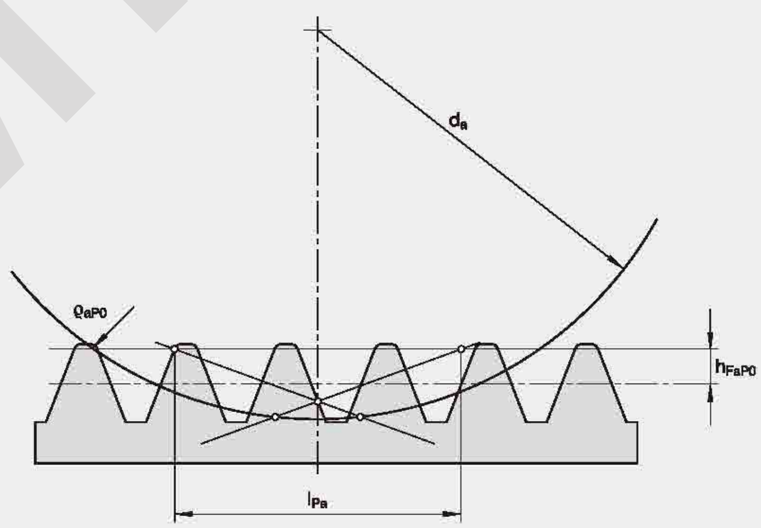
3


C
l_{P0}
2
l_{P0}
2
l_{P0}

4


d_a
ϱ_{aP0}
h_{FaP0}
l_{Pf}

5


d_a
ϱ_{aP0}
h_{FaP0}
l_{Pa}

移位距离
Shift distance

滚刀加工区域的碎屑截面形状是很难知道的。因为单个的滚齿所受到的负载应力值各有不同，因而他们的磨损程度也不尽相同。所以从逻辑上讲，滚刀必须切向移动，而一个或多个工件在同一位置上进行加工。这种切向移动称为“移位”。

The chip cross-sections within the working area of a hob are known to be very different. In consequence, the individual cutter teeth are subject to different loads, and therefore exhibit non-uniform wear patterns. It is therefore logical for the hob to be moved tangentially in stages once one or more workpieces have been machined in one position. This tangential movement is termed "shifting".

移位操作使加工区域不断出现新的加工齿。被磨损的齿离开加工区域，从而使整个加工过程中的磨损平均分布到滚刀的所有的有效滚齿刃上。在连续地重复磨削加工中能够生成齿轮轮廓的数量是由滚刀长度决定的，因此也同样由移位距离的长度决定。

Shifting continuously brings new teeth into the working area of the hob. The worn teeth leave the working area and the wear is distributed uniformly over the useful cutter length. The number of workpieces upon which a gear profile can be generated between successive regrinds is determined by the length of the hob and therefore also by the length of the shift distance.

从经济性角度考虑——具有较高刀具寿命，低的刀具成本，刀具更换次数少所具有的较低的停工时间——选择移位距离当然应选择越长越好。因此移位距离的最大长度是由滚齿机的设计情况决定的，因此表明它是有极限的。图6显示了刀具可用长度，刀具切削刃长度，轮廓形成区域长度和移位距离之间的关系。

In view of economic considerations – high tool life quality, low proportional tool costs, low machine downtimes for cutter changes – shift distances are selected which are as long as possible. The maximum length of the shift distance is determined by the design of the hobbing machine and therefore represents an absolute limit. The relationship between the useful cutter length, the tool cutting edge length, the length of the profile generating zone and the shift distance is shown in fig. 6.

$$l_s = l_3 - l_e - l_{P0} / 2 - 3 \cdot m_n$$

$$l_s = l_3 - l_e - l_{P0} / 2 - 3 \cdot m_n$$

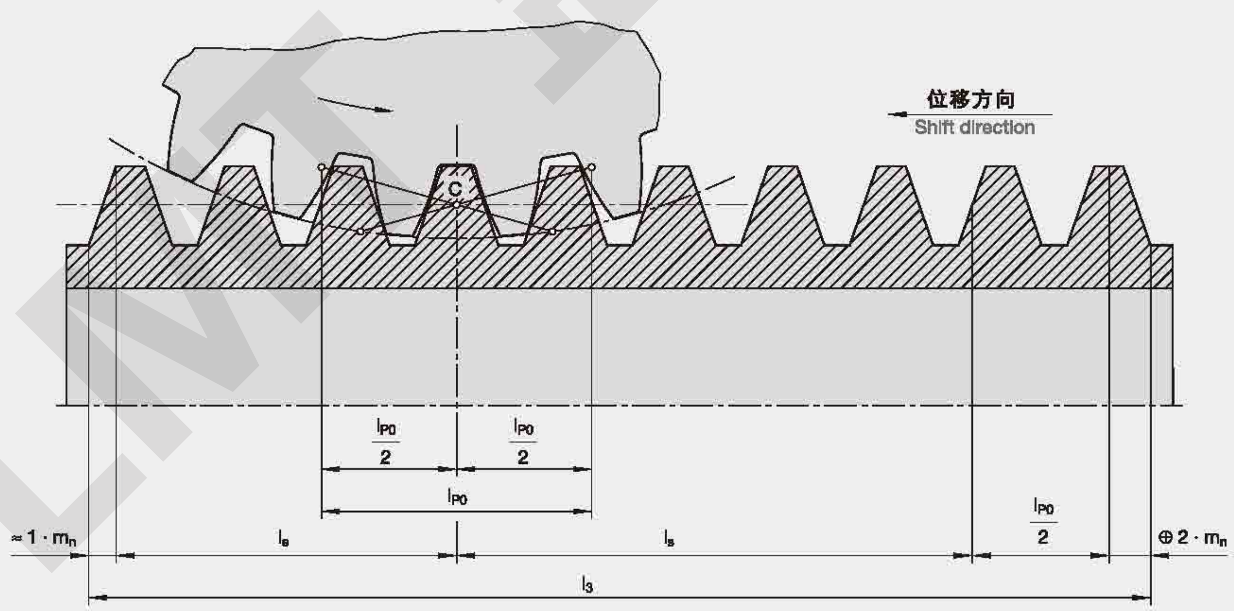
$3 \times m_n$确定了滚刀末端未加工完成的齿的切削余量。

The quantity $3 \cdot m_n$ makes allowance for the incomplete teeth at the ends of the hob.

6

移位距离分析图

Ascertainment of the shift distance



l_3 = 刀具可用长度 Useful length of cutter
l_e = 刀具切削刃长度 Tool cutting edge length
l_s = 移位距离 Shift distance
l_{P0} = 轮廓形成区域的长度 Length of the profile generating zone

LMT • FETTE

假设刀具寿命	$L_{ZF} = \frac{m}{Zahn}$
每个齿轮的切削长度	$L_{ZR} = \frac{z_2 \cdot l}{\cos\beta \cdot 1000}$
每次重磨加工工件的数量	$N = \frac{Shl \cdot i \cdot L_{ZF}}{m_n \cdot \pi \cdot L_{ZR}}$
移位增量	$Sh_s = 1 \times p\,(m \cdot \pi)$
移位增量的次数	$Sh_N = \frac{Shl}{Sh_s}$
操作数量	$D_N = \frac{N}{Sh_s}$
开始错位值	$Stv = \frac{Sh_s}{D_s}$

Shl = 移位长度
i = 容屑槽数
m_n = 法向模数
z_2 = 齿轮齿数
β = 螺旋角
p = 节距
L_{ZF} = 每齿刀具寿命
L_{ZR} = 每个齿轮的切削长度

Assumed tool life	$L_{ZF} = \frac{m}{Tooth}$
Gear cut length per gear	$L_{ZR} = \frac{z_2 \cdot l}{\cos\beta \cdot 1000}$
Number of workpieces per regrind	$N = \frac{Shl \cdot i \cdot L_{ZF}}{m_n \cdot \pi \cdot L_{ZR}}$
Shift increment	$Sh_s = 1 \times p\,(m \cdot \pi)$
Number of shift increments	$Sh_N = \frac{Shl}{Sh_s}$
Number of operations	$D_N = \frac{N}{Sh_s}$
Starting offset	$Stv = \frac{Sh_s}{D_s}$

Shl = Shift length
i = Number of gashes
m_n = Normal module
z_2 = Number of teeth on the gear
β = Helix angle
p = Pitch
L_{ZF} = Tool life per tooth
L_{ZR} = Gear cut length per gear

滚齿加工的轴向距离
滚刀在进行轴向加工时的轴向距离通常包括进入距离，齿轮宽度和空行程长度。图7显示了顺铣加工过程中滚刀轴向距离的示意图。

进入距离是滚刀必须沿齿轮轴方向移动的距离，具体是从滚刀的第一个接触点到滚刀与齿轮轴线到达齿轮最低面位置之间的交叉点。

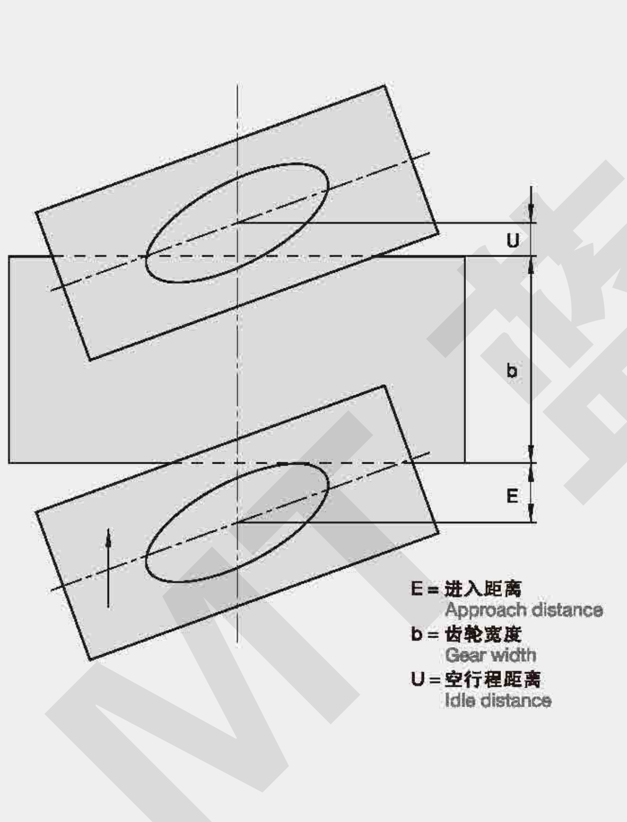
进入距离等于位于水平面上的贯穿曲线穿过刀具和齿轮轴所在平面交叉点中的最高点的高度。计算贯穿曲线的公式可以参见第188页中"滚齿加工的磨损现象"章节的图13内容。

Axial distance in hobbing
The axial distance of a hob during axial machining is generally composed of the approach distance, the width of the gear and the idle travel distance. Fig. 7 represents a schematic diagram of the axial distance of a hob during climb hobbing.

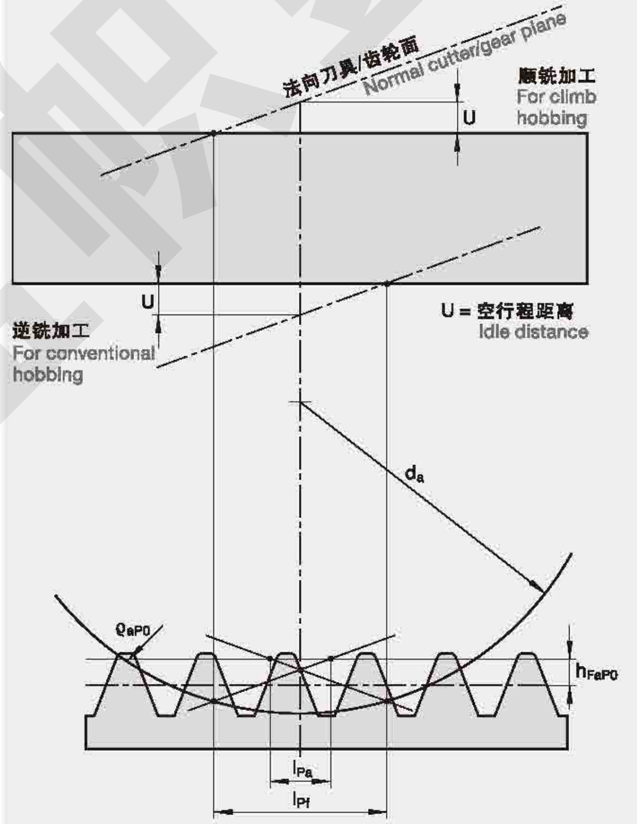
The approach distance is the distance which the hob must travel parallel to the gear axis, from the first point of contact to the point at which the intersection of the cutter and the gear axis has reached the lower face plane of the gear body.

The approach distance is equal to the height of the highest point on the penetration curve above the horizontal plane through the intersection of the cutter and gear axes. The formulae for calculation of the penetration curve can be found in the Chapter "Wear phenomena in hobbing", page 188, fig. 13.

7



8



LMT·FETTE

该进入距离也可以采用下述公式计算并能达到一定的精度：

The approach distance can also be calculated with sufficient accuracy by means of the following formula:

直齿轮：

$$E = \sqrt{h \cdot (d_{a0} - h)}$$

斜齿轮：

$$E = \tan\eta \cdot \sqrt{h \cdot \left(\frac{d_{a0}}{\sin^2\eta + d_a - h}\right)}$$

E = 进入距离
h = 切削深度
d_{a0} = 滚刀直径
η = 绕轴旋转角
d_a = 齿轮的齿顶圆直径

For straight teeth:

$$E = \sqrt{h \cdot (d_{a0} - h)}$$

For helical teeth:

$$E = \tan\eta \cdot \sqrt{h \cdot \left(\frac{d_{a0}}{\sin^2\eta + d_a - h}\right)}$$

E = Approach distance
h = Cutting depth
d_{a0} = Cutter diameter
η = Pivoting angle
d_a = Tip circle diameter of the gear

除保证安全余量外，空行程长度一般不适用于直齿。

No idle distance, except for a safety allowance, is required for straight teeth.

斜齿轮的空行程长度是由齿轮面内轮廓形成区域确定的。(图8)

The idle distance for helical teeth is determined by the profile-generating zone in the face plane (fig. 8).

l_{Pa}和l_{pf}的尺寸是由“滚齿加工的轮廓形成长度”章节中的公式计算得到的，其计算方法如下：

The dimensions for l_{Pa} and l_{Pf} are determined by the formulae in the chapter “Profile generating length for hobbing” and are calculated as follows:

如果 $l_{Pa} > l_{Pf}$, 则 $U = l_{Pa} \cdot \tan\beta$
如果 $l_{Pf} > l_{Pa}$, 则 $U = l_{Pf} \cdot \tan\beta$
U = 空行程距离
轴距 = $E + b + U$

If $l_{Pa} > l_{Pf}$, then $U = l_{Pa} \cdot \tan\beta$
If $l_{Pf} > l_{Pa}$, then $U = l_{Pf} \cdot \tan\beta$
U = Idle distance
Axial distance = $E + b + U$

介绍

在齿轮生产加工工艺领域，滚齿加工无论在今天还是在将来，都将占有非常突出的地位，而对滚刀的质量和经济性方面的保养与维护仍需要不断的努力。

从这一点来看，我们必须将滚齿加工看作是一个由设备、刀具、切削参数所组成的一个系统。而该系统必须始终保持最优化状态，以确保能够完成各种情况下的齿轮切削加工任务。

由于高性能滚齿设备和滚刀的不断发展，加工周期时间和辅助工艺时间都得到大大的缩短。这的确提高了对加工齿轮的成本，换刀成本和对滚动维护费用的分析的重要性。

因此我们必须通过高性能磨削加工方法提高滚刀再磨削技术，例如深度磨削工艺，以及通过使用合适的耐磨剂来适应各种滚刀切削材料。因此，除了采用传统的磨削材料外，例如碳化硅(SiC)和氧化铝(Al203)，还应采用水晶立方氮化硼（CBN）和金刚石材料来制造砂轮。

尽管对滚刀进行再磨削的初始目的是为了去除滚刀刀齿的磨损，但同时也应该满足其它范围内的要求，以及下列内容所总结出的加工任务。

加工任务

随着每次使用规定的切削刃去除金属加工工艺的完成，切削刃位置产生的磨损情况影响着碎屑的生成，因而产生大量的切削应力，从而降低齿轮的加工质量。这就是为什么当磨损达到一定值时必须将刀具进行重新磨削的原因。下面将会讨论刀刃磨损的许可最大宽度。

Introduction

In the field of the machining processes for the manufacture of gears, hobbing occupies a prominent position which, also in the future, can only be maintained through constant improvements in quality and economy.

From this point of view, hobbing must be regarded as a system consisting of machine, tool and cutting parameters, which must always be optimized afresh as regards an extremely wide range of gear cutting tasks.

Through developing high-performance hobbing machines and hobs the machine cycle times and the auxiliary process times were considerably shortened. This did of course increase the importance in the analysis of the gear cutting costs for a specific workpiece the tool costs, the costs of the tool change and the maintenance costs of the hob.

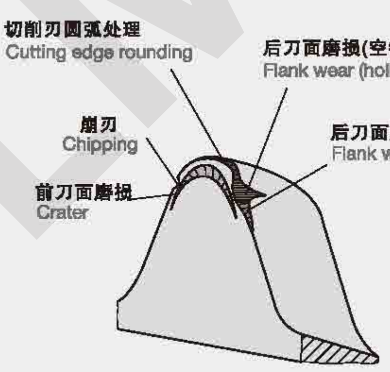
It was therefore essential to advance also the technology of the regrinding of hobs by means of high-performance grinding methods, such as the deep grinding process, and by means of suitable abrasives adapted to the various hob cutting materials. Therefore, grinding wheels made from crystalline cubic boron nitride (CBN) and diamond should be used in addition to the conventional grinding materials such as silicon carbide (SiC) and corundum (Al_2O_3).

Although the initial purpose when regrinding a hob is to remove the wear marks from the cutter teeth, a range or other requirements must be met which are formulated below as a task description.

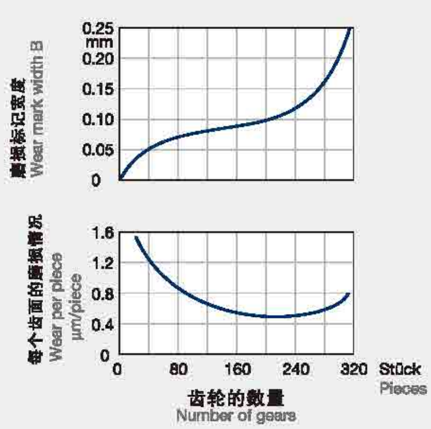
Task description

As with every metal removing machining process with a defined cutting edge, wear marks occur on the cutting edges of the cutter which affect chip formation, produce higher cutting forces and which could therefore reduce gear quality. This is why the wear has to be removed when it has reached a certain value. The maximum width of a still permissible wear mark will be discussed below.

1
滚刀刀齿的磨损形式
Forms of wear on the hob tooth



2
工件加工数量与齿面磨损的关系图
Flank wear as a function of the number of workpieces cut



所有铲齿或铲磨滚刀都必须对前刀面进行磨削使其保持锋利。这个工艺过程必须采用高质量及高精度的工具，而且在加工过程中必须有专业指导，并做到小心谨慎。

任何设计要求、加工尺寸、刀具切削刃几何角度和滚刀的材料，在磨削过程中必须完全满足以下要求：

- 切削刃的几何角度必须符合滚刀质量等级要求，
- 磨削过程中作用在刀具材料上的热量必须控制到最小，
- 切削表面以及切削刃的粗糙度必须保持尽量小，
- 必须选择合适的磨削方法和磨削材料，使刀具维护和检测所需的费用保持在经济条件允许的范围内。

所有准备工作，磨削工艺的操作和监督必须按照上述列出的总观察要求达到加工目标。

除此以外，在对硬质合金滚刀进行保养维护操作过程中还必须观察以下几点内容：
标记有“ISOK”类的硬质合金滚刀：
1.去除涂层
2.磨削前刀面使其锋利
3.重新涂层

滚刀的磨损现象
在滚齿加工章节中有关磨损标记宽度的参考位置，在这里一般指滚齿齿顶角的齿侧磨损长度。如图1中标记所示，这称为齿侧磨损。齿侧磨损标记的形成也是决定滚刀使用寿命期限的主要因素。

在图2上方曲线表示的特性曲线反映了磨损痕迹宽度的形成。磨损痕迹与工件加工数量没有比例关系。
图2下方曲线中，在上方曲线上升部分的转折点位置有一个较明显的刀具比例磨损的最小值痕迹。

考虑被加工的齿轮，如果以单个刀具最小费用为目标，高速钢滚刀的最大磨损厚度不超过0.25mm，硬质合金滚刀不得超过0.15mm。

由于上述提到的情况不能确定所有情况下磨损曲线，图3给出了一些参考值。

与此同时，显然存在大量的其它标准要求，例如切削材料，模数值，生产次序或要求的加工齿质量，在评估磨损痕迹宽度时必须考虑上述内容。

All relief turned or relief ground hobs are sharpened by grinding on the cutting face. This process must with such high-quality precision tools be carried out expertly and with the necessary care.

