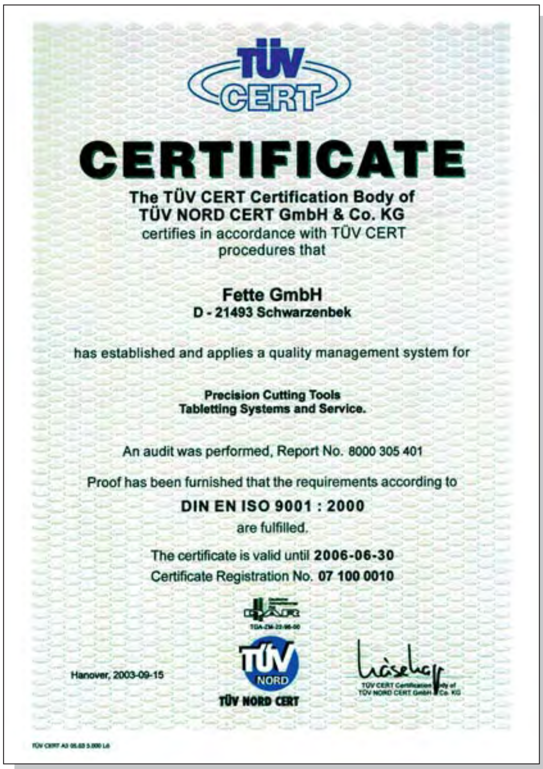
FETTE

Gear Cutting Tools

- Hobbing
- Gear Milling

Leitz Metalworking Technology Group
BELIN • BILZ • BOEHLERIT •
FETTE • KIENINGER • ONSRUD


TÜV CERT

CERTIFICATE

The TÜV CERT Certification Body of
TÜV NORD CERT GmbH & Co. KG
certifies in accordance with TÜV CERT procedures that

Fette GmbH
D - 21493 Schwarzenbek

has established and applies a quality management system for

Precision Cutting Tools
Tabletting Systems and Service.

An audit was performed, Report No. 8000 305 401

Proof has been furnished that the requirements according to

DIN EN ISO 9001 : 2000

are fulfilled.

The certificate is valid until **2006-06-30**

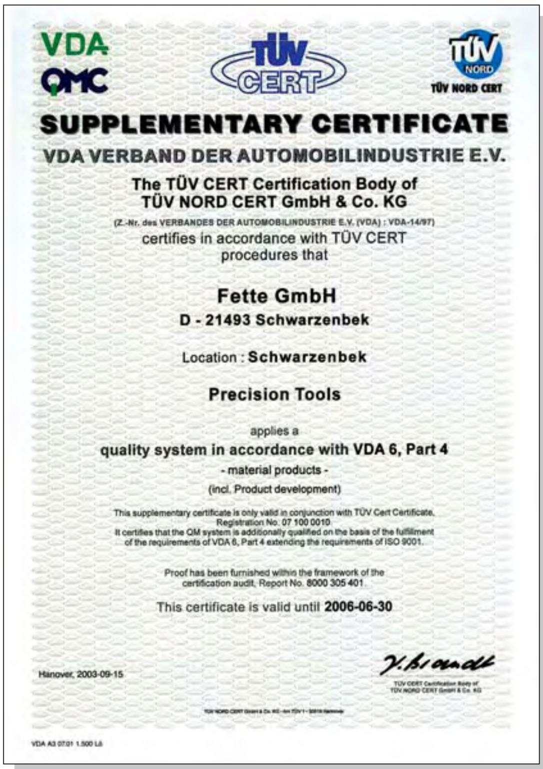
Certificate Registration No. **07 100 0010**

Hanover, 2003-09-15

TÜV NORD CERT

TÜV CERT Certification Body of TÜV NORD CERT GmbH & Co. KG

TÜV CERT A3 05.03 5.000 Lö


VDA QMC

TÜV CERT

TÜV NORD CERT

SUPPLEMENTARY CERTIFICATE

VDA VERBAND DER AUTOMOBILINDUSTRIE E.V.