Regardless of the design, the dimensions, the cutting edge geometry and the material of the hobs, the following requirements must absolutely be met when regrinding:

- The cutting face geometry must be produced in accordance with the quality grade of the hob,
- heat stress on the cutter material by the grinding process must be restricted to a minimum,
- the roughness of the cutting faces and therefore the raggedness of the cutting edges must be kept as low as possible,
- grinding methods and aids must be chosen so that maintenance and inspection costs are kept within economical limits.

All preparations, the execution and the supervision of the regrinding process must have as their aim the total observation of the requirements listed above.

In addition, the following points must be observed during maintenance operations on carbide hobs
Carbide hobs assigned to the "ISO K" group:
1. Remove coat
2. Sharpen the cutting face
3. Re-coat

Wear phenomena on the hob
Where reference is made to the wear mark width in the context of hobbing, this generally refers to the length of the flank wear on the tip corners of the cutter teeth. In fig. 1, this is described as flank wear. This particularly marked form of flank wear also determines the end of the service life of the hob.

In the upper curve of fig. 2 the characteristic course is represented for the formation of the wear mark width. This does not develop proportionately to the number of workpieces cut.
The lower curve in fig. 2 has a marked minimum for the proportionate wear of a tool at the transition to the progressive part of the upper curve.

For the gear under consideration, the maximum wear should not therefore exceed 0.25 mm on coated KHSS-E hobs or 0.15 mm on carbide hobs if the lowest possible unit tool costs are an objective.

Since the wear curves cannot be determined in all cases in the form mentioned, some guide values are included on page 162 in fig. 3.

At the same time it also becomes clear, however, that there are a range of other criteria, such as cutting material, module size, production sequence or required tooth quality, according to which the wear mark width must be evaluated.

图3的“粗加工”一列显示了大模数齿轮粗加工时具有较大的磨损痕迹宽度。

这些数据显然处于磨损不断增长的范围以内。然而这些情况往往无法避免，因为要切除的部分会随着模数的增加而急剧增加，而参与材料切削的刀齿数量则保持不变甚至减少。这就导致每个切削齿上所受的应力增加，从而导致磨损加剧。

磨损痕迹宽度

对于精加工的情况，磨损痕迹宽度必须保持尽量低，因为被磨损的切削刃上的偏差和较大的切削应力会降低齿轮的加工精度。

经实践证明，刀具磨损标记宽度达到0.2mm后，不是硬质涂层而是基质材料决定磨损的发展。

当使用硬质合金刮削滚刀铣削硬质齿轮时，刀刃的磨损标记宽度可以达到0.15mm。增加的切削应力和切削温度会导致刀刃变钝，这不仅会影响加工工件上的应力，降低加工质量，而且会产生很多零散的加工碎屑，并可能导致刀具崩裂。

对于干加工的整体式硬质合金滚刀，其磨损量不得超过0.15mm。过度的磨损会损坏刀具的使用。因此在每次重磨后检查刀具的寿命是非常重要的。干加工过程中磨损加剧的一个首要标志就是加工工件的温度上升，并产生火花。当火花很严重时，应立即停止加工作业。

从经济性角度考虑，除了控制磨损痕迹宽度以外，分散磨损是非常重要的。

The “Roughing” column in fig. 3 shows relatively large wear mark widths for roughing of gears with a high module.

These certainly already fall within the range in which wear increases progressively. This can, however, often not be avoided in these cases, because the volume to be removed increases quadratically with the module, whereas the number of cutter teeth involved in the metal removal process remains the same or even decreases. The results are higher stress on individual cutter teeth and therefore greater wear.

Width of wear mark

For finishing, the wear mark widths must be markedly lower, because wear-related cutting edge deviations and higher cutting forces reduce gear cutting accuracy.

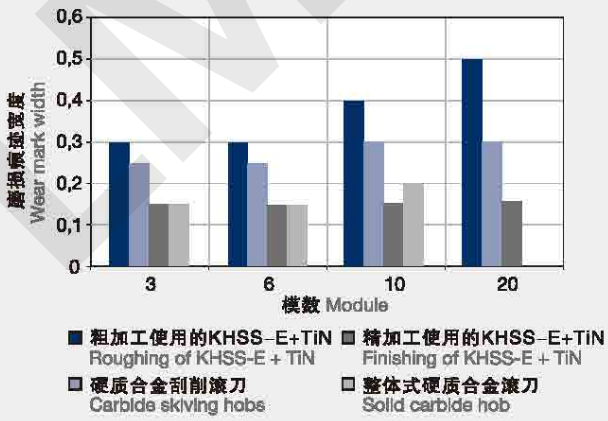
Experience with coated hobs shows that with wear mark widths from 0.2 mm no longer the hard coating but the base material determines wear development.

When milling hardened gears with carbide skiving hobs, a critical wear mark width is reached at 0.15 mm. The increased cutting forces and cutting temperatures resulting from the blunting of the cutting edge not only stress the workpiece and reduce its quality, but also lead to sporadic chipping and splintering of the tool.

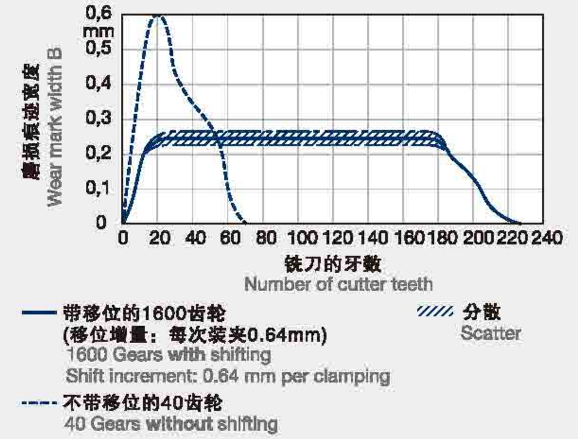
On solid carbide hobs for dry machining, the wear should not exceed 0.15 mm. A further increase in wear leads to destruction of the tool. It is therefore important to determine the tool life quality per regrind. The first sign of increased wear during dry machining is the increase in workpiece temperature and in sparking. Should sparking become severe, the machining process must be stopped immediately.

For economical operation, wear distribution is of decisive importance, in addition to the wear mark width.

3
不同滚刀材料的磨损痕迹宽度
Wear mark width for different hob materials



4
当滚刀使用/不使用移位操作时的磨损标记宽度情况
Wear mark width when hobbing with and without shifting



如果对每个刀具刀齿的磨损情况进行检查就可以发现，如果刀具只使用某一固定部分进行滚削，其磨损情况的分布如图4中的阴影部分所示。反过来，如果刀具在每次加工周期内沿轴向进行加工（移位），新的刀齿不断进入加工区域。磨损量会分布在更多的切削齿上，因而在连续磨削后生产率会增加好几倍。

刀具重磨部门里面经验丰富的工匠会通过观察刀具的磨损标记宽度和磨损分布，从加工质量和经济性角度了解该刀具是否正确地加以使用。如果建议值过高，或过低，那么应该将该情况向产品生产部门报告。

一般注意事项：
磨削砂轮的圆/轴向跳动值＜0.01mm。必须挑选刚性尽可能好的磨削砂轮。如有可能，应选择较小的接触面。在磨削硬质合金刀具时，优选乳化液而不选油类。
工件与刀具之间的振动会影响表明加工质量。位手工件和磨削加工作业台之间的传递力矩的所有夹紧元件和结构。

重要注意事项：
硬质台金滚刀对碰撞非常敏感。在运输和存储过程中应注意对刀齿边缘的保护。装置都必须保证最大的刚度以防止出现振动现象。

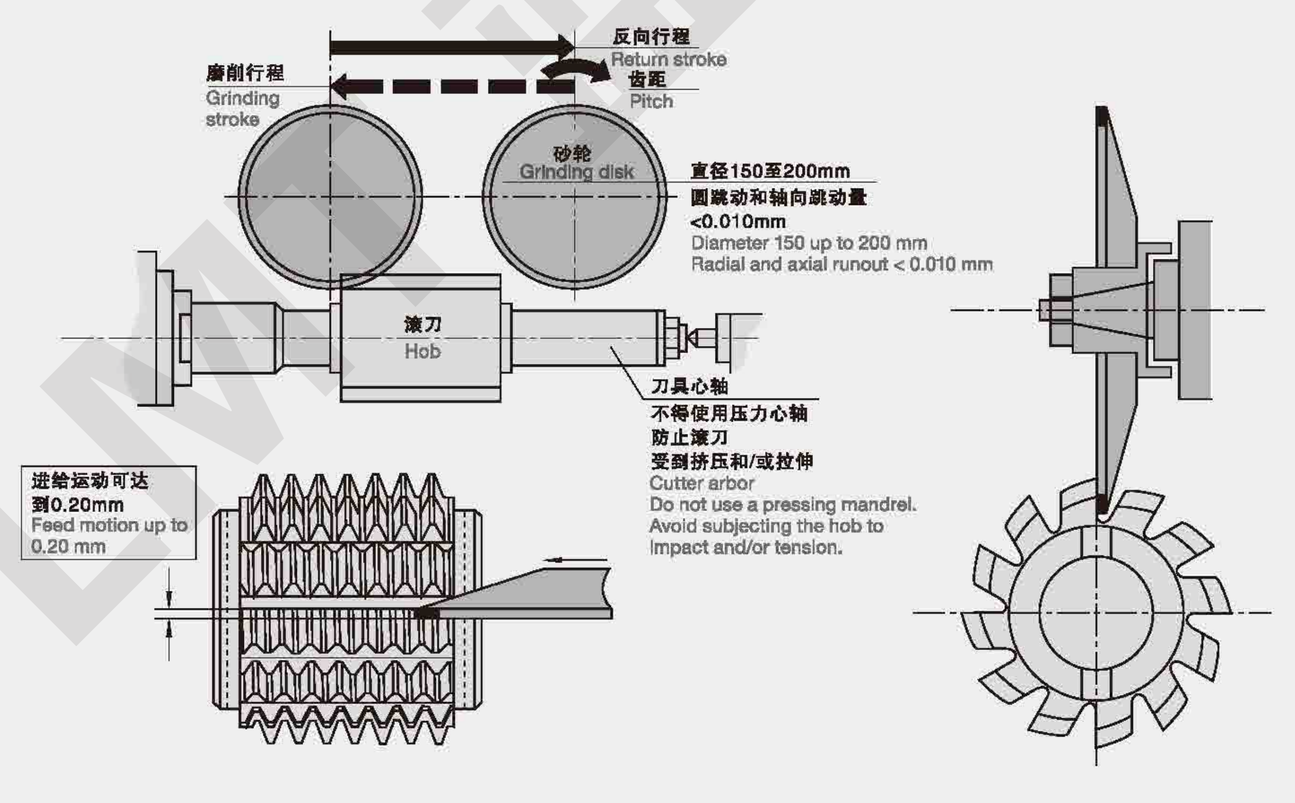
If the wear of each individual cutter tooth is examined, the distribution is found to be that shown in the hatched curve in fig. 4, if the cutter has been used in one position only. Conversely, if the cutter is displaced axially (shifted) following each machining cycle, new teeth are continuously brought into the working area. The wear is distributed evenly over a greater number of cutter teeth, and the productivity between successive regrinds is increased several times.

The experienced craftsman in the tool grinding shop knows by looking at the wear mark width and the wear distribution whether a hob has been used correctly from the points of view of quality assurance and economy. If the recommended values are substantially over- or undershot, this should always be reported to the production sector.

Requirements placed upon the cutting face grinder (Fig. 5)
Radial/axial runout of the grinding disk < 0.01 mm. A grinding disk form which is as rigid as possible should be selected. If possible, select small contact surfaces. Emulsions should be preferred to oil for the grinding of carbide.
Vibrations between workpiece and tool impair the surface quality. All structural and clamping elements in the torque transmission system between the workpiece and the grinding disk must be kept as rigid as possible in order to avoid vibrations.

Important
Carbide hobs are very sensitive to impact. Protect the tooth tips during transport and storage.

5



滚刀公差

滚刀的齿面切削刃是由切削面与齿侧经过铲齿或铲磨的螺旋面的交叉而形成的。由于在滚齿加工过程中齿廓是由包络切削形成的，每一次包络切削都是由刀具一组切削刃生成的，无论是切削刃的精确形状还是切削刃之间的相互位置都必须保证其正确性。

切削表面的重新磨削都会形成新的切削刃。因此滚刀的加工精度主要受到再磨削质量的影响。当新形成的切削面与原来的切削面在形状、位置、方向和齿距等方面保持一致时，在正确的形状和位置上进行再磨削才能得到合适的切削刃。如果再磨削过程是正确无误的，那么刀具的精度就可以保持新加工条件下的要求。加工渐开线直齿圆柱齿轮的单头滚刀的公差是依据DIN3968标准的。根据精度不同，共分为五个等级，即AA，A，B，C和D。

该标准包括了17个需要保证的允许偏差值。其中五个是与切削表面公差有关。

因此在重磨削加工后，前刃面必须达到下面要求的允许偏差值。

- 切削面的形状和位置误差。
- 切屑槽的单个和累积节距
- 切屑槽的导向

毫无疑问，对于高精度滚刀而言，在每次再磨削完成后都需要使用合适的检测仪器对滚刀的公差值进行检测。

滚刀轴台的径向跳动量和夹具表面的轴向跳动量（DIN3968第4和第5项内容）所有对滚刀的维修和检测操作进行的先决条件是磨削和测量心轴运行准确，滚刀轴台中心相互之间以及与心轴之间的显示值准确无误。(图6和图7)

其目的是将刀具螺纹轴与旋转轴的误差进行叠加，并通过测量径向跳动值对其误差进行测量。

如果两个轴台的高点和低点位于刀具轴线所在的平面，那么刀具螺纹轴和旋转轴的轴线就会存在偏心情况——那么刀具的旋转就不正确了。

如果两个轴台的高低两处在刀具旋转时的显示值互相关联，那么刀具的旋转轴和螺纹轴便产生倾斜，例如滚刀的摆动，此时会发现存在轴向跳动现象。

当使用滚刀进行加工时，使用人员必须知道他在切削时所能得到的有效齿轮系统，当重磨时不犯错误，当检测滚刀时获得充分信息和可再加工性结果，并且保证径向和轴向跳动尽量小。

Hob tolerances

The flank cutting edges of the hob are formed by the intersection of the cutting faces with the relief turned or relief ground helical surfaces of the tooth flanks. Since during the hobbing process the tooth profile is formed by enveloping cuts and each individual enveloping cut is generated by another cutting edge of the tool, both the exact form of the cutting edges and the relative position of the cutting edges to each other must be correct.

Regrinding on the cutting face always creates new cutting edges. The working accuracy of a hob can therefore be considerably impaired by regrinding. The cutting edges produced by regrinding only achieve their correct form and position when the newly created cutting faces correspond to the original ones in form, position, orientation and pitch.

Only if regrinding is faultless, will tool accuracy be kept identical with the new condition. The tolerances of single-start hobs for pur gears with involute teeth are quoted in DIN 3968. Depending on the accuracy, a distinction is made between five quality grades, namely AA, A, B, C and D.

The standard contains the permissible deviations for 17 values to be measured. Five of these alone concern the cutting faces.

Regrinding must therefore be carried out so that the permissible deviations for the following measurement values are maintained:

- Form and positional deviation of the cutting faces,
- individual and cumulative pitch of the gashes and
- lead of the gashes.

For high-precision hobs it therefore also goes without saying that the tolerances are checked on suitable inspection instruments after each regrind.

Radial runouts on the indicator hubs and axial runouts on the clamping surfaces (item nos. 4 & 5 DIN 3968)
A prerequisite for all repair and inspection operations on the hob is that the grinding and measuring arbors are running true and that the indicator hubs of the hob run true to each other and to the arbor (figs. 6 & 7).

The aim is to superimpose the axis of the cutter screw with the instantaneous rotary axis and to check this by measuring the radial runouts.

If the high or low points of the two indicator hubs lie in one axial plane of the cutter, the axis of the cutter screw and the rotary axis are offset – the cutter does not run true.

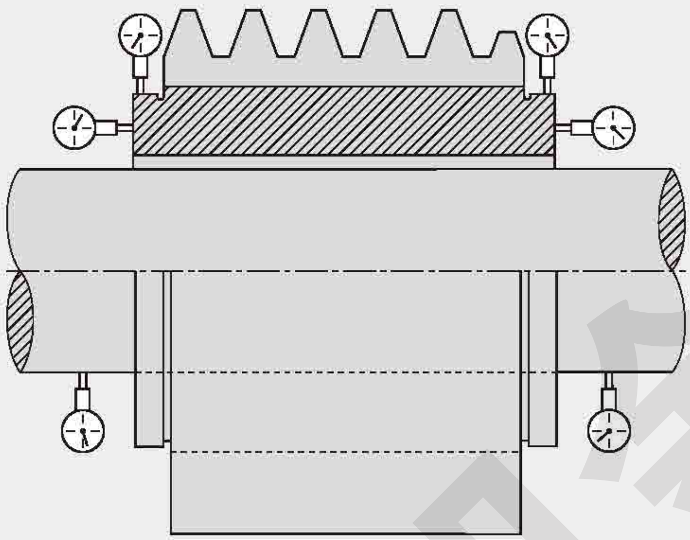
If the high or low points of the two indicator hubs are rotationally displayed in relation to each other, the rotary axis and the axis of the cutter screw are askew, i. e. the hob wobbles, and axial runout will also be found.

When working with or on the hob, the user must know that he will only achieve a sound tooth system when cutting, faultless geometry when regrinding and an informative and reproducible result when checking the hob if the radial and axial runouts are kept as small as possible.

6

测量芯轴和滚刀肩台的径向跳动及装夹端面的轴向跳动

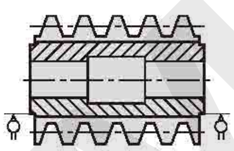
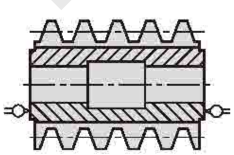
Measurement of the radial runout on arbor and indicator hubs and of the axial runout on the clamping surfaces



7

DIN3968标准允许的径向跳动和轴向跳动

Permissible radial and axial runouts to DIN 3968

测量值 Value to be measured	偏差符号 Symbol of the deviation	精度等级 Quality class	不同模数范围的公差μm (1μm =0.001mm) Tolerances in μm (1 μm = 0.001 mm) at module 大于 over 0,63–1	1–1,6	1,6–2,5	2,5–4	4–6,3	6,3–10	10–16	16–25	25–40
基于轴孔的两个轴台的径向跳动 Radial runout at the two indicator hubs based on the axis of the bore 	f_{rp}	AA	5	5	5	5	5	5	6	6	8
		A	5	5	5	6	8	10	12	16	20
		B	6	6	6	8	10	12	16	20	25
		C	10	10	10	12	16	20	25	32	40
		D	未确定 not determined								
		两个轴台中心测得的最高值不能旋转90度来抵消 The highest points measured at the two indicator hubs must not be offset by more than 90°.									
基于轴孔的装夹表面轴向跳动量 Axial runout at the clamping surfaces based on the axis of the bore 	f_{ps}	AA	3	3	3	3	3	4	5	5	6
		A	3	3	3	5	5	8	8	10	10
		B	4	4	4	6	6	10	10	12	12
		C	6	6	6	10	10	16	16	20	20
		D	10	10	10	16	16	25	25	32	32

因此可以理解为什么对加工过程中的径向跳动和轴线跳动量的允许误差要求如此严格，因为这不仅是确保对滚刀的测试结果能够令人接受，而且也关系到每次再磨削加工过程中的检查结果是否有效。

It is therefore understandable that the permissible deviations for the radial and axial runouts are very restricted and that it is essential to measure them not only during the acceptance test of the hob, but also during the inspection after each regrind.

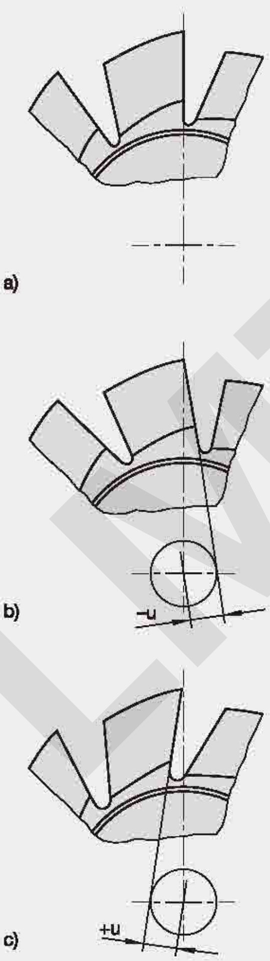
切削面的形位公差
(D1N3968标准第7项)
由直线生成的切削面通常经过滚刀的刀具轴线（图8a）。这时这些从刀具轴线前方或后方经过的直线所在的位置会形成与半径之间的正向或负向的前角。（图8b，c)根据前角大小，磨削砂轮和修整金刚石必须固定在距离滚刀轴为u的前面或后面。在检查形位公差时同样还需要按照上述要求设置量规指针的高度。

对带有正向前角的粗加工滚刀，在加工过程中保持刀具偏位的测量值u就足够了。而对于带有正向或负向前角的精加工刀具，例如硬质合金刮削滚刀，必须认真阅读再磨削加工图，其u测量值与刀具直径是相关的。

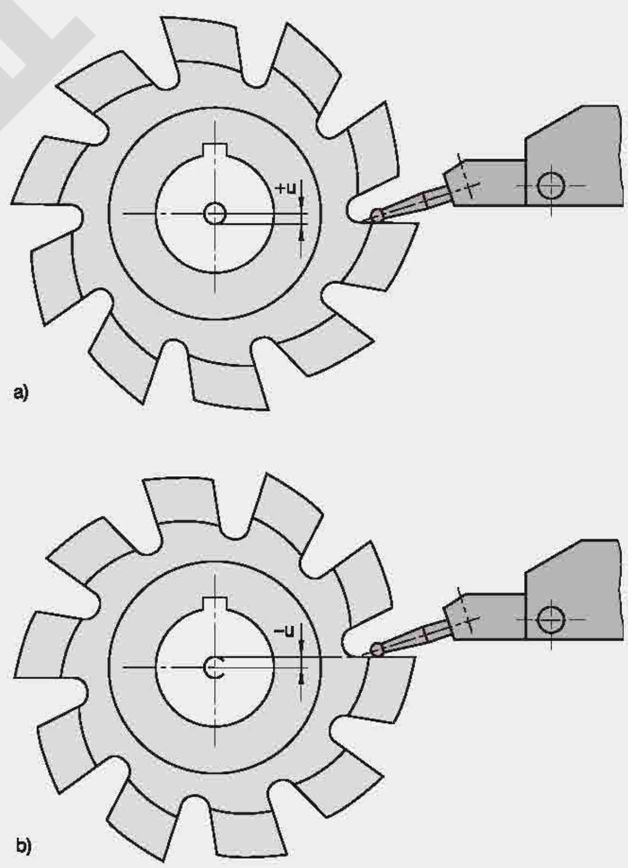
Form- and positional deviation of the cutting faces
(item no. 7 DIN 3968)
The cutting faces are generated by the straight lines which normally run through the cutter axis of the gear hob (fig. 8a). In those cases in which these straight lines run in front of or behind the cutter axis, they form negative or positive rake angles with the radials (fig. 8b, c). The grinding wheel must be set by the rake angle distance "u" in front of or behind the cutter axis to match the rake angle. This also applies to the height setting of the gauge stylus when checking the form and positional deviations (fig. 9).

For roughing cutters with a positive rake angle it is enough to maintain the u-measurement specified in the cutter marking when regrinding. In the case of finishing cutters with positive or negative rake angle, e. g. carbide skiving hobs, the u-measurement must be read off a regrinding diagram as a function of the cutter diameter.

8
滚刀的前角
Rake angle on the hob



9
量规指针设置a)
正前角，b)负前角
Setting the gauge stylus for
a) positive rake angle, b) negative rake angle

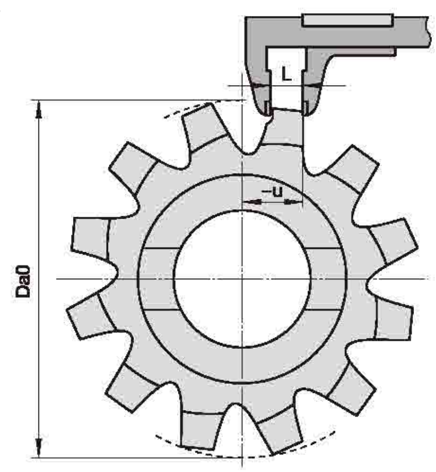


10

齿轮滚刀重磨表
Sharpening table for gear hobs

公司编号 Ident No.		图号： Drawing No.:	4-62069
刀具编号： Cutter No.:	J1105	刀号： Tool No.:	
模数： Module:	4,5	压力角： Pressure angle:	20°
K值： Cam:	5,34	齿宽： Tooth length:	10,58
容屑槽 No. of gashes:	15		
实际外径尺寸 Outside-Ø (actual dimension)	119,899	实际错位值： u (actual dimension)	–20,521
实际刀具齿顶宽 Tooth tip length (actual dimension)	8		

L	u	Da0	L	u	Da0
8	–20,521	119,899	2,508	–20,104	117,559
7,858	–20,51	119,839	2,369	–20,093	117,499
7,716	–20,5	119,779	2,229	–20,083	117,439
7,574	–20,489	119,719	2,09	–20,072	117,379
7,432	–20,478	119,659	1,951	–20,061	117,319
7,291	–20,468	119,599	1,811	–20,05	117,259
7,149	–20,457	119,539	1,672	–20,04	117,199
7,007	–20,446	119,479	1,533	–20,029	117,139
6,866	–20,436	119,419	1,394	–20,018	117,079
6,724	–20,425	119,359	1,255	–20,007	117,019
6,583	–20,414	119,299	1,116	–19,997	116,959
6,442	–20,404	119,239	0,977	–19,986	116,899
6,3	–20,393	119,179			
6,159	–20,382	119,119			
6,018	–20,372	119,059			
5,877	–20,361	118,999			
5,736	–20,35	118,939			
5,595	–20,34	118,879			
5,454	–20,329	118,819			
5,313	–20,318	118,759			
5,172	–20,308	118,699			
5,031	–20,297	118,639			
4,89	–20,286	118,579			
4,75	–20,275	118,519			
4,609	–20,265	118,459			
4,469	–20,254	118,399			
4,328	–20,243	118,339			
4,188	–20,233	118,279			
4,048	–20,222	118,219			
3,907	–20,211	118,159			
3,767	–20,201	118,099			
3,627	–20,19	118,039			
3,487	–20,179	117,979			
3,347	–20,168	117,919			
3,207	–20,158	117,859			
3,067	–20,147	117,799			
2,927	–20,136	117,739			
2,788	–20,126	117,679			
2,648	–20,115	117,619			



L = 刀具齿顶宽
Tooth length at tooth tip
u = 刀具错位值
Cutting face offset
Da0 = 刀具外径直径
Cutter diameter

该重磨图表适用于刀具直径，前角和铲磨加工，它随刀具一起提供（图10）。

切削面规定数值的误差会导致被加工工件的齿面形状和基本齿距的误差。

较大的前角(图11）会延长刀具切削齿，减小了轮廓倾角。

较小的前角(图12）会缩短刀具切削齿，并增加了轮廓倾角。

切削面形状误差可分为三类：凸出型，凹陷型以及凸凹结合型。

This regrinding diagram applies to the cutter diameter, the rake angle and the relief grinding operation and is supplied with the cutter (fig. 10, page 167).

Deviations from the specified value of the cutting face distance result in flank form and base pitch deviations on the hobbed workpieces.

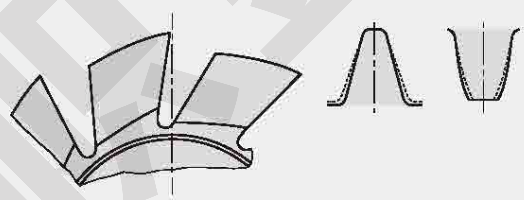
A bigger rake angle (fig. 11) elongates the cutter tooth and reduces the profile angle.

A smaller rake angle (fig. 12) results in a shorter cutter tooth and a greater profile angle.

The cutting face form deviations can be divided into three main forms: crowned, concave and undulating.

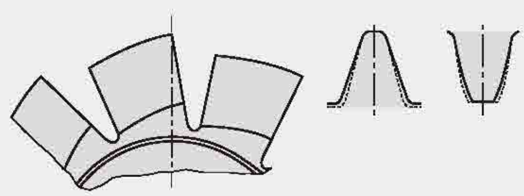
11
切削面的位置公差
a)缺陷，正切削面位置
b)刀具滚齿增长
c)工件齿在端部变厚，顶部接触
虚线轮廓表示刀具或工件齿的理论正确形状。

Positional deviation of the cutting face
a) Faulty, positive cutting face position
b) Elongated cutter tooth
c) The workpiece tooth becomes thicker at the head, tip contact
The broken-line contours indicate the theoretically correct profile of the cutter- or workpiece tooth.



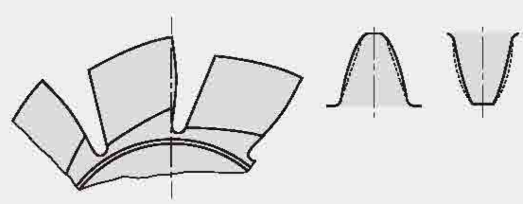
12
切削面的位置公差
a)缺陷，负切削面位置
b)刀具滚齿缩短
c)工件齿朝顶部变薄

Positional deviation of the cutting face
a) Faulty, negative cutting face position
b) Shortened cutter tooth
c) The workpiece tooth becomes thinner towards the top



13
切削面的形状公差
a)缺陷，凸形切削面
b)凸形切削齿
c)工件齿面凹陷面形状，齿顶和齿根接触

Form deviation of the cutting face
a) Faulty, crowned cutting face
b) Crowned cutter tooth
c) Concave flank form on the workpiece tooth, tip and root contact



当使用直边砂轮加工螺旋槽的滚刀，切削面会形成凸出型结构。切屑槽越短，刀齿高度越大，砂轮直径越大，则凸出的程度越大。

The crowned cutting face form is found when hobs which have a gash lead are ground with straight dressed grinding wheels. This crowning increases with shorter gash lead, greater tooth height and large grinding wheel diameters.

带有凸形切削刃(图13)的滚刀所加工的工件齿会在齿顶和齿根区域余留过多的材料。这种齿轮在运行过程中会出现不稳定情况，因而降低齿轮的承载能力，所以不能接受。

Hobs with crowned cutting faces (fig. 13) produce workpiece teeth on which too much material remains in the tip and root area. These gears exhibit an uneven running behaviour and reduced load bearing capacity and are therefore not accepted.

在加工时选择直径较小的砂轮可以减小切削面的凸出缺陷。生产用来修整这种形状缺陷的砂轮也可以产生一个平直的或者甚至凹形的切削面（图14，图15）。

By choosing a grinding wheel with a smaller diameter the crowned form on the cutting face can be reduced. A correspondingly crowned grinding wheel, manufactured in or dressed to this shape, generates a straight or even concave cutting face (fig. 14, 15).

切削面带有轻微凹陷的滚刀在加工齿轮时，是用其齿顶和齿根来参与切削的。这种形状误差对于理论的渐开线形状而言是允许的，而且在许多情况下甚至是符合规定要求的。

Hobs with a slightly concave cutting face produce workpiece teeth with tip- and root relief. This form of the deviation from the ideal involute form is permissible and is in many cases even specified.

切削面形状的波浪形误差通常是由于修整形状较差的砂轮或磨损的或修整面很差的金刚砂轮加工造成的。(图16)

Undulating form deviations on the cutting face are generally caused by badly dressed grinding wheels or worn or badly guided dressing diamonds (fig. 16, page 170).

切屑槽的节距误差

当切削面之间的间距不一致时，齿距会发生误差。在实际情况下，每个切削面位于预先精确规定等分的假定径节的前后位置。

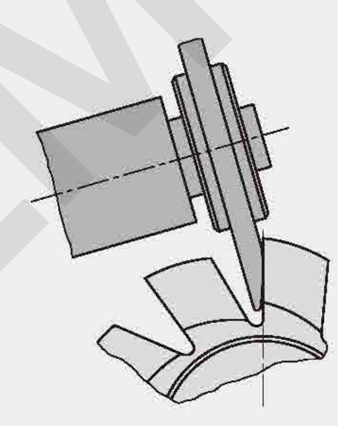
Pitch deveation of the gashes

Pitch deviations occur when the distances of the cutting faces from each other are not uniform. In practice, individual cutting faces lie in front of or behind the assumed radial pitches, which predetermine the exact specified pitch.

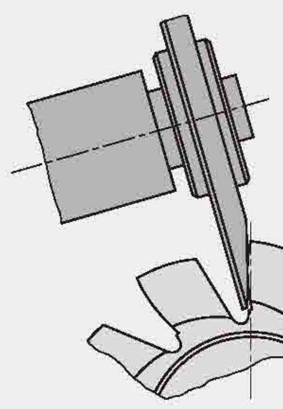
如果齿的切削面在规定距离后面较远的位置，那么所生成的齿面形状会超过规定的形状. 此时切削面加工齿面时会削除过多的材料。

If the cutting face of a tooth is further back than the specified position, the tooth will generate a flank form which projects beyond the specified form. A tooth with a projecting cutting face will cut away too much metal at the tooth flank.

14
螺旋槽滚刀的切削面。
带凸形磨削轮的磨削加工。
Cutting face on a hob with gash lead.
Ground with convex-ground grinding wheel.



15
螺旋槽滚刀的切削齿面形状误差。
使用直线修整磨削砂轮进行磨削处理。
Cutting face form error on a hob with gash lead.
Ground with straight-dressed grinding wheel.



每个切屑槽的不允许的相邻误差或累积性误差都会导致工件加工齿的齿面形状和基本齿距产生不规则形状或周期性误差。

Impermissible deviations from the individual or cumulative pitch of the gashes may cause irregularly or periodically occurring flank form and base pitch deviations on the workpieces.

当刀具移位时，这种误差肯定会作用在工件的加工齿面上。其原因在于节距误差对滚刀的滚齿的影响是相当大的，以致关系到存在问题的齿面生成区域以及在移位时相关加工齿的位置变化。

To this must be added that the flank form on the workpiece changes when the cutter is shifted. The reason for this is that it is important where the hob tooth afflicted by a pitch deviation, is situated relative to the profile forming zone in question and that the corresponding tooth changes its position when shifting.

切屑槽的单个节距（DIN3968第8条）
如果单个节距的误差是通过两次测量确定的，则该数值必须按照下述要求进行转换：增加刀具完整回转周期内的测量值，标上+号或–号。其差值即代表单个节距的误差。

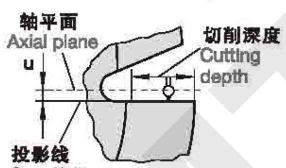
Individual pitch of the gashes (item no. 8 DIN 3968)
If the individual pitch deviations are to be determined by means of dualgauge measurement, the values read off must be converted as follows: The measured values for a complete cutter rotation are added, noting the + or – signs. The differences correspond to the individual pitch deviations.

每两个相邻节距的误差值即是齿和齿的节距的误差。

The difference between two adjecent individual pitch deviations is referred to as a tooth to tooth pitch error.

16
DIN3968标准的切削面形位公差
Form- and positional deviation of the cutting faces to DIN 3968

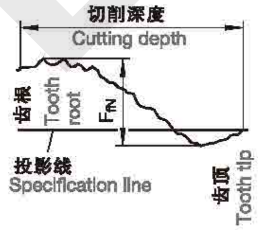
测量值 Value to be measured	公差符号 Symbol of the deviation	质量等级 Quality class	模数公差μm (1 μm = 0.001mm) Tolerances in μm (1 μm = 0.001 mm) at module 大于 over 0,63–1	1–1,6	1,6–2,5	2,5–4	4–6,3	6,3–10	10–16	16–25	–40
切削面的形位公差 Form- and positional deviation of the cutting faces	F_{fN}	AA	10	10	12	16	20	25	32	40	50
		A	12	16	20	25	32	40	50	63	80
		B	25	32	40	50	63	80	100	125	160
		C	50	63	80	100	125	160	200	250	315
		D	100	125	160	200	250	315	400	500	630



从投影线到轴平面的规定距离(u后倾角0度＝零)

Distance "u" of the specified line from the axial plane (at rake angle 0° = zero)

检查视图
Inspection diagram



可以通过比较各类分度盘或测量设备分度装置进行测量。所读到的测量值表示相对于第一个切屑槽的归零位置的测量切屑槽的累积节距值。每个节距的误差值等于两个相邻累积节距误差的差值。（图17）

计算过程的归纳如图18所示。

切屑槽的累积等分值(DIN3968第10条)
累积节距值误差表示以其中一个切削面为参考面时，切屑槽规定位置与实际所在位置之间的差值。

如果使用带有分度盘或相应的具有精确分度装置的测量设备进行测量，那么累积节距误差值可以直接读出。

当然，如果将每个节距的误差连续相加，那么累积节距误差值也可以通过双刻度测量结果计算得到。

DIN3968标准的第10条的公差是关于总节距误差的。这里所指的总节距误差值是指最大正累积节距误差与最大负累积节距误差的相差值。(图18)

切屑槽导程(DIN3968标准第11条)
切屑槽导程误差的公差值是沿轴线方向对100mm长度的切屑槽进行测量而得到的。该公差值适用于斜齿加工滚刀和直齿滚刀。该切屑槽误差会直接导致齿面形状、基本齿距和压力角的误差，对于斜滚齿的加工也会导致齿厚和齿导程的误差。

The measurement can also be carried out by comparison with an indexing plate or with the indexing arrangement of a measuring machine. The values read off represent in comparison to the zero position of the first gash the cumulative pitch of the measured gashes. The individual pitch deviation equals the difference of two adjacent cumulative pitch deviations (fig. 17).

A summary of the computation processes is shown in fig. 18, page 172.

Cumulative pitch of the gashes (item no. 10 DIN 3968)
The cumulative pitch deviation indicates the difference between actual and required gash positions, one cutting face being used for reference.

The cumulative pitch deviations can be read off directly, if the measurement is carried out with the aid of an indexing plate or with a correspondingly accurate indexing arrangement.

The cumulative pitch deviations can however also be calculated from the twodial measurement, if individual pitch deviations are added continuously.

The tolerances in DIN 3968 item no. 10 relate to the total pitch deviation. The total pitch deviation is here the distance between the biggest positive and the biggest negative cumulative pitch deviation (fig. 18, page 172).

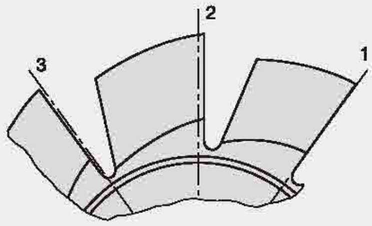
Gash lead (item no. 11 DIN 3968)
The tolerances for the deviations in the gash lead are based on an axially parallel measuring distance of 100 mm and they apply equally to hobs with a helix and to hobs with axially parallel gashes.

Directional deviations of the gashes result in flank form-, base pitch and pressure angle deviations and in the case of diagonal hobbing also in tooth thickness and tooth lead deviations.

17

切屑槽的节距误差
切削面1：理论上正确位置。
切削面2：齿距过短，齿形与切削面的齿形有关。
切削面3：齿距过长，齿形后移，与切削面的形状有关。

Pitch deviation of the gashes
Cutting face 1: Theoretically correctly placed
Cutting face 2: Pitch too short, tooth profile projects relative to the profile on the cutting face
Cutting face 3: Pitch too great, tooth profile set back relative to the profile on cutting face 1



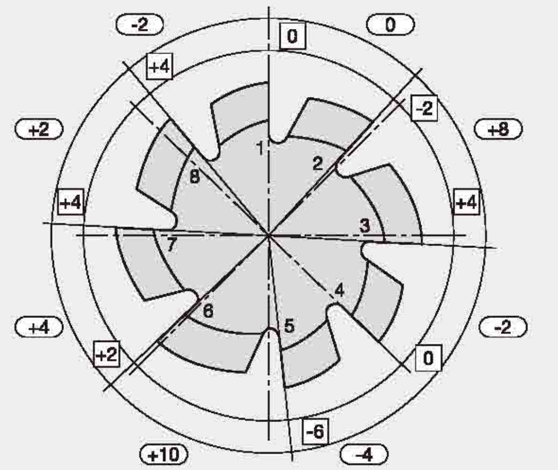
18

通过双刻度测量仪读出的测量的单个节距误差，齿与齿节距误差和累积节距误差计算图

Computation diagram for individual pitch deviation, tooth to tooth pitch error and cumulative deviation from the measured value readings of the two-dial measurement

单个节距误差f_{tN},齿与齿节距误差f_{uN}，累积节距误差F_{tn}

Individual pitch deviation f_{tN}, tooth to tooth pitch error f_{uN}, cumulative pitch deviation F_{tN}



读取测量值 Measured value reading　累积节距误差值F_{tN} Cumulative pitch deviation F_{tN}

切削面 Cutting face	读取测量值 Measured value reading	单个节距误差f_{tN} Individual pitch deviation f_{tN}		齿与齿节距误差f_{uN} Tooth to tooth pitch error deviation f_{uN}		累积节距误差F_{tn} Cumulative pitch deviation F_{tN}
1/2	0	−2			+8	−2
2/3	+8		+6	−10		+4
3/4	−2	−4		−2		0
4/5	−4	−6			+14	−6
5/6	+10		+8	−6		−2
6/7	+4		+2	−2		+4
7/8	+2	0		−4		+4
8/1	−2	−4			+2	0
(1/2)	(0)	(−2)				(−2)
	16 : 8 = +2	−16	+16	−24	+24	

单个节距误差f_{tN}是指所读到的双刻度测量和修正值之间的差值?
修正值是由所有读数的代数和除以节距数。

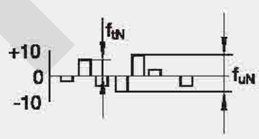
Individual pitch deviation f_{tN} is the difference between the reading of the 2-dial measurement and the correction value. The correction value is determined from the algebraic sum of all read values, divided by the number of pitches

1. 修正值的计算
   0 + 8 − 2 − 4 + 10 + 4 +2 − 2 = + 16
   16/8 = **+2 修正值**

1. Calculation of the correction value
   0 + 8 − 2 − 4 + 10 + 4 +2 − 2 = + 16
   16/8 = **+ 2 correction value**

2. 单个节距误差的计算

显示值	−修正值	= 单个节距误差
0	− (+2)	= −2
+8	− (+2)	= +6
−2	− (+2)	= −4
−4	− (+2)	= −6
+10	− (+2)	= +8
+4	− (+2)	= +2
+2	− (+2)	= 0
−2	− (+2)	= −4

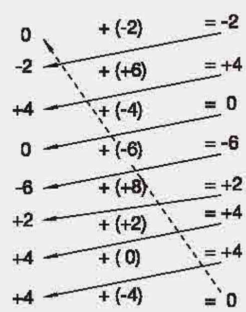


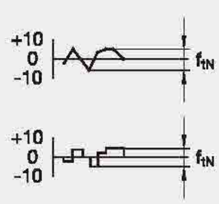
2. Calculation of the individual pitch deviation

indicated value	− correction value	= individual pitch deviation
0	− (+2)	= −2
+8	− (+2)	= +6
−2	− (+2)	= −4
−4	− (+2)	= −6
+10	− (+2)	= +8
+4	− (+2)	= +2
+2	− (+2)	= 0
−2	− (+2)	= −4

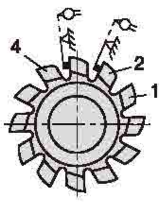
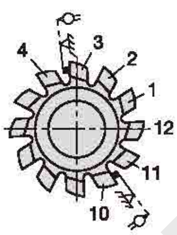
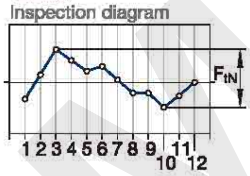
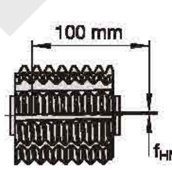
齿与齿节距的误差f_{uN}是将前一个单个节距误差与每个节距误差相减得到。
累积节距误差f_{tN}单个节距误差相加得到的结果。

Tooth to tooth pitch error f_{uN} is calculated by subtracting the previous individual pitch deviation from the individual pitch deviation.
Cumulative pitch deviation F_{tN} results from the addition of the individual pitch deviations.





切屑槽单个节距和累积和切削槽导程的允许误差值
Permissible deviations for individual pitch and cumulative pitch of the gashes as well as the gash lead

测量值 Value to be measured	公差符号 Symbol of the deviation	质量等级 Quality class	不同模数范围的公差 µm (1 µm = 0.001mm) Tolerances in µm (1 µm = 0.001 mm) at module 大于 over 0,63–1	1–1,6	1,6–2,5	2,5–4	4–6,3	6,3–10	10–16	16–25	25–40
单个切屑槽的间距在齿一半高度位置进行测量 Individual pitch of the gashes measured at half tooth height  检查表 Inspection diagram 	f_{tN}	AA	±10	±10	±12	±16	±20	±25	±32	±40	±50
		A	±12	±16	±20	±25	±32	±40	±50	±63	±80
		B	±25	±32	±40	±50	±63	±80	±100	±125	±160
		C	±50	±63	±80	±100	±125	±160	±200	±250	±315
		D	±100	±125	±160	±200	±250	±315	±400	±500	±630
切屑槽的累积节距在齿高度的一半位置测量 Cumulative pitch of the gashes measured at half tooth height  检查表 Inspection diagram 	F_{tN}	AA	20	20	25	32	40	50	53	80	100
		A	25	32	40	50	63	80	100	125	160
		B	50	63	80	100	125	160	200	250	315
		C	100	125	160	200	250	315	400	500	630
		D	200	250	315	400	500	630	800	1000	1250
切屑槽导程超过100mm以基准圆柱面上的刀具长度 Gash lead over 100 mm cutter length based on the reference cylinder 	f_{HN}	AA	±50								
		A	±70								
		B	±100								
		C	±140								
		D	±200								

切屑槽导程误差的公差值相对较大，由于它仅仅对齿形几何角度有很小的部分影响。应该考虑到公差量对齿的精度的影响，对大模数要比对小模数严重，因为齿加工区域轮廓长度会随着模数大小的增加而增加。

The tolerances for the deviations of the gash lead are relatively wide, since they only fractionally affect the tooth geometry. It should be taken into account, however, that the effect on the directional deviations on tooth accuracy is greater with high than with low modules, since the length of the profile formation zone increases with the module size.

粗加工滚刀的重磨

FETTE的粗加工滚刀可以在任何滚刀刃磨设备上进行刃磨加工。

Regrinding of roughing hobs

LMT Fette roughing hobs can be reground on any hob regrinding machine.

所制造的滚刀有一个正前角。因此切削面是偏心的，该偏心距的值为”u”，并刻在每个滚刀上。

The hobs are manufactured with a positive rake angle. The cutting face is therefore off-center. The deviation from the center is indicated by the dimension "u" which is indicated on each hob.

在重磨加工之前，调整砂轮并偏离中心线“U”个长度。

Prior to beginning regrinding work, offset the grinding disk from the centre by the dimension "u".

对FETTE螺旋切屑槽粗加工滚刀进行刃磨时，应确保磨削砂轮的砂轮表面呈凸出状，从而确保加工出平直的切削面。

On LMT Fette roughing hobs with a finite gash lead, ensure that the grinding disk is crowned, in order to ensure straight cutting faces.

所有FETTE粗加工滚刀都有8（10）个齿组，每个齿组包含2个切屑槽，即总共有16(20)个切屑槽。

All LMT Fette roughing hobs have 10 teeth groups, each of which has 2 gashes, i.e. 20 gashes in total.

每次磨削加工完成后，必须检查切削槽节距，形状和位置以及顶部跳动。例如使用通用齿距测量仪。公差值应保证符合DIN3968标准规定的A类等级要求。

The gash pitch, the form and location of the gash, and the tip runout must be checked following each regrind operation, for example on a universal pitch tester. The tolerances should be within quality grade A to DIN 3968.

粗切滚刀的重磨加工过程

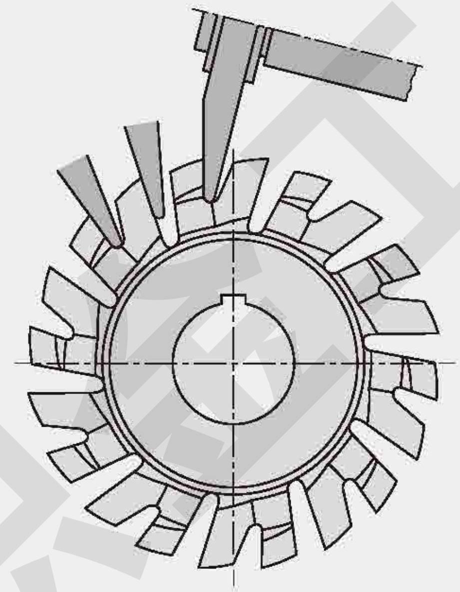
Regrinding of roughing hobs

为了获得最佳切屑槽节距，滚刀首先应对16(20)切屑槽进行刃磨加工。砂轮插入小齿间隙中。

符合D1N3968标准的A质量等级的切削槽节距应通过本次磨削加工实现。

然后滚刀对8(10)切屑槽进行刃磨加工。
在本次操作中，插入大齿间隙深度中。

本次磨削加工必须进行到精磨削齿顶部分达到16(20)节距一致为止。

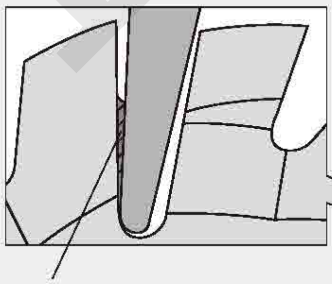


In order to obtain a perfect gash pitch, the hob is first ground with the 20 pitch disk. The grinding disk is plunged as far as the small tooth gap.

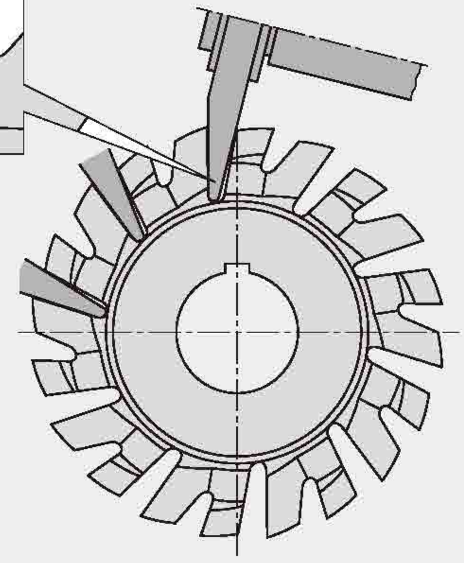
A gash pitch within quality grade A to DIN 3968 should be attained by this grinding operation.

The hob is then ground with the 10 pitch disk.
In this operation, the grinding disk is plunged to the depth of the large tooth gap.

This grinding operation must be performed until a smooth transition to the reground tooth tip portion of the 20-pitch is achieved.



第二部磨削时金属切除过程
Metal removal in the second grinding operation



总则

带有凸角的滚刀是一种粗加工用刀具，其形状轮廓不同于DIN3972的标准类型规定轮廓，其凸角位于刀齿的齿顶，并超出了基本齿廓的平直齿面。

凸角的作用是为了在切削直齿轮的齿根位置时形成挖根。这对于使用剃削加工、磨削加工或使用硬质合金刮削加工完成的精加工是非常必要的。

齿轮上的挖根对于避免削弱齿根的强度非常必要，它通过加工(图2)完成—它也是为于防止磨削砂轮或剃刀碰撞齿轮的齿根部分，由于这会对齿面的加工质量产生负面影响。通过磨削作用力而作用在齿根位置的附加载荷也必须考虑在内。在加工时应达到图3所示的间隙切削形状，当切除加工余量后，它会使齿根圆滑平稳过渡到齿面。在实际情况下该要求形状往往无法实现，因为实现磨削砂轮与工件之间的精确定位的花费十分昂贵，对允许的尺寸偏差和可能产生的热变形的补偿是不可能的。

图4显示了一般情况下使用的切削间隙形状。间隙尺寸和凸角量超过了加工余量。剩余的间隙会保留在加工完成的齿轮上。但是增大的凸角也会增加齿根圆的直径大小(d_{Ff})。

对于直齿轮而言，必须区别结构圆和有效圆。齿顶和齿根结构圆是延长到渐开线轮廓线位置的圆，例如，如果一个直齿轮有齿顶倒角，则该齿顶结构圆直径是指倒角起始位置所在圆圈的直径。因此，齿轮的齿顶结构圆直径比该齿轮的齿顶圆直径小两个倒角半径的高度，齿根结构圆直径是位于齿根圆弧或根切起始位置的直径。齿根圆轮廓并不与实际使用的配合齿轮实际啮合的齿顶和齿根结构圆直径之间的相交面重合。其大小取决于齿轮付的齿面圆直径大小，中心距以及由有效齿顶圆直径和齿根圆直径形成的压力角。有效圆可能与对应的结构圆尺寸一样。但有效齿顶圆直径不能超出齿顶结构圆直径，有效齿根圆不能小于齿根结构圆直径。在确定凸角时，必须确保齿根结构圆直径小于有效齿根圆直径；然后才能根据有效齿根圆直径计算实际要求的接触面大小。

General principles

Hobs with protuberance (fig. 1) are roughing cutters whose profile differs from the standard type to DIN 3972 in that protuberances are present on the tooth tips which project beyond the straight flanks of the basic profile.

The purpose of the protuberance is to create a clearance cut on the tooth roots of spur gears. This is necessary when the teeth are to be finish machined by shaving, grinding or by hobbing with a carbide skiving hob.

The clearance cut on the gear flank is necessary to avoid a weakening of the tooth root through the formation of steps (fig. 2). It is also intended to make it impossible for the grinding wheel or the honing wheel to strike the tooth root of the gear, since this would have adverse effects – through the deflection of the grinding or honing wheel – on the quality of the flank form. An additional load on the tooth root through grinding stresses could then not be excluded. A clearance cut shape as in fig. 3 should be aimed at, which results after removing the machining allowance in a smooth transition of the root rounding into the tooth flank. This shape can however not be achieved in practice, because, for example, a faultless positioning of the grinding wheel relative to the workpiece would be very expensive and compensation of permissible dimensional deviations and possibly occuring heat distortion is not possible.

Fig. 4 shows a generally used form of the clearance cut. The clearance size – and therefore also the amount of protuberance – exceeds the machining allowance. A residual clearance remains on the finished gear. Increasing the protuberance does however also increase the root form circle diameter (d_{Ff}, fig. 5).

On straight spur gears, a distinction must be drawn between the form circle and the effective circle. Tip and root form circles are circles up to which the involute profile extends. If, for example, a spur gear has a tip chamfer, the tip form circle diameter is the diameter at which the chamfer begins. The tip form circle diameter is therefore smaller than the tip circle diameter of the gear by twice the radial height of the chamfer. The root form circle diameter is located at the point at which the root rounding or the undercut begin. It does not follow however that the flanks between the tip and root form circle diameter actually engage with the mating gear, i. e. are actually used; this depends upon the tip circle diameters of the gear pair, the centre distance, and

有时候在剃削加工前进行粗加工过程中将切削间隙完全进行分配处理，但应保证齿根切削完全，以防剃刀接触到齿轮的齿根半径。切削间隙的最小和最大尺寸受到精加工方式的限制，例如剃削加工或磨削加工，剃刀或砂轮齿顶的相对运动轨迹的形位值，允许齿厚偏差等等，而且一方面淬火处理导致变形，另一方面受到齿根结构圆直径的尺寸大小影响。

由于齿根结构圆直径的重要性，下面详细给出了不同齿根结构圆直径下各种刀具和工件参数的影响。

总的来说，所有具有相同模数的被加工的齿数或齿轮数都可以使用一种凸角形状的滚刀完成加工。

刀具的齿顶高度应按照1.25 × m来计算。

the pressure angle which result from the effective tip and root circle diameter. The effective circles may have the same dimensions as the corresponding form circles. The effective tip circle diameter cannot however exceed the tip form circle diameter, and the effective root circle diameter cannot be smaller than the root form circle diameter. When specifying the protuberance it must be ensured that the root form circle diameter is less than the effective root circle diameter; only then can it be ensured that the effective root circle diameter calculated for the requisite contact ratio is actually present.

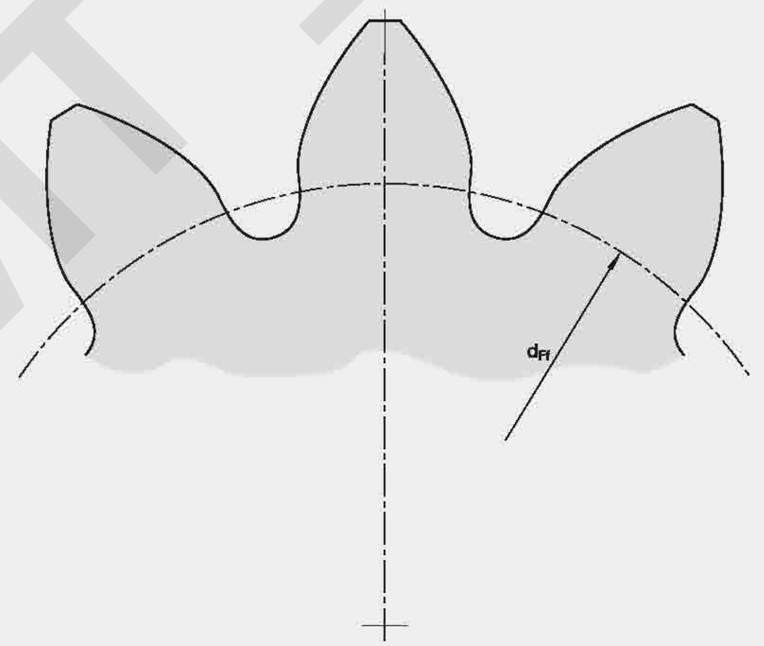
In some cases one dispenses during roughing prior to shaving completely with the clearance cut, but makes sure that the tooth root is cut out sufficiently for the shaving cutter no longer to touch the root radius of the gear. The minimum and maximum sizes of the clearance cut are therefore limited by the finishing method – shaving or grinding, form and position of the relative tooth-crest track of the shaving cutter or the grinding wheel, permissible tooth thickness deviations etc. – and by the amount of hardening distortion on the one hand and by the size of the root form circle diameter on the other hand.

In accordance with the importance of the root form circle diameter, the details given below will only deal with the effects of the various tool and workpiece parameters on the size of the root form circle diameter.

Generally, all the teeth/gear numbers of a module can be cut with one protuberance profile.

The addendum of the tools should be greater than 1.25 x m.

5



凸角量是由加工余量和在已加工好的齿轮上所附加的挖入量构成的。这两个值是由后续加工工艺根据工件的尺寸（小齿轮还是环形毛坯）以及在热处理工艺时工件的变形情况决定的。因此在这里不同刀具的轮廓形状都是需要的，因此，制造小型齿轮或齿数(小于15个)的齿轮，以及制造具有较大负轮廓位移的齿轮，需要设计一种特殊的刀具轮廓。

被加工工件上齿根结构圆的直径参数：模数、压力角、齿数、螺旋角和轮廓位移。滚刀参数：齿顶高，齿顶圆角半径，凸角量和凸角的角度。

The amount of protuberance is made up of the machining allowance and the residual undercut remaining on the finished gear. These two values depend on the subsequent machining process, on the size of the workpieces (pinion or ring) and on the distortion during heat treatment. It is therefore entirely possible that different tool profiles are needed here. A special design of the tool profile may also become necessary at smaller teeth/gear numbers (less than 15) and with large negative profile displacements.

The parameters for the root form circle diameter are on the workpiece: module, pressure angle, number of teeth, helix angle and profile displacement on the hob: addendum, tip circle radius, amount of protuberance and protuberance angle.

为了防止您对下面内容中所使用的术语产生误解，以下术语在给出定义时将给予示例帮助说明。

To ensure that no misunderstandings will occur in the text below about the meaning of the terms used, these terms will be defined with the aid of the illustration.

滚刀基本齿廓的使用术语

图6显示了滚刀的基本齿廓形状。下面是对有关基本齿廓所定义的术语的辅助解释。

Terms used on the basic hob profile

Fig. 6 shows the basic hob profile. This is complemented by the definition of the terms used in conjunction with the basic profile.

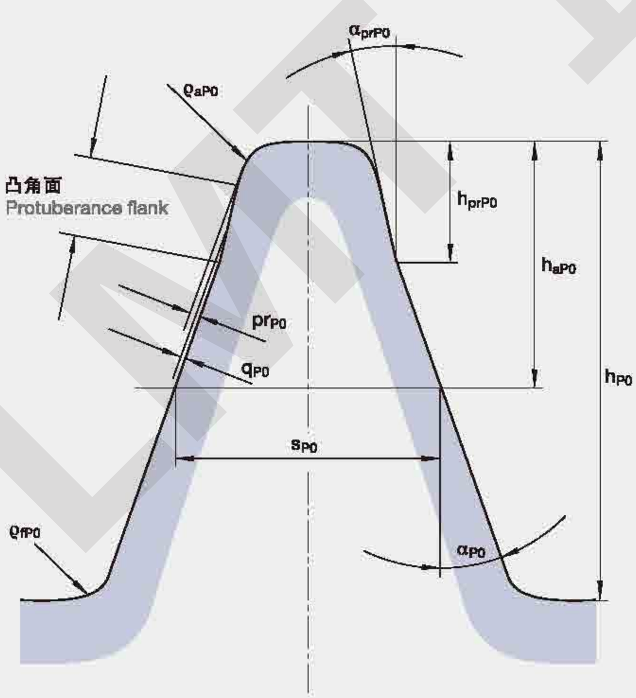
下面给出的例子显示了滚刀基本齿廓的不同尺寸。凸角轮廓在很多场合中使用得很成功。

An example showing the different dimensions of a basic hob profile is given below. This protuberance profile has been particularly successful in many cases.

6

法向截面位置处滚刀的基本齿廓

Basic hob profile in the normal section



ϱ_{aP0} = 0,40 · m

ϱ_{fP0} = 0,2 · m

α_{P0} = 20°

α_{prP0} = 10°

q_{P0} = 0,09 + 0,0125 · m

pr_{P0} = 0,129 + 0,0290 · m
模数 7 ≤ Module 7
(u = 0,039 + 0,0165 · m)

pr_{P0} = 0,181 + 0,0235 · m
模数 7 > Module 7
(u = 0,091 + 0,011 · m)

h_{aP0} = 1,4 · m

h_{P0} = 2,6 · m

$$s_{P0} = \frac{m \cdot \pi}{2} - \frac{2 \cdot q_{P0}}{\cos \alpha_{P0}}$$

ϱ_{aP0} = 齿顶圆半径 Tooth tip radius

ϱ_{fP0} = 齿根过度圆半径 Root fillet radius

α_{P0} = 轮廓 ∢ Profile ∢

α_{prP0} = 凸角角度值 ∢ Protuberance angle

q_{P0} = 加工余量 Machining allowance

pr_{P0} = 凸角数量 Amount of protuberance

h_{prP0} = 凸角高度 Height of protuberance

h_{aP0} = 齿顶高 Addendum

h_{P0} = 轮廓高度 Profile height

s_{P0} = 齿厚 Tooth thickness

u = 加工完成的齿轮的齿根切削间隙
Root clearance cut on the finished gear

u = $pr_{P0} - q_{P0}$

齿根结构圆直径的计算

齿根结构圆直径可以使用FETTE开发的软件进行计算。

理论上，齿根位置的曲线是由齿顶圆角半径包络的区域和凸角面构成的轮廓线组成的。第二个区域是渐开线轮廓区域，渐开线与主渐开线的齿根曲线在该区域相交。其交点位置是由齿根结构圆直径的大小决定的。然而在所检查的大多数情况下，相切曲线的渐开线区域并不存在，由齿顶圆角半径产生的齿根圆弧与主渐开线形成相交。

现在已经得到了根据计算的齿根曲线进行绘制的方法以及对绘图结果的进行分析的有效方法。齿根曲线与主渐开线的交点位置对于后续加工过程中对齿根结构圆直径大小进行判断的精确性的影响非常重要。对于经过淬硬和磨削过的齿轮，必须考虑淬火处理生成的变形以及磨削砂轮的偏心量导致粗加工齿面被磨去的不同加工量。这可能会将齿根结构圆的直径用计算得出的理论尺寸代替。这时，必须确保计算得出的齿根结构圆直径与需求齿根结构圆直径之间的预留余量。

实践经验表明，当齿根结构圆直径大时，如果齿轮的齿数较少，并且正向轮廓移位量很小时会发生问题。此时可以使用更少的凸角量，加大齿顶高或减小滚刀基本齿廓的齿顶圆半径进行改善。

Calculation of the root form circle diameter

The root form circle diameter can be calculated using the software developed by LMT Fette.

In theory, the root curve comprises the region generated by the tooth tip radius and that profiled by the protuberance flank. The second region is an involute profile, in which the involute intersects the root curve of the main involute. The intersection is determined by the root form circle diameter. In the majority of cases examined, the involute region of the undercut curve is not present, however, and the root rounding generated by the tooth tip radius forms the intersection with the main involute.

It has proved practical to plot the computed root curve and to analyse the result of the plot. The intersection of the root curve with the main involute following machining is of decisive importance for evaluation of the root form circle diameter. On gears which have been hardened and ground, it must be considered that hardening distortion and incorrect centring of the grinding disk result in different volumes being ground off the roughed tooth flank. This may result in the root form circle diameter being displaced from the theoretical dimension arrived at by calculation. In such cases, it must be ensured that an adequate reserve remains between the calculated root form circle diameter and the requisite root form circle diameter.

Practical experience has shown that gears with a small number of teeth and only a small positive profile displacement may lead to problems if the root form circle diameter is too large. The result

有效齿根圆直径的计算

Calculation of the effective root circle diameter

如果工件图纸上没有给出齿根结构圆直径或有效齿根圆直径的大小，那么必须根据下列公式计算配合齿轮数据的有效齿根圆直径：

If the root form circle diameter or the effective root circle diameter are not specified in the workpiece drawing, the effective root circle diameter must be calculated from the gear pair data according to the following formulae:

(1) $d_{Nf1} = \sqrt{(2 \cdot a \cdot \sin \alpha_{wt} - \sqrt{d_{Na2}^2 - d_{b2}^2})^2 + d_{b1}^2}$

(2) $d_{Nf2} = \sqrt{(2 \cdot a \cdot \sin \alpha_{wt} - \sqrt{d_{Na1}^2 - d_{b1}^2})^2 + d_{b2}^2}$

(3) $\cos \alpha_{wt} = \frac{(z_1 + z_2) \cdot m_t}{2 \cdot a} \cdot \cos \alpha_t$

(4) $m_t = \frac{m_n}{\cos \beta}$

(5) $\tan \alpha_t = \frac{\tan \alpha_n}{\cos \beta}$

(6) $d_b = \frac{z \cdot m_n \cdot \cos \alpha_t}{\cos \beta}$

其中
Where:

d_{Nf1}, d_{Nf2} = 有效齿根圆直径
Effective root circle diameter

d_{Na1}, d_{Na2} = 有效齿顶圆直径
Effective tip circle diameter

a = 齿轮中心距
Centre distance

α_{wt} = 加工压力角
Operating pressure angle

d_b = 基圆直径
Base diameter

z_1, z_2 = 齿数
Number of teeth

m_t = 实际模数
Real module

α_t = 实际压力角
Real pressure angle

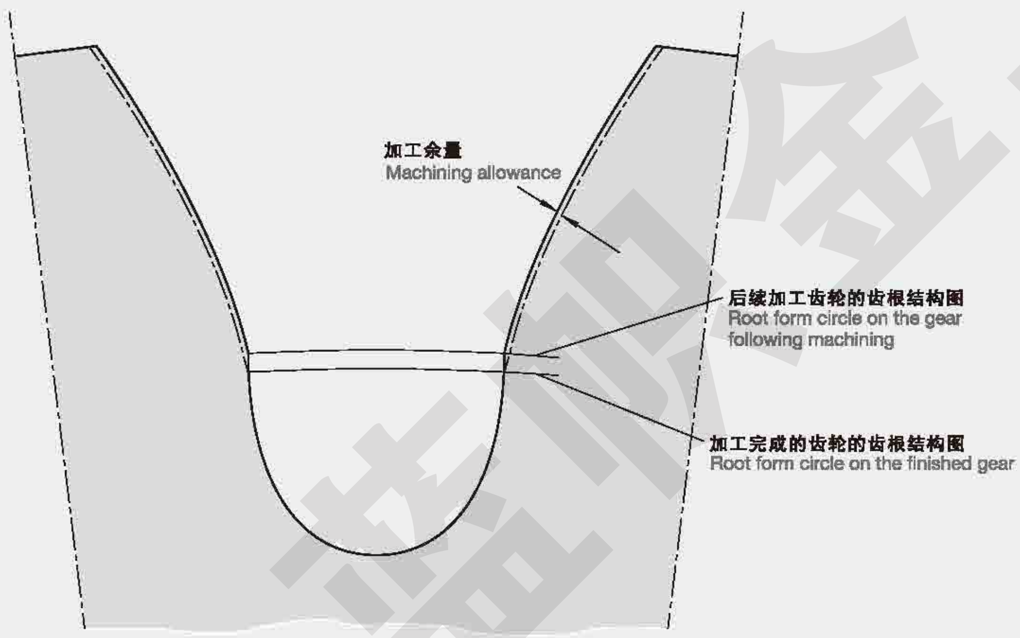
β = 螺旋角
Helix angle

公式(1)和(2)中179页，齿顶圆直径或倒角值是已知的，相配合齿轮的齿顶圆直径也可以作为有效齿顶圆直径进行使用。

can be improved by a smaller protuberance quantity, a larger addendum, or a smaller tooth tip radius on the basic hob profile.

In formulae (1) and (2), page 179, either the tip circle diameter, or if a chamfer is present, the tip form circle diameter of the corresponding mating gears, are employed as the effective tip circle diameter.

齿平面上的齿间隙形状
Tooth gap profile in the face plane



切削应力

滚齿加工已经有超过100年的历史了，从滚齿加工工艺开始，人们就一直在与滚刀的磨损问题进行斗争。
然而金属切削工艺可以用三个特征值来概括：即切削速度v，进给量f_a，以及横向进给量a，在滚齿加工中有两点需要特别引起注意。
与车削和铣削相比，滚削工艺中存在着更多的切削变量。这些变量来源于加工过程并且超出刀具和工件的几何角度范围。

切削工艺所产生的影响并不能通过这三个参数之间的相互关系加以简单的解释。

Thamer(1)在他对切削应力的研究过程中已经发现，滚齿加工过程中作用在每个刀刃上的切削应力可以根据切削截面面积的大小计算出来。
因此对于截面面积的计算对于二者的关系非常重要。
除此之外，知道滚齿加工时的切削截面面积后还可以预测刀具的磨损情况，并能够评估适合滚齿加工的切削材料。
小模数滚刀的切屑厚度和切屑长度受切削速度和进给速率的影响很小，而它们主要还是由滚刀和工件的几何角度决定的，
图1给出了在三种不同轴向进给量的情况下每个切削刃上的切削应力情况，切削实例是采用逆铣法进行直齿轮的加工。
在刀刃进刀侧我们可以看到，切削应力在初始加工时急剧上升，而在啮合长度末尾位置切削应力开始逐渐下降。

除去第一个刀具切削刃后我们可以发现，实际情况中尽管轴向切削进给不同，但几乎其它所有切削刃上的切削应力大小几乎相同。造成这一现象的原因在于这些切削刃的切屑形状基本上是由刀具和工件的尺寸决定的。我们还可以看到，参与金属切削的切削刃数量会随着轴向进给速度的加快而增多。

The cutting forces

The hobbing process has been known for over a century. For almost as long, people in the trade have grappled with the problem of hob wear.
Whereas in turning and milling the metal cutting process can be characterized by 3 values, namely the cutting speed "v", the feed "f_a" and the infeed "a", two special points must be taken into account in hobbing.
In contrast to turning and milling, considerably more parameters act on the cutting process. These parameters result from the manufacturing process and beyond that from the geometry of the tool and the workpiece.

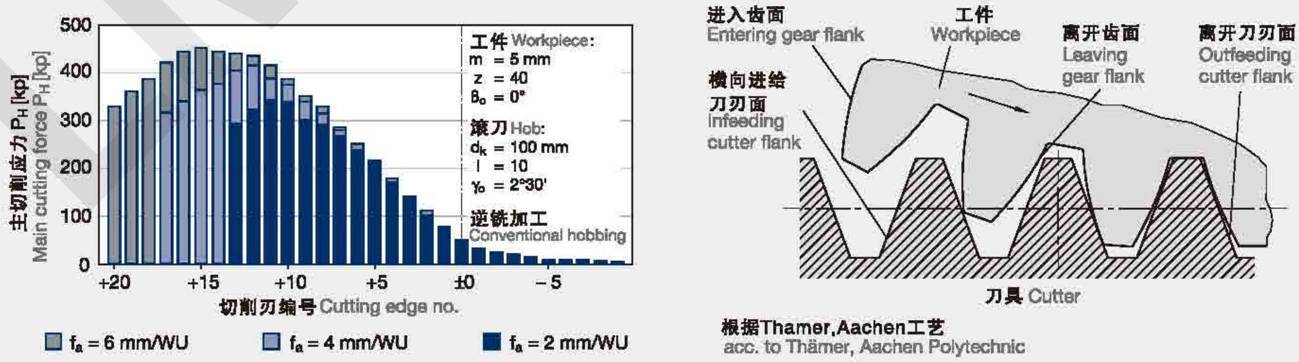
The effects arising from the cutting process cannot easily be explained by the interrelationship of these parameters.

Thämer (1) found already during his studies of the cutting forces during hobbing that the cutting forces occurring on each tool cutting edge can be calculated from the cross-sectional area of cut involved. Calculating the cross-sectional areas of cut is therefore very important in this connection.
In addition to this, knowing the crosssectional areas of cut occurring in hobbing also makes it possible to forecast the tool wear and to assess the suitability of specific cutting materials.
The chip thicknesses on small modules and the chip lengths can be influenced only slightly by the cutting speed and the feed rate, and are determined principally by the geometric dimensions of the hob and the workpiece.

Fig. 1 shows the cutting forces occurring on the individual cutting edges for three different axial feeds, as they arise when conventional hobbing a spur gear. At the entering cutter side one can see that the cutting forces initially rise steeply, after which they gradually decrease up to the end of the engagement length.
Apart from the first working cutting edges it is found that almost equal cutting forces are present on virtually all other cutting edges despite different axial feeds.

The reason for this phenomenon is that the chip shapes at these cutting edges are determined almost exclusively by the cutter- and workpiece size.

1
滚齿时进给量对切削应力的影响
Effect of the feed on the cutting force in hobbing



根据Thamer,Aachen工艺
acc. to Thämer, Aachen Polytechnic

然而在我们的例子中，当刀具每转轴向进给量为2mm时，只有13个切削刃在进刀侧进行加工，当刀具以每转轴向进给量量为4mm时，有17个切削刃的进刀侧参与加工。最后当刀具每转轴向进给量为6mm时，有20个切削刃的进刀侧参与加工，比进给量为2mm时大50%。

这些切削应力图还告诉我们，在滚齿加工过程中每个切削刃所承受的载荷应力大小是不同的，这就自然导致其磨损程度不同。轴向进给对最大主切削应力的影响效果如图2所示。在该例子中，当工件每次回转的进给量递减为3mm时切削应力开始增加。进给量超过3mm时切削应力开始逐步增加，而当进给量达到6mm时应力开始逐渐减少。当进给量达到10mm时的切削应力大约是4mm进给量时的两倍左右。

在滚齿加工过程中，从每个刀具切削刃位置断开的切屑厚度如图3内容所示。我们可以看到从刀片切入点位置开始，切屑的厚度按照线性比例增加。除了第一个加工切削刃存在一定的偏差外，几乎其它所有轴向进给速度下的情况是相同的。当工件每转进给量为10mm时，切屑的最大厚度超过0.5mm。该例子中，工件每转进给量为6mm时，切屑的最大厚度大约为0.45mm，而当工件每转进给量为4mm时：切屑的最大厚度大约为0.35mm，进给量为2mm时，切屑的最大厚度大约为0.28mm。

Ziegler（2）说明切削速度对主切削应力无明显影响。(图4)当切削速度维持在50m/min时，对任何切削材料进行加工时，主切削应力大小几乎维持不变。而当切削速度降低时切削应力则有所增加。逆铣加工时切削应力的增加幅度比顺铣加工时要大。当切削速度达到50m/min时，切削应力开始呈现下降趋势，并与齿轮的参数数据和切削工艺无关。

当切削速度达到一定值后，切削应力不会继续减少。这一特性在使用模数为1.5的硬质合金滚刀进行加工时尤为显著。所有刀具的进给量可以选取该刀具模数数量的2/3作为其进给量值。主切削应力的大小与工件尺寸加工条件有关外，特别与齿数和轮廓位移量有关。然而，主切削应力的大小还与使用的刀具节数有关，特别是刀具中实际参与加工并转动的刀具节数有关。

Ziegler（3）研究表明，其它方面也对切削应力有一定的影响，包括刀具的进刀方向，工件圆周面的应力，以及此应力和工作台的旋转方向的协调。如果刀具的进刀方向和相关工件的运动方向相同，那么主切削应力的分力与工件转动方向相反。这就表明圆周应力对机床工作台产生压力作用，因此分度蜗轮对驱动蜗杆有很强的作用力。这样工作台就不会产生附加运动。另一方面，如果进刀方向相反，主切削应力的分力顺着工作台旋转的方向。

It can also be seen that the number of cutting edges taking part in the metal removal increases with faster axial feed. Whereas in our example only 13 cutting edges work on the entry side of the cutter at an axial feed of 2 mm per work rotation, this becomes 17 cutting edges already at 4 mm feed per work rotation and finally 20 cutting edges at 6 mm feed per work rotation, i. e. about 50 % more than at a feed of 2 mm.

These cutting force diagrams also reveal that in hobbing the individual cutting edges carry different loads, which naturally results in a non-uniform wear pattern. The effect of the axial feed on the maximum main cutting force is shown in fig. 2. The cutting force increases in the present example degressively up to a feed of 3 mm per work rotation. Over 3 mm feed a slightly progressive increase in cutting force is found, which changes at 6 mm into a slightly degressive course. At 10 mm feed the cutting force is approximately double that at 4 mm feed.

The chip thickness which have to be parted off from the individual cutting edges during hobbing are shown in fig. 3. One can see that the chip thickness increase lineary from the point of contact towards the entering cutter side. They are almost the same for all axial feeds and only exhibit certain deviations at the first working cutting edges. At a feed of 10 mm per work rotation the maximum chip thickness is over 0.5 mm. At a feed of 6 mm per work rotation a maximum chip thickness of about 0.45 mm occurs in the present case, whereas at a feed of 4 mm per work rotation the maximum chip thickness becomes 0.35 mm and at a feed of 2 mm per work rotation it becomes about 0.28 mm.

Ziegler (2) demonstrated that the cutting speed has no appreciable effect on the main cutting forces (fig. 4). With all materials, the main cutting forces remain almost constant at cutting speeds above 50 m/min., whereas they rise when the cutting speeds decrease. The rise is somewhat steeper during conventional hobbing than with climb hobbing. The decreasing trend is found up to about 50 m/min., independently of the milling process and the gear data.

At higher cutting speeds the cutting forces can not be reduced any further. This was confirmed particularly by the use of a module 1.5 carbide hob. For the feed, a value was chosen with all cutters which corresponds numerically to about 2/3 of the module.The main cutting forces depend apart from the machining conditions on the workpiece dimensions, in particular the number of teeth and profile displacement. They are also affected, however, by the number of segments of the cutter and particularly by the latter's true running.

Ziegler (3) studied, among other aspects, also the effect of the lead directions of cutter and workpiece on the circumferential force and the coordination of this circumferential force with the direction of rotation of the table. If the lead directions of cutter and workpiece correspond, the component from the main cutting force opposes the workpiece rotation.

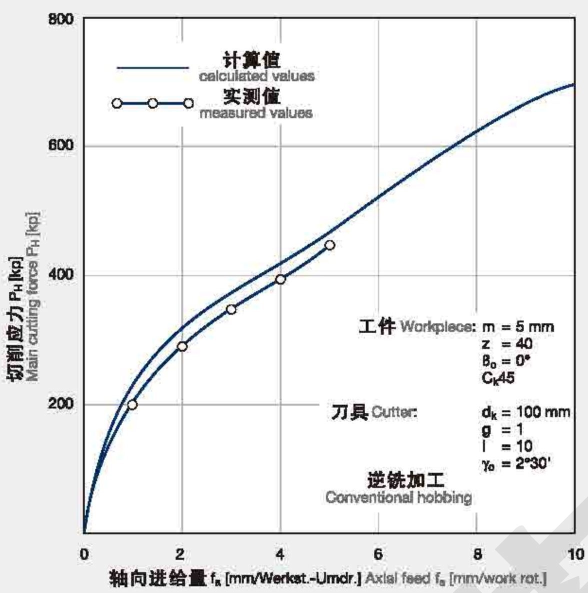
如果圆周作用力与工作台转向相反，则事实上该作用力对工作台没有任何影响。但是如果二者方向相同，那么逆铣滚齿加工设备的工作台会按照滚刀节圆相互啮合的频率产生运动，该频率大小

This means that the circumferential force presses the machine table and therefore the indexing worm wheel more strongly against the drive worm. No additional table motions can then take place. If on the other hand the lead directions are opposite, the compo-

2

轴向进给量对最大主切削应力的影响

Effect of the axial feed on the maximum main cutting force

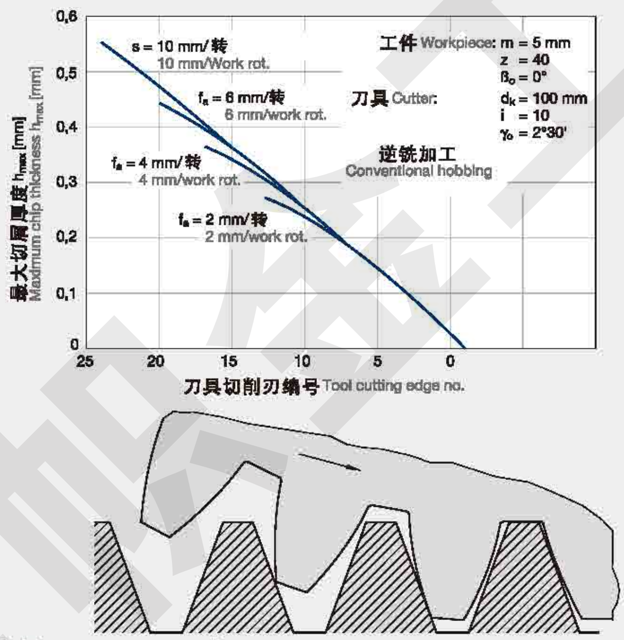


根据Thamer, Aachen工艺
acc. to Thämer, Aachen polytechnic

3

轴向进给量对切削厚度的影响

Effect of the axial feed on the chip thicknesses

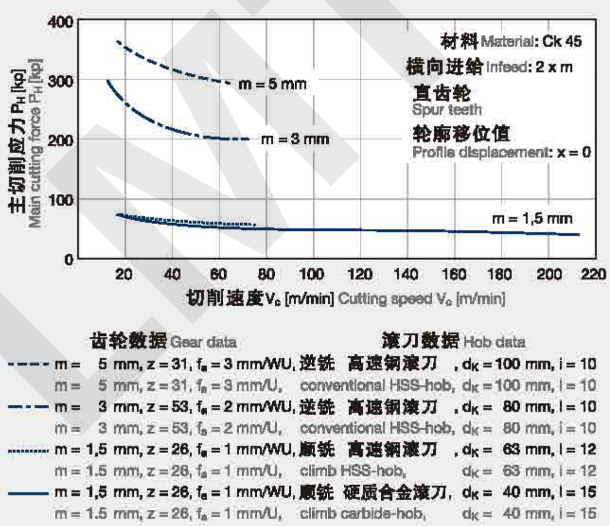


根据Thamer, Aachen工艺
acc. to Thämer, Aachen polytechnic

4

切削速度对主切削应力的影响

Effect of the cutting speed on the main cutting forces

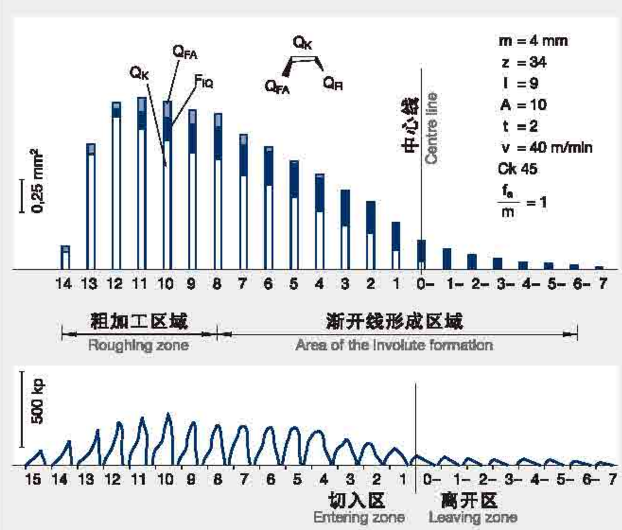


根据Ziegler WZL–RWTH工艺
acc. to Ziegler, Aachen polytechnic

5

单个齿间隙工件加工时切削横截面和切削应力

Cross-sectional areas of cut and cutting forces in the case of a workpiece with only one tooth space



根据Ziegler WZL–RWTH工艺
acc. to Ziegler, Aachen polytechnic

与蜗轮和蜗杆齿轮之间的相互作用情况有关，并会导致加工齿面上产生粗糙加工质量和细波浪式的表面。主切削应力的分力顺着工作台旋转的方向。

如果圆周作用力与工作台转向相反，则事实上该作用力对工作台没有任何影响。但是如果二者方向相同，那么逆铣滚齿加工设备的工作台会按照滚刀节圆相互啮合的频率产生运动，该频率大小与蜗轮和蜗杆齿轮之间的相互作用情况有关，并会导致加工齿面上产生粗糙加工质量和细波浪式的表面。

切口横截面区域
在研究滚刀的磨损状态时，需要了解每个切削齿的切口横截面情况。Ziegler(4)对切削应力的研究为切口横截面的研究提供了理论保证。

在滚齿加工过程中，滚刀的每个切削齿的主切削应力和切削横截面都是不一样的。这使得滚齿加工与其他机械加工工艺有所不同，因为其它加工的进给量增加会迅速导致切屑厚度的改变。图5中，对应某个特定的齿轮，下方是测量的切削应力，上方是计算得到的最大切削横截面。横截面再根据齿顶的切削刃以及刀齿的两个齿面进行划分。我们可以很清楚地看到位于刀具齿顶位置的粗切削区域的横截面远远大于刀齿齿面的截面。为了得到该图中的值，切除只有一个齿间隙的齿轮，从而使切削横截面的面积与相应的切削力保持一致。当切削应力和切削截面面积之间的关系确立后，所要做的工作就是确定刀具切齿的磨损形状和产生原因。

磨损标准
您需要了解滚刀刀齿中齿面磨损，切削刃钝化，粘屑和点蚀等术语之间的差别(图6)。为了客观地研究滚刀的磨损情况，我们与厂商合作，通过大量产品进行测试。图7中，磨损痕迹宽度“B”指的是齿面磨损。图7上方的曲线给出了已知的磨损特性，即初始时略有下降，然后上升，上升阶段几乎是以线性比率进行的。随着加工数量增加，磨损宽度也逐步上升。下方的曲线是以切削齿轮数量为基础的。我们可以找到曲线的最低点，该点对应的磨损痕迹值表示此时刀具耗费最小。如果观察每个刀具滚齿的磨损情况，其结果如图8所示。此时有40个齿被切，刀具处于一个特定的位置。

此时的粗加工往往是使用相同的切削刃完成的，此时只有少量的切削齿达到最大的磨损量，而其它切削齿则磨损很少甚至没有磨损。另一方面，当刀具产生轴向位移时（滚刀位移）。每个加工周期内其它切削刃会移向最大应力作用区域，所以事实上大多数刀具切削齿的磨损痕迹宽度是相同的。

nent from the main cutting force acts in the direction of rotation of the table.

If the circumferential force acts against the table rotation, it has virtually no influence on the latter. If it acts in the same direction, however, the table on conventional hobbing machines is subjected to movements at the segment engagement frequency, the magnitude of which corresponds to the play between the worm and the worm gear, and which may lead to a rough, rippling machining pattern along the tooth flank to be machined.

The cross-sectional areas of cut
To study the wear behaviour of hobs it is necessary to know the cross-sectional areas of cut for the individual cutter teeth. Already the study by Ziegler (4) of the cutting forces presupposed a knowledge of the cross-sectional areas of cut.

The main cutting force and the cross-sectional area of cut are in hobbing different for each individual tooth of the cutter. This makes hobbing quite different from other machining processes, where an increase in feed immediately produces a change in chip thickness. In fig. 5, page 183, the measured cutting forces below and the calculated maximum cross-sectional areas of cut above are plotted one above the other for a particular gear. The cross-sections are sub-divided according to the cutting edges on the tip and on the two flanks of the cutter teeth. It can be clearly seen that in the roughing zone the cross-sections on the cutter tip far outweigh those of the flanks. To obtain the values for this figure, gears with only one tooth space were cut, so that the cross-sectional area of cut could be coordinated with the corresponding cutting force. After the connection between cutting force and cross-sectional area of cut has been established, the task was to define the wear forms and their causes on the cutter tooth.

Wear criteria
On the hob tooth a distinction is made between flank wear, cutting edge rounding, chipping and pitting (fig. 6). To be able to study the wear behaviour of hobs realistically, the tests were carried out in cooperation with the industry under mass production conditions. In fig. 7 the wear mark width "B" refers to the flank wear. The upper curve of the figure shows the well known characteristic with an initially degressive rise, which is followed by an almost linear section. As the number of units increases, the rise becomes progressive. In the lower curve the wear is based on the number of units cut. A minimum is then found and consequently a specific value for the wear mark at which the proportional tool costs become minimal. If one looks at the wear of each individual cutter tooth, a representation as shown in fig. 8, page 185, results. Here, 40 gears were cut in a quite specific cutter position.

The roughing work is in the case always carried out by the same cutting edges, so that maximum wear occurs on a few cutter teeth which have to be reground although other teeth show little or no wear. With axial cutter displacement (hob shift) on the other hand, other cutting edges move into the maximum stress area

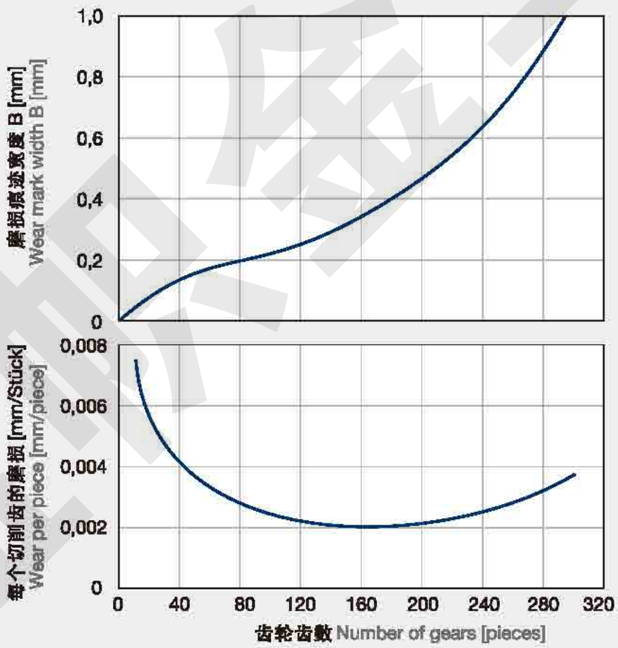
我们对切削条件对刀具磨损的影响特别感兴趣。进给量对磨损痕迹宽度“B”的影响如图9所示。当进给量较小时，切屑厚度和切削应力比较小，然而起始切削齿的数量很多。当进给量增加时，切口横截面的面积将会增加，然后切削刃的作用力和温度会提高，而起始切削齿数则减少。

如果我们查看一下图10中平均磨损量与进给量的函数关系，我们可以看到随着进给量的增加，磨损量的增长幅度很小，而通过增加进给量来缩短切削时间与刀具的轻微磨损而言是非常合算

during each work cycle, so that a large number of cutter teeth have a virtually identical wear mark width.
The effect of the cutting conditions on tool wear is of particular interest.
The dependence of the wear mark width “B” on the feed is shown in fig. 9. With small feeds the chip thicknesses and the cutting forces are small, whereas the number of starting cuts is high. With greater feed the cross-sectional areas of cut increase, and with them the cutting edge stress and temperature, whereas the number of starting cuts decreases.

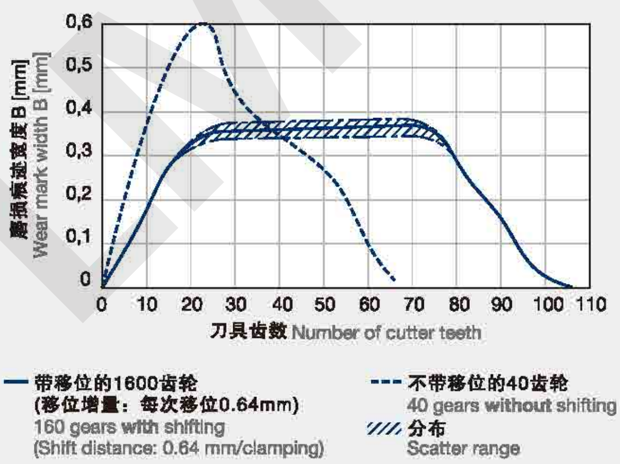
6
滚刀切削齿的磨损类型
Types of wear on the hob tooth

7
齿面磨损(背面磨损)和加工数量的关系
Flank wear (back wear) as a function of the number of units



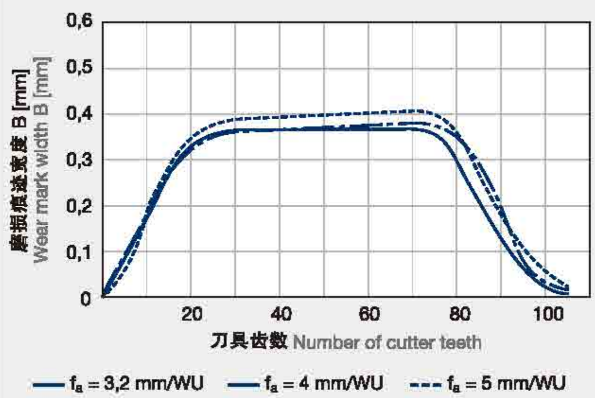
根据Ziegler,Aachen工艺 acc. to Ziegler, Aachen polytechnic

8
使用和不使用移位磨损痕迹宽度
Wear mark width when hobbing with and without shifting



根据Ziegler,Aachen工艺 acc. to Ziegler, Aachen polytechnic

9
磨损痕迹宽度和进给量的关系
Wear mark width as a function of the feed



根据Ziegler,Aachen工艺 acc. to Ziegler, Aachen polytechnic

的，从该区域的研究可以推断，进给量的增加并不受到磨损的限制，而是根据齿轮的实际质量，特别是进给痕迹确定的，与进给量相比，切削速度对刀具磨损的影响要大得多。稍后我们将回到这一事实上来。

Hoffmeister（5）根据他的研究发现，按照刀具，加工和齿轮标准的要求对滚刀磨损的影响进行了分类，磨损是受刀具直径，刀具刀头数量以及滚刀移位数量影响的。其他影响因素还有齿顶圆半径，刀具轮廓的铲背角，切削刃的前角，最后还有刀具的设计和使用的材料等。

磨损主要受以下加工条件的影响：
进给量“f_a”，刀具位移“S_H”，切深“a”，切削速度“v”。其它影响因素还有滚齿加工工艺，滚齿加工设备的状况，工装夹具，最后是冷却液。

齿轮对滚刀磨损的影响因素包括：齿轮的直径，模数，螺旋倾角，轮廓位移x・m以及齿轮的厚度。同时我们也不能忽略齿轮材料对刀具磨损的影响。对磨损影响的诸多因素可以分为两类：
1. 构成齿的几何角度的数值以及确定切削弧长度和切屑厚度的刀具。

If one looks in fig. 10 at the mean wear as a function of the feed, one can see that the increase in wear at greater feed is so little, that the reduction in cutting time achieved by increasing the feed is much more important than the only slightly worse tool wear. It can be deduced from this that in the area studied an increase in feed is not limited by the wear, but by the attainable gear quality, particularly as regards the feed markings.

In contrast to the feed, the cutting speed affects tool wear far more. We shall come back to this fact later.

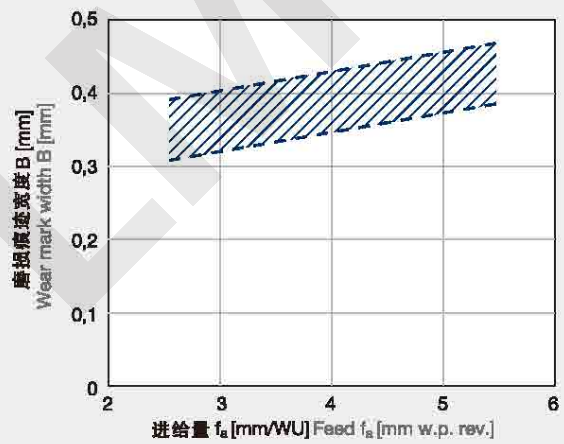
Hoffmeister (5) classified the effects on hob wear according to cutter, machining and gear criteria. According to his findings, the wear is influenced by the diameter of the tool, the number of starts of the tool, and the number of segments. Further influencing factors are the tip radius, the relief angle of the cutter profile, the rake angle of the cutting edges, and finally factors such as the tool design and material.

Wear is strongly influenced by the following machining conditions:
By feed “f_a”, by shift “s_H”, cutting depth “a”, cutting speed “v”. Other factors affecting wear are the machining method, the condition of the hobbing machine, the mounting and clamping of the tool (run-out) and the gear and, finally, the coolant.

The gear affects hob wear through its diameter, the module size, the helix angle of its teeth, the profile displacement x · m and through the gear width. The effect of the gear material on tool wear must not be forgotten either. This large number of factors affecting wear can be divided into two groups.

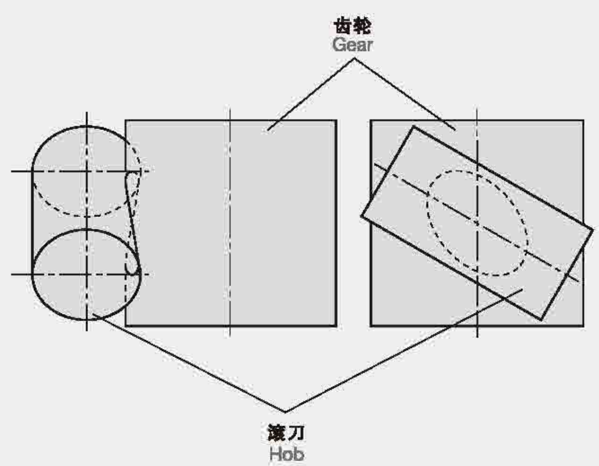
1. Values which from the geometry of the teeth and the cutter determine the length of the cutting arc and the chip thickness.

10
磨损痕迹宽度和进给量的关系
Wear mark width as a function of the feed



根据Ziegler,Aachen工艺 acc. to Ziegler, Aachen polytechnic

11
贯穿曲线的基本原理
Principle of the penetration curve



2. 技术性影响因素，例如切削速度，切削材料/配合刀具，切削刃的几何角度，所使用的切削润滑油等。

2. Technological effects, such as cutting speed, cutting material/ tool pairing, cutting edge geometry, use of cutting oil etc.

啮合条件

Hoffmeister(6)对刀具切入边和离开边加以区分，它们由中心齿分开，并位于齿廓生成区域和预切割区域之间。刀具的中心齿是位于滚刀 / 齿轮轴线的交叉点的齿。中心齿位于齿廓生成区域的中心位置，预切削区域主要取决于滚刀的外部形状。带有圆柱形刀具的区域比具有锥形或圆形引导末端的区域要大一些。

Engagement conditions

Hoffmeister (6) distinguishes between the cutter entering and leaving sides, which are separated by the central tooth, and between a profile generating zone and a precutting zone. The central tooth is the cutter tooth which is situated in the axial hob/gear crossing point. The central tooth lies in the centre of the profile generating zone. The pre-cutting zone depends on the external shape of the hob. This will be greater with cylindrical tools than with tools which have a tapered or round leading end.

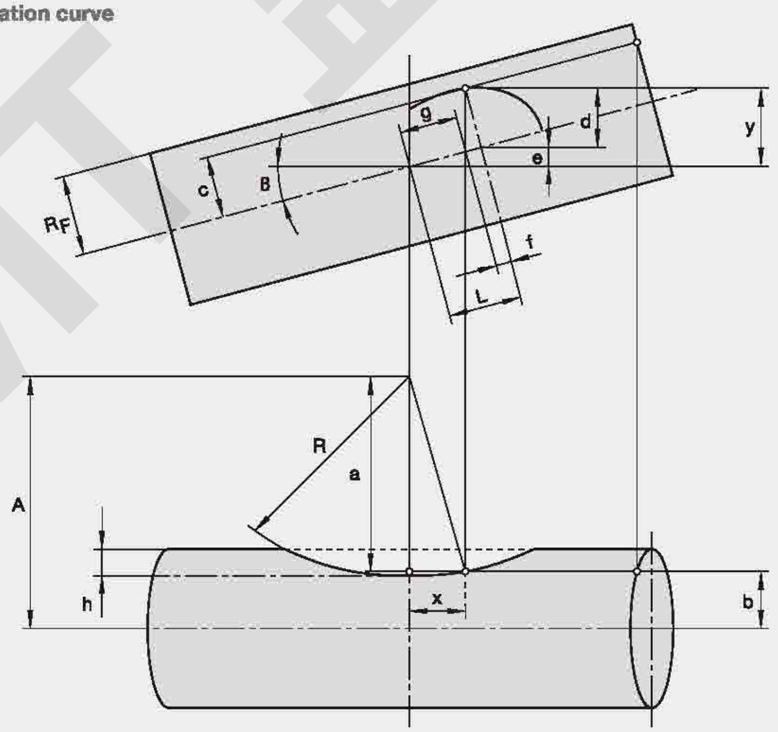
为了计算切削弧的长度和切屑的厚度，需要精确定义刀具/工件的贯穿曲线：

To be able to calculate the length of the cutting arc and the chip thickness, it was necessary to define the tool/workpiece penetration curve accurately.

在刀具/工件贯穿位置（7），贯穿曲线在齿轮的圆柱表面形成一个椭圆形切削截面。椭圆截面的位置取决于两个轴线相交的角度。另外，椭圆的形状由齿轮和滚刀的尺寸所决定。
对滚齿机上的刀具进行正确设置的基本要点是平行于滚齿设备所在平面的切削椭圆的投影。如果使用图12中的参数名称，那么可以使用图13，188页中的公式。

In the tool/workpiece penetration (7), fig. 11, the penetration curve forms a cutting ellipse on the cylindrical generated surface of the gear. The position of this ellipse depends on the crossing angle of the two axes. In addition, the shape of the ellipse is determined by the sizes of the hob and the gear.
The essential point for assessing the correct setting of the tool on the hobbing machine is the projection of this cutting ellipse in a plane which is parallel to the hobbing machine. If the designations given in fig. 12 are used, the formulae presented in fig. 13, page 188, can be developed.

12
贯穿曲线的比例分布
Proportions of the penetration curve



通过这些公式的帮助，我们可以通过作图来对刀具的设置进行估算（图14）。通过投影椭圆，我们可以在Y轴上得到一个最大值。

该值在刀具轴线上的投影值表示逆铣加工时的切入区域。如果该曲线沿着Y_{max}向上延伸到$Y = Y_{max}$，工件每旋转一圈的进给量，我们可以在曲线上得到该点的位置，从而确定顺铣加工的切入区域的位置。

当刀具和加工齿轮的移动方向相同时，该曲线投影在刀具轴线上的位置与斜齿轮切入区域的刀具长度相等。如果考虑带锥度导程的刀具，那么贯穿线的有关知识对大齿轮尤其重要。
图15解释了同圆柱形刀具相比锥度形刀具的接近长度是如何迅速缩短的。

With the help of these formulae a graphic drawing can be produced which makes it possible to assess the tool setting (fig. 14).

In the penetration ellipse we obtain a maximum value for the Y-axis. The projection of this value onto the cutter axis shows the entering zone for conventional hobbing. If the curve is traced beyond $Y_{max.}$ up to a value $Y = Y_{max.}$ feed per workpiece rotation, we obtain a point on the curve from which the entering zone for climb hobbing can be determined.

The projection of this curve location onto the cutter axis corresponds to the cutter length for the entering zone on helical gears when the tool and the gear have the same direction of lead. If a tool with a tapered lead is brought into the consideration, knowledge of the penetration line is important particularly with large gears.

13

贯穿曲线的计算

Calculation of the penetration curve

R_F = 刀具圆角半径
Tool radius

h = 齿高/切深
Tooth height = Cutting depth

R = 工件外径
Workpiece outside diameter

$\beta = \beta_0 - \gamma_0$

β_0 = 齿轮螺旋角
Helix angle of the gear cutting

γ_0 = 滚刀导程角
Lead angle of the hub

$$A = R_F - h + R$$

$$a = R\sqrt[2]{1-\left(\frac{x}{R}\right)^2}$$

$$b = A - R\sqrt[2]{1-\left(\frac{x}{R}\right)^2}$$

$$c = R_F\sqrt[2]{1-\left[\frac{A-R\sqrt[2]{1-\left(\frac{x}{R}\right)^2}}{R_F}\right]^2}$$

$$d = R_F\sqrt[2]{1-\left[\frac{A-R\sqrt[2]{1-\left(\frac{x}{R}\right)^2}}{R_F}\right]^2}\;\frac{1}{\cos\beta}$$

$$e = x \cdot \tan\beta$$

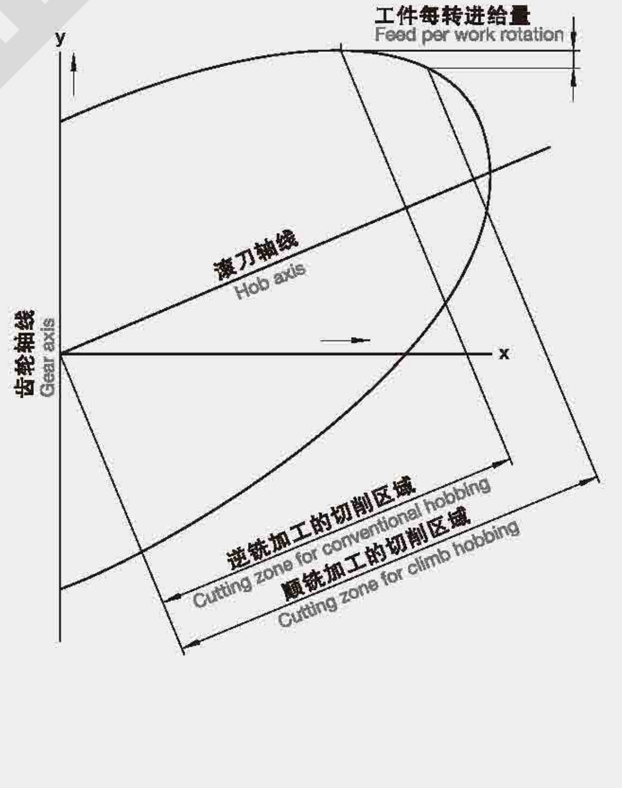
$$f = R_F\sqrt[2]{1-\left[\frac{A-R\sqrt[2]{1-\left(\frac{x}{R}\right)^2}}{R_F}\right]^2}\cdot\tan\beta$$

$$g = \frac{x}{\cos\beta} \qquad y = d + e \qquad L = f + g$$

14

刀具/齿轮的交互关系

Tool/gear penetration



这里应该指出的是，刀具导程的角度和形状也应该与工作条件保持一致，以防止切齿部分负载过大：这样会可能再次导致刀具切削刃的过早磨损。通过对滚齿设备上滚刀定位有关知识的认识，现在我们可以系统地完成有关磨损情况的认识和研究(图16)。

在测量磨损量时，我们应该区别以下术语，刀刃磨损，这里用"B_K"表示，移出切削面磨损，用"B_A"表示，以及切入面磨损，用"B_Z"表示。移出切削面是指相对运动方向与移出齿轮面相同的刀刃表面。刀具切入面是指生成运动过程中向齿轮面移动的刀具切削面，当我们把顺铣加工时刀具磨损的测量值与逆铣加工时刀具磨损的测量值进行比较时，齿轮面的旋转方向与刀具的旋转方向保持一致。

这就表示，当画出磨损曲线后，顺铣加工的中心齿（称作0）位于磨损图表的右侧方，而逆铣加工的中心齿位于磨损图表的左侧方。从图表中我们可以看到，顺铣加工时参与切削加工的齿数要比逆铣加工参与切削的齿数多。逆铣加工时作用在刀具切削刃上的应力值要比较顺铣加工时的作用力大一些。这一点我们可以在逆铣方式滚齿时参与切削的齿数比顺选方式少。这一事实中得到解释。所以，逆铣加工时的切削应力和切入齿面的磨损量最高。对于切入刀具有较大的切削弧长度时该情况尤其明显。

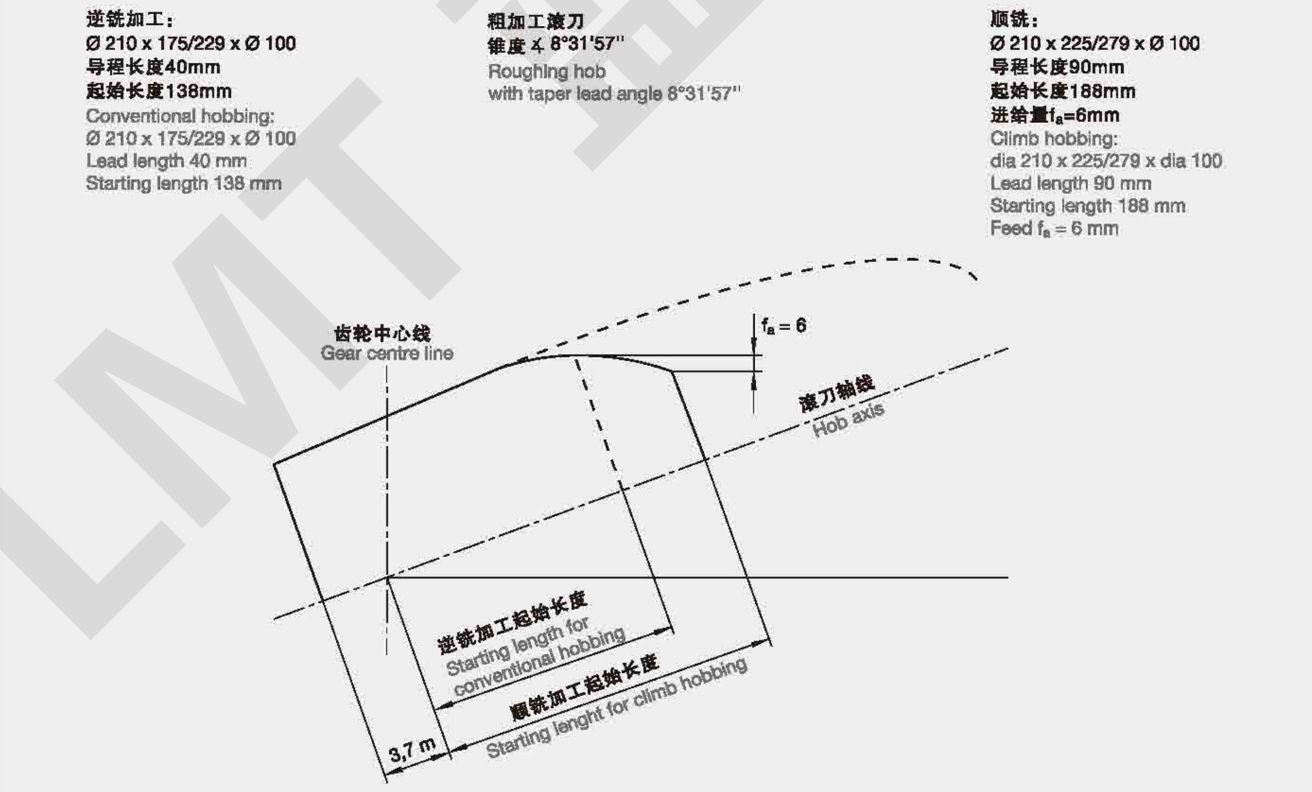
Fig. 15 shows how the approach lengths become decidedly shorter in the tool with tapered lead as compared with the cylindrical tool. It should here be pointed out that the angle and shape of the lead should also be carefully matched to the conditions, to prevent overloading the entering teeth, because this would again lead to premature wear. Backed by the knowledge of the hob positioning on the hobbing machine the wear studies could now be systematically carried out (fig.16, page 190).

In the wear measurements one makes a distinction between the tip wear, here identified by "B_K", the wear of the outgoing cutter flank called "B_A", and the wear of the approaching flank called "B_Z". The outgoing cutter flank is the flank whose relative motion is the same as that of the leaving gear flank. The approaching tool flank is the cutter flank towards which the gear flank moves during the generating motion. When comparing the results of the wear measurements on the hob which had been used for climb hobbing with the wear measurements on the hob which had been used for conventional hobbing, the direction of rotation of the gear blank and the direction of rotation of the cutter were kept the same.

This means that when the wear curve is drawn, the central tooth (called 0) lies in the wear diagram for climb hobbing on the right-hand diagram side, whereas the central tooth for con-

15

带锥度的滚刀的贯穿曲线 齿轮：模数10，405齿，螺旋角29°
Penetration curve for a hob with lead. Gear: module 10, 405 teeth, helix angle 29°



逆铣加工时，主要的切削应力由移出切削面承受的。这时，在齿的生成区域磨损情况往往更为严重。这一点我们可以通过以下事实加以解释，即在逆铣加工时齿生成区域内大部分切削弧线的长度仍然比较长。因此，在顺铣加工过程中，加工区域主要位于刀具的切入端，而逆铣加工时加工区域主要位于移出端。

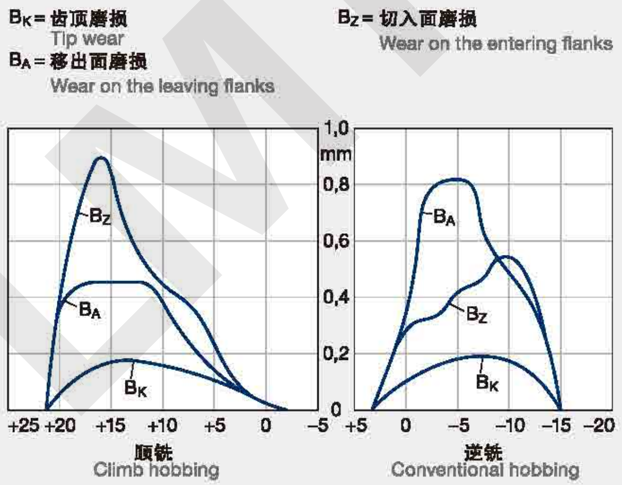
我们可以对磨损图作出如下解释：在顺铣加工时，位于外侧切削齿面的有效后角比内侧齿面的有效后角小，这就是外侧切削齿面的最大磨损量会受到小角度后角的影响的原因，这种解释对逆铣是无效的。尽管外层切削齿面也存在齿面磨捐情况，但其有效后角的角度较大。因此，后角角度大小不是齿面磨损的唯一原因。为了给齿面磨损做出一个合理的解释，需要对此做出进一步的研究。

ventional hobbing is situated on the left-hand diagram side. It can be seen from the diagram that in climb hobbing more teeth participate in the entering cut than is the case with conventional hobbing. The stress on the tip cutting edges is with conventional hobbing only slightly greater than with climb milling. This is explained by the fact that fewer hob teeth are engaged in conventional hobbing than in climb hobbing. The stress and therefore the wear of the approaching cutter flank is highest with climb milling. This is particularly the case in the entering cutter portion with the greater cutting arc length.

The main stress in conventional hobbing is borne by the teeth of the leaving cutter flank. Here, relatively severe wear takes place even in the profile forming zone. This is explained by the fact that in conventional hobbing the greater cutting arc length still prevails even in the profile forming zone. In climb hobbing the working range is therefore situated on the cutter entering side, in conventional hobbing on the leaving side.

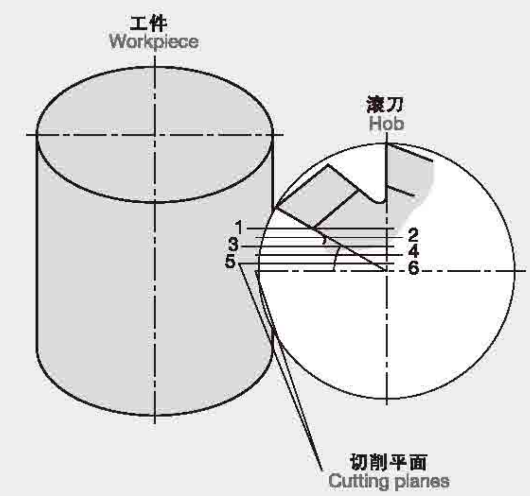
The wear diagrams can also be interpreted as follows: In climb hobbing the effective relief angle is smaller on the outer cutter tooth flank than on the inner one, which is why the maximum wear on the outer cutter tooth flank can be caused by the effect of the smaller relief angle. This explanation is not valid for conventional hobbing. Although flank wear also occurs on the outer cutter tooth flank, the latter has the greater effective relief angle. For this reason the effect of the relief angle cannot be the only cause of the flank wear. To find a credible explanation for the origin of the flank wear, further studies were necessary.

16
滚刀的磨损分布情况
Wear distribution on the hob



根据Sulzer,Aachen工艺
acc. to Sulzer, Aachen polytechnic

17
切屑横截面的判断
Determination of the chip forming cross-sections



根据Sulzer,Aachen工艺
acc. to Sulzer, Aachen polytechnic

滚齿加工时切屑几何形状

Sulzer(B)拟定了一个能够精确判断每个切屑几何形状的计算方法。为此，他研究了在许多切削平面上经过切削齿的切屑生成。目前计算机支持对每个切削面的切屑厚度值的计算。这些值以图表的形式给出——水平线为切削面，标注为1到6(图18)。为了得到各个尺寸关系的整体印象，左侧图表中给出了切屑横截面得到测量值。切削区域的名称位于端线的下方。AB段相当于刀具切入面。BC段相当于刀齿宽度。CD段对于刀具移出面。当计算机提供的切屑横截面的数值用绘图仪表示出来后，我们可以得到一张位于切削面上的切屑截面图。这个坐标图描述了切屑的横截面和切屑轮廓。

如果输出切屑横截面(图17)的计算值代表所有啮合的滚刀刀齿，我们可以得到切屑横截面与滚齿加工时切屑形成过程的总图(图192页)，另外我们还可以得到作用在每个滚齿上的作用应力值以及负载的变化情况。

在模拟各种滚齿加工工艺时，例如同向或反向的逆铣加工或顺铣加工过程，计算机会提供不同的切屑的横截面以及构成形状。同方向的滚齿加工是指刀头和齿轮的加工齿方向是单向的，例如右旋滚刀加工右旋方向的齿轮，而左旋的滚刀加工左旋方向的齿轮。

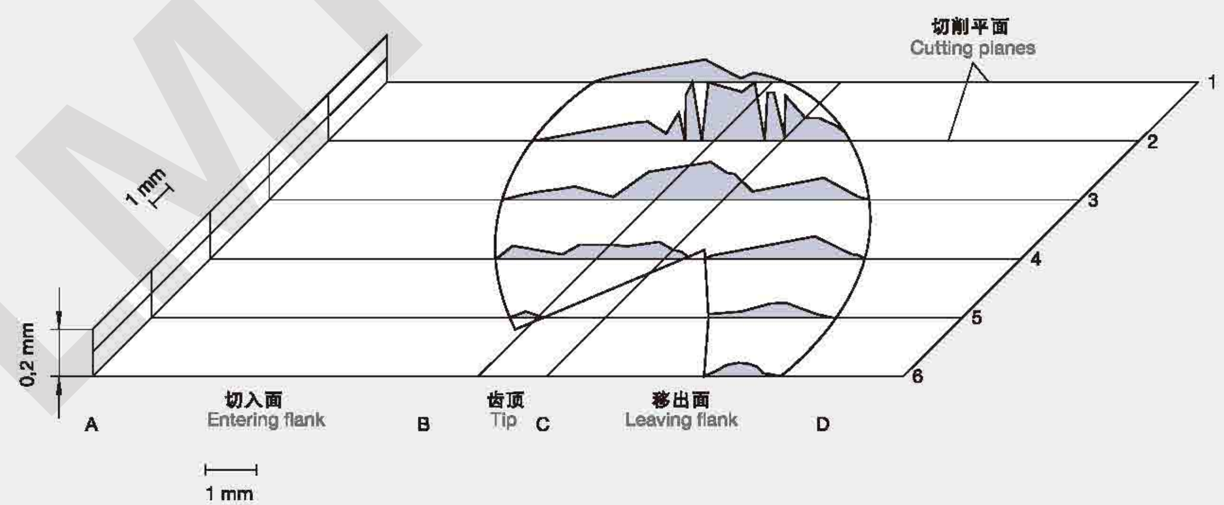
Chip geometry in hobbing

Sulzer (8) drew up a computation process which accurately determines the geometry of the individual chip. For this purpose he studied the chip formation in a number of cutting planes during the passage of a cutter tooth. The computer now supplies for each cutting plane numerical values which correspond to the chip thickness formed. These values – shown diagramatically – produce horizontal lines for the cutting planes with the designations 1 to 6 (fig. 18). To gain an overall impression of the size relationships, the scale of the chip forming cross-sections is given on the left-hand side of the diagram. The designations for the cutting zones are situated underneath the base line. The section AB corresponds to the entering cutter flank. Section BC corresponds to the tooth tip width. Section CD corresponds to the leaving cutter flank. When the values supplied by the computer for the chip forming cross-sections are represented by the plotter, we obtain a picture of the chip cross-sections on the cutting planes. This plotter image provides a representation of the chip cross-sections and the chip outline.

If this calculation of the chip cross-section (fig. 17) is carried out with a representation for all meshing hob teeth, one obtains an overview of the chip forming cross-sections and the chip forms in hobbing (fig. 19, page 192). Furthermore one can recognize the stresses on the individual hob teeth and the varying load within the tooth under observation.

When simulating the individual hobbing processes such as conventional hobbing and climb hobbing and hobbing in the same or in the opposite direction, the computer supplies different chip forming cross-sections and forms. Hobbing in the same direction means that the direction of start of the hob and the tooth lead of the gear are unidirectional, i. e. a cutter with right-hand start ma-

18
切屑横截面的判断
Determination of the chip forming cross-sections



根据Sulzer,Aachen工艺
acc. to Sulzer, Aachen polytechnic

在滚齿加工过程中遇到刀具切削方向与加工齿轮相反的情况，即右旋滚刀加工左旋方向的齿轮，而左旋的滚刀加工右旋方向的齿轮。Thamer(1)对这种情况下切屑结构形状的计算方法在他的研究中。得到证实。齿面磨损精确发生在刀具齿顶到齿面的转换过程中，它不再有效参与金属切削过程。他指出：“在这种情况下，位于角落处的刀具切削刃不能清除切屑，并出现较大程度的磨损痕迹宽度，反过来，我们可以清楚地知道，切屑厚度与刀具磨损没有直接的关系。”

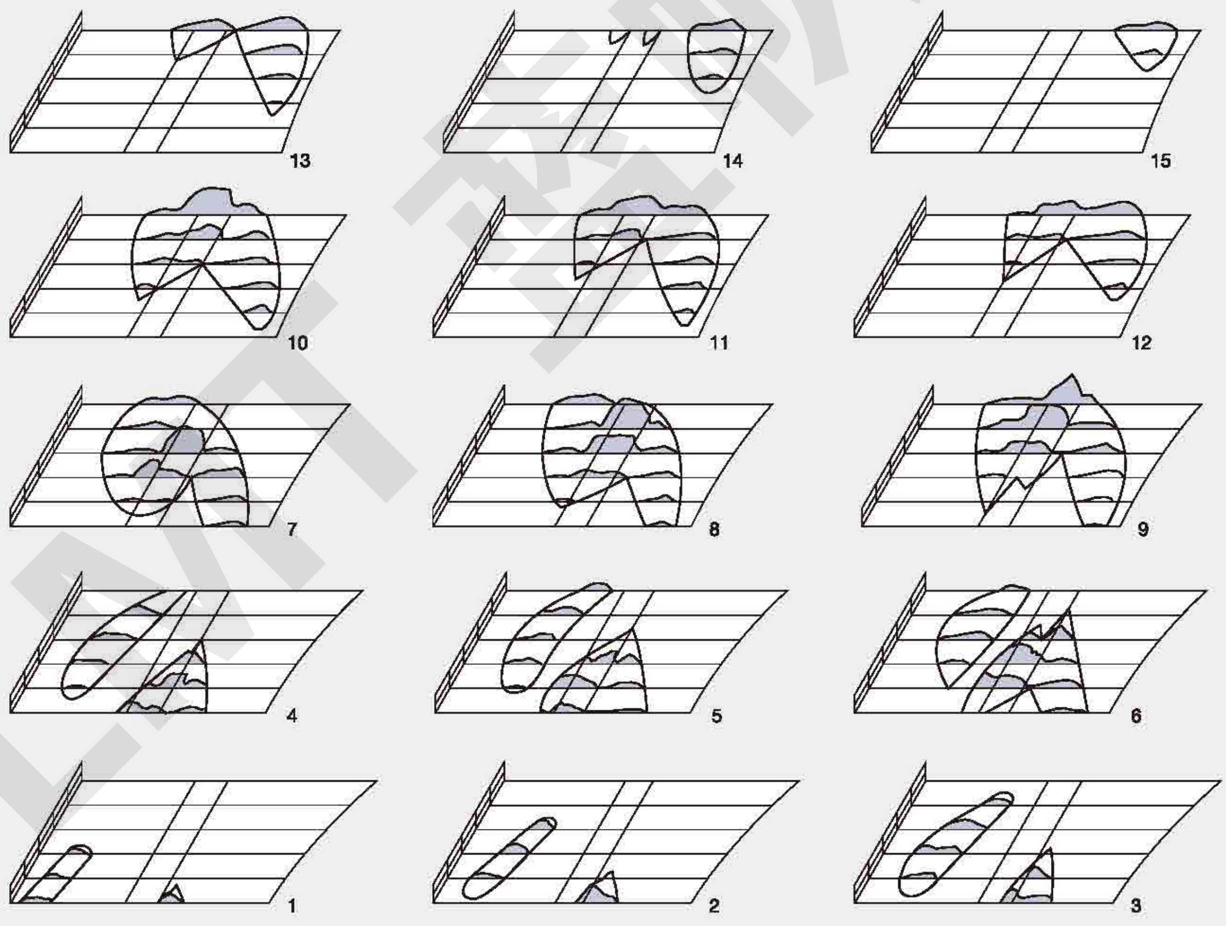
采用Sulzer方法（9和10）绘制的坐标图证实了这种假设。Sulzer的研究主要涉及硬质合金滚刀的磨损情况。他发现了齿面磨损区域的微小粘屑。通过电子显微镜的观察，他研究了切屑轨迹上的移出切削面。并在切削面上发现了压力焊接沉积物。他指出：“切削轨迹和生成条纹的不同方向显示这些条纹是由清除的切屑划出的。没有与对应刀齿相啮合的齿面上会产生这些划痕条纹。切削刃和切削面之间往往会形成一个间隙”。

chines a gear with right-handed teeth and a cutter with left-hand start machines a gear with left-handed theeth.

In the case of hobbing in the opposite direction a cutter with right-hand start machines a gear with left-handed teeth and a cutter with left-hand start machines a gear with right-handed teeth. This computational consideration of chip forming geometry confirmed what Thämer (1) had already found in his studies. Flank wear takes place precisely at those transitions from tool tooth tip to tool flank which are no longer actively participating in the metal cutting process. He states: “In this case the tool cutting edge which just at this corner no longer removes a chip exhibits particularly large wear mark widths, which in turn makes it clear that no direct connection exists between chip thickness and tool wear.”

The plotter images produced by Sulzer's method (9 and 10) confirm this assumption. Sulzer's studies covered mainly the wear behaviour of carbide hobs. Instead of flank wear, he found micro-chipping in this area. Using the scanning electron microscope,

19
网格化滚齿上不同切削碎屑的横截面结构
Different chip forming cross-sections on the meshing hob teeth



根据Sulzer,Aachen工艺
acc. to Sulzer, Aachen polytechnic

切屑和工件表面的碰撞现象可以用切屑形状和切屑的流动现象加以解释。当移出齿面靠近刀具齿顶位置时，切削工艺开始进行。这一阶段中切屑仍然可以自由卷曲。然后，刀具切齿的齿顶部分向啮合区域移动。由于齿间隙的复杂形状和紧密的空间状况，切屑不能自如弯曲。最后，切屑破切入齿面推动离开刀削面到其它工件的加工表面，并在该位置生成焊接沉积点。随着刀具切齿的切削运动，压力焊接点被挤破，然后由后面的切屑重新形成。另外在切削运动中工件产生旋转。这表明工件面逐渐远离移出刀具齿面。切屑以该相对速度从切削面推至切削刃。它会在切削刃产生拉伸应力，该应力会导致硬质合金滚刀产生粘屑。当使用高速钢加工时，该位置产生的挤压应力会造成更多自由齿面产生磨损。当滚齿以反方向运动时，也会产生该现象，但其损坏程度没有这么高。

因此，我们往往把反方向加工作为防止齿面磨损的灵丹妙药。当按照反方向进行滚齿加工时，圆周应力沿着工作台转动方向。此时，圆周应力作用在蜗杆和分度蜗轮中间的空隙上，它按照刀具端节啮合的频率在分度齿轮上生产干涉。这将导致齿轮面上出现碰瞳标记和整个齿轮队列的震荡。通过切削齿顶面的不断交替转换来减少齿面的摩擦是切实可行的。该领域的长期测试工作还未完成，因此对于该方法的成功性判断尚无加以精确描述。

参考

1) Thamer，滚齿加工中切削应力的研究．研究报告，Aachen工艺，1964
2) Ziegler,滚齿加工中切削应力条件的优化方法，研究报告，Aachen工艺，1965
3) Ziegler,滚齿加工中直齿轮和斜齿轮的切削应力，研究报告，Aachenpolytechnic,1966
4) Ziegler,直齿轮滚齿加工过程中主切削应力的研究。Thesis，19S7，Aachen工艺
5) Hoffmeister,硬质合金滚齿加工的磨损寿命研究．研究报告，Aachen工艺，1968
6) Hotfrneistef，滚齿加工中的磨损情况研究．研究报告，Aachen工艺，1969
7) Hoffmeister，滚刀的磨损情况．论文，1970，Aachen工艺
8) Sulzer，滚齿加工中硬质合金滚刀的优化设计．研究报告，Aachen工艺，1970
9) Sulzer，硬质合金滚齿加工的现状与发展，切削刃与切削运动几何学的研究．研究报告，Aachen工艺；1971
10) Sulzer，硬质合金滚刀的粘屑预防．研究报告，Aachen工艺，lg72
11) Sulzer，滚齿加工中硬质合金滚刀粘屑的原因及预防．研究报告，Aachen工艺，1973
12) Sulzer，深入理解金属切削运动学及圆周齿轮加工的性能提高，Theis，1973，Aachen工艺

he studied the leaving flanks for chip traces and found pressure welded deposits on the flanks. He states: "The different direction of the cutting traces and of the streaks indicates that these streaks are caused by the chips being removed. They occur at those points on the tooth flank which do not come into engagement with the cutter tooth concerned, i. e. there is generally a gap between the cutting edge and this flank area."

The collision between chip and workpiece flank can be explained by the chip form and the chip flow. The cutting process commences at the leaving flank near the cutter tooth tip. At this stage it can still curl freely. After that the tip area of the cutter tooth moves into engagement. Because of the complicated shape and the tight space conditions in the tooth gap the chip can no longer curl freely. It is at the end pushed by the entering flank beyond the cutting face to the other workpiece flank, where it is welded on. As a result of the cutting motion of the cutter tooth the pressure welds are separated, but are formed afresh by the flowing chip. In addition, a workpiece rotation takes place during the cutting motion. This means that the workpiece flank moves away from the leaving tool flank. It is this relative speed at which the chip is pushed from the cutting face over the cutting edge. This produces tensile forces on the cutting edge which can in the case of carbide lead to chipping. When machining with high-speed steel, squeezing forces occur at this point which produce the greater free flank abrasion. This phenomenon also occurs with hobbing in the opposite direction, but not to such an extent.

It is therefore easy to regard hobbing in the opposite direction as a cure-all for flank wear. With hobbing in the opposite direction the circumferential force acts in the direction of rotation of the table. Since this circumferential force favours the flank clearance between the worm and the indexing worm wheel, it creates a disturbance in the indexing gear unit with the segment engagement frequency. This results in chatter markings on the gear flanks and vibration throughout the gear train. It is feasible that flank wear could be reduced by alternate cutting of the tip flanks. Long-term tests in this field have not yet been completed, so that no definite statement can as yet be made about the success of this measure.

References

1) Thämer, Investigation of the cutting force in hobbing. Research report, Aachen polytechnic, 1964
2) Ziegler, Determination of optimum cutting force conditions for hobbing. Research report, Aachen polytechnic, 1965
3) Ziegler, Cutting forces when hobbing straight- and helical tooth spur gears, Research report, Aachen polytechnic, 1966
4) Ziegler, Study of the main cutting force when hobbing spur gears. Thesis, 1967, at the Aachen polytechnic
5) Hoffmeister, Wear life studies and hobbing with carbide. Research report, Aachen polytechnic, 1968
6) Hoffmeister, General wear studies in hobbing. Research report, Aachen polytechnic, 1969
7) Hoffmeister, About wear on hobs. Thesis, 1970, at the Aachen polytechnic
8) Sulzer, Optimum design of hobs and use of carbide in hobbing. Research report, Aachen polytechnic, 1970
9) Sulzer, State and development of carbide hobbing, study of the cutting edge- and cutting action geometry. Research report, Aachen polytechnic, 1971
10) Sulzer, The prevention of chipping on carbide hobs. Research report, Aachen polytechnic, 1972
11) Sulzer, Causes and prevention of chipping when hobbing with carbide tools. Research report, Aachen polytechnic, 1973
12) Sulzer, Performance enhancement in cylindrical gear manufacture through a precise understanding of metal removal kinematics. Thesis, 1973, at the Aachen polytechnic

LMT · FETTE

渐开线齿轮加工刀具
可转位刀片可用于内外直齿轮以及蜗杆螺纹和齿条切削的粗、精铣削加工。

Involute gear cutter
with carbide indexable inserts
For roughing and finish-milling of internal and external straight spur gears, and for worm thread and rack cutting

渐开线粗加工铣刀
切向分布的硬质合金可转位刀片，压力角20度，基本轮廓IV，DIN3972标准。这些工具允许对大型齿轮进行相对经济的粗加工生产工艺。在某些条件下，这些刀具会大大有益于高强度齿轮材料的粗加工过程。（Rm>1000N／mm2）。齿间隙使用直边齿面的刀具按梯形次序粗加工。基本齿廓为BPIV，符合DIN3972标准。其它齿廓可根据客户要求提供非标准化刀具。

Involute roughing hob
With tangentially arranged carbide indexable inserts, pressure angle 20°, basic profile IV to DIN 3972.These tools permit an economical production process for the roughing of large gears. Under certain conditions, they offer considerable advantages for the roughing of high-strength gear materials (R_m > 1000 N/mm^2). The tooth gaps are roughed trapezoidally with straight-sided flanks. The basic tool profile corresponds to BP IV according to DIN 3972. Other profiles can be supplied as non-standard versions upon request.

要求
使用硬质合金切削材料可以大大提高刀具的加工性能。当然加工设备必须保证有足够的功率和刚性。插入工艺的铣削也是可行的。顺铣工艺是首选。

Requirements
The user of carbide cutting materials enables considerable increases in performance to be achieved. A powerful and sufficiently rigid machine is however essential. Milling using the plunge process must also be possible. Preference should be given to climb milling.

渐开线精加工铣刀
该方法适用于对齿轮质量要求为中等等级的情况；可以获得的质量等级为9，符合DIN3962／68标准。

Involute finishing hob
This method can be employed where medium quality requirements are placed upon the gear quality; quality grade 9 to DIN 3962/68 can be attained.

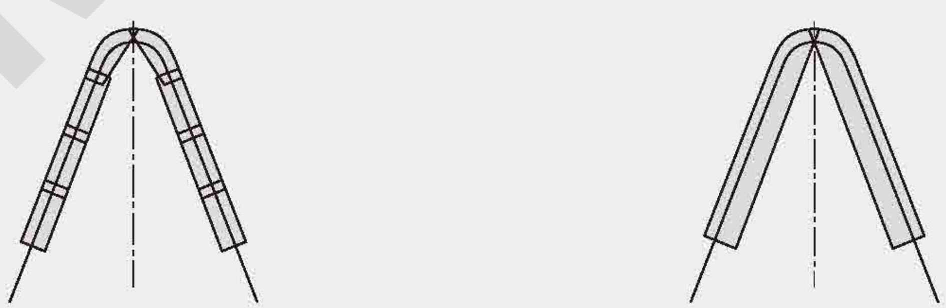
该工艺常常用来制造滚珠轴承的转动挡环(转臂式起重机的控制齿轮即回转支承)，以及内外齿轮的轮廓加工。

This process is often employed for the manufacture of ball bearing slewing rims (control gear for jib cranes), and for the profiling of external and internal gears.

设计原则
连续可转位刀片可以完成整个外形高度的精加工铣削操作。并能够防止从起始位置向下一位置转移时出现问题。
可转位刀片可以转位两次。一侧可以重磨一次。切削刃形状可根据客户规定由刀齿间隙轮廓决定。很大程度上是由齿轮齿数和轮廓移位因数决定的。

Design features
Continuous indexable cutting inserts edges enable the entire profile height to be finish-milled. Problematic transitions are thus prevented from leading to banding.

The indexable inserts can be indexed twice. The cutting edge form is determined by the tooth gap profile specified by the customer. It is dependent to a large degree upon the number of gear teeth and the profile displacement factor.



渐开线粗加工参数要求的推荐值
其中：
Recommended values for the power requirement for involute roughing:

R_m = 抗拉强度 (N/mm²)
Tensile strength (N/mm²)

V_c = 切削速度 (m/min)
Cutting speed (m/min)

h_{m1} = 平均切屑厚度 (mm), 值 ≈ 0,1 mm
Mean tip chip thickness (mm), Value ≈ 0.1 mm

z = 切削槽数量/2
Number of gashes / 2

f_z = 刀齿进给量 (mm)
Tooth feed (mm)

a = 径向进给量 (mm)（切削深度）
Radial feed (mm) (cutting depth)

D = 刀具直径
Tool diameter

v_f = 进给量 (mm/min)
Feed (mm/min)

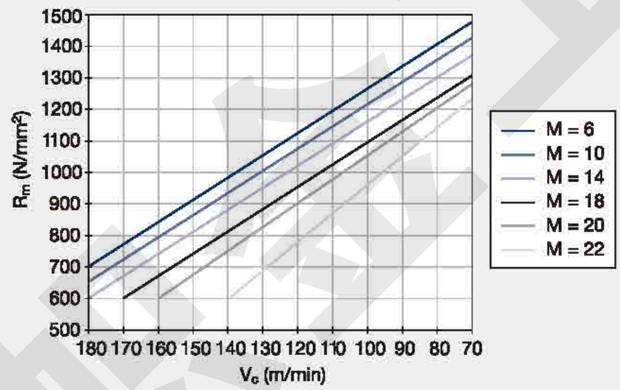
$Q_{spez.}$ = 功率因子 (cm³ min · kW)
(取自表中数值)
Power factor (cm³ min · kW)
(Value taken from table)

该公式适用于全轮廓深度情况：
Formula applicable for full profile depth:

$$P_{(kW)} = \frac{3{,}19 \cdot Mod.^2 \cdot v_f}{1000 \cdot Q_{spez.}}$$

$$v_f = f_z \cdot n \cdot z$$

$$f_z = \frac{h_{m1}}{\sqrt{\frac{a}{D}}}$$



材料 Material	R_m/UTS (N/mm²)	动力因子 Power factor $Q_{spez.}$ cm³/min · kW
非合金结构钢 Unalloyed structural steel	– 700	22 – 24
自由切削钢 Free cutting steel	– 700	22
结构钢 Structural steel	500 – 900	18 – 20
热处理钢，中等强度 Heat-treatable steel, medium strength	500 – 950	18 – 20
铸钢 Cast steel	– 950	18 – 20
淬火铸钢 Case hardening steel	– 950	18 – 20
不锈钢，铁素体，马氏体 Stainless steel, ferritic, martensitic	500 – 950	16 – 18
热处理钢，高强度 Heat-treatable steel, high-strength	950 – 1400	13 – 18
渗氮材料钢，热处理 Nitriding steel, heat-treated	950 – 1400	13 – 18
工具钢 Tool steel	950 – 1400	13 – 18
不锈钢，奥氏体 Stainless steel, austenitic	500 – 950	18 – 20
灰口铸铜 Grey cast iron	100 – 400 (120–600 HB)	28 – 35
合金灰口铸铁 Alloyed grey cast iron	150 – 250 (160–230 HB)	22
球墨铸铁 Nodular cast iron	400 – 800 (120–310 HB)	24
可锻铸铁 Malleable cast iron	350 – 700 (150–280 HB)	24

LMT • FETTE

DIN标准号与索引
DIN number index

图标概述
Pictogram overview

切削材料
Cutting materials

- Car-bide — 硬质合金 Carbide
- KHSS-E — 含钴高速钢 Cobalt alloyed high speed steel
- Solid Carbide — 整体硬质合金 Solid Carbide
- Speed Core — 速切王 SpeedCore
- HSS-PM — 粉沫高速钢 High speed steel PM

涂层
Coating

- AL2 Plus

标准
Standards

- DIN 3968A
- DIN 3968 AA
- DIN 3968 B/C
- DIN ISO 5294
- DIN 5480
- DIN 5481
- DIN 5482
- DIN 8187
- DIN 8188
- DIN 8196

基本齿形
Basic profile

- DIN 3972 BP I
- DIN 3972 BP II
- DIN 3972 BP III
- DIN 3972 BP IV
- Special BP

几何尺寸
Geometry

- 压力角20° Pressure angle 20°
- RH1 — 单头右旋 Single-start right-handed
- 压力角30° Pressure angle 30°
- LH1 — 单头左旋 Single-start left-handed
- 正前角 Rake positive
- RH — 右旋 Right-handed
- 负前角 Rake negative
- LH — 左旋 Left-handed
- 断屑槽 Chipbreaker

Ausführung
Version

- 轴向键槽及端面键槽 Keyway and drive slot
- 阴转子 Female rotor
- 轴向键槽 Keyway
- 刀段 Segment
- 端面键槽 Drive slot
- 刀片 Insert
- 端面键槽 Drive slot
- 键槽 Keyway
- 螺杆泵 Screw pump
- Relief turned — 铲齿 Relief turned
- 阳轮子 Male rotor
- Relief ground — 铲磨 Relief ground

LMT 上海办事处：
上海市长宁区金钟路968号凌空SOHO6幢608室
(邮编：200335)
电话: 021-62959800
传真: 021-62959855

LMT Shanghai Office
608#, Blk.6, Sky SOHO, No.968 Jinzhong Rd.,
Changning District, Shanghai, 200335, PRC
Tel: 021-62959800
Fax: 021-62959855

LMT 南京办事处：
南京市江宁经济开发区蓝帜路9号
（邮编：211100）
电话: 025-52128866
传真: 025-52106376

LMT Nanjing Office
9 Lanzhi Road, Jiangning Development Zone,
Nanjing, 211100, PRC
Tel: 025-52128866
Fax: 025-52106376

LMT 北京办事处：
北京市朝阳区东四环中路39号华业国际中心B座605座
(邮编: 100025)
电话: 010-84801475
传真: 010-84801474

LMT Beijing Office
605#, Blk.B, No.39 Middle East 4th Ring Road,
Chaoyang District, Beijing, 100025, PRC
Tel: 010-84801475
Fax: 010-84801474

LMT 沈阳办事处：
沈阳市铁西区建设中路12-5号万科金域国际4号2-17-2
（邮编：110021）
电话：024-25635819
传真：024-25635245

LMT Shenyang Office
2-17-2#, Blk.4, Vanke Jinyu International, No.12-5 Middle Jianshe Rd.,
Tiexi District, Shenyang, 110021, PRC
Tel: 024-25635819
Fax: 024-25635245

LMT 重庆办事处：
南京市江宁经济开发区蓝帜路9号
（邮编：211100）
电话: 025-52128866
传真: 025-52106376

LMT Chongqing Office
9 Lanzhi Road, Jiangning Development Zone,
Nanjing, 211100, PRC
Tel: 025-52128866
Fax: 025-52106376

LMT 武汉办事处：
南京市江宁经济开发区蓝帜路9号
（邮编：211100）
电话: 025-52128866
传真: 025-52106376

LMT Wuhan Office
9 Lanzhi Road, Jiangning Development Zone,
Nanjing, 211100, PRC
Tel: 025-52128866
Fax: 025-52106376

Printed in China　2016年5月版

南京蓝帜金属加工技术有限公司
LMT China Co., Ltd.
南京市江宁经济开发区蓝帜路9号（邮编：211100）
9 Lanzhi Road, Jiangning Development Zone,
Nanjing, 211100, PRC
电话：025-52128866
传真：025-52106376
Email：info.cn@lmt-tools.com
www.lmt-tools.com.cn

公司网站

微信公众平台

LMT·TOOLS