The TÜV CERT Certification Body of
TÜV NORD CERT GmbH & Co. KG
(Z.-Nr. des VERBANDES DER AUTOMOBILINDUSTRIE E.V. (VDA) : VDA-14/97)
certifies in accordance with TÜV CERT procedures that

Fette GmbH
D - 21493 Schwarzenbek

Location : **Schwarzenbek**

Precision Tools

applies a

quality system in accordance with VDA 6, Part 4

- material products -

(incl. Product development)

This supplementary certificate is only valid in conjunction with TÜV Cert Certificate, Registration No. 07 100 0010.
It certifies that the QM system is additionally qualified on the basis of the fulfillment of the requirements of VDA 6, Part 4 extending the requirements of ISO 9001.

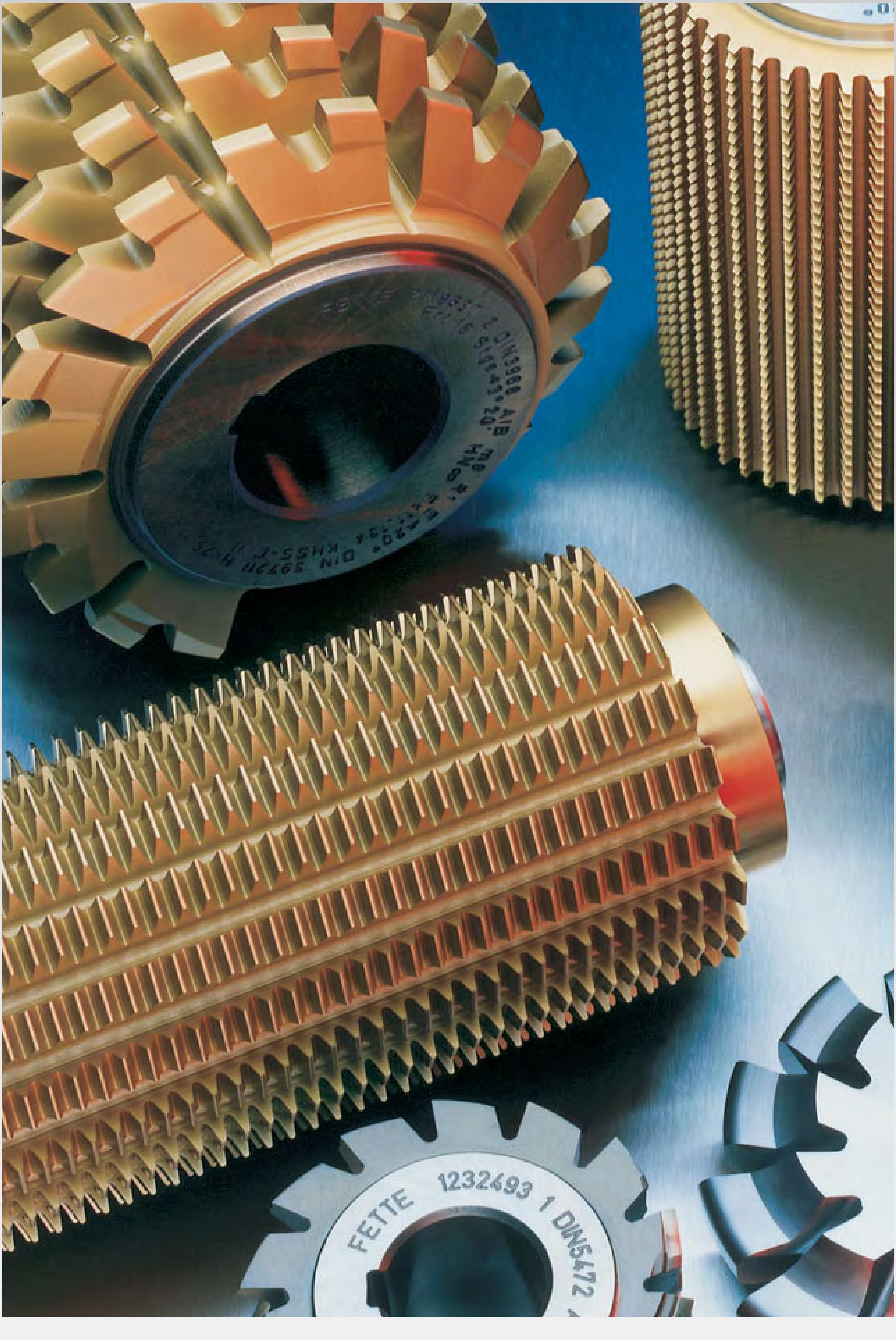
Proof has been furnished within the framework of the certification audit, Report No. 8000 305 401.

This certificate is valid until **2006-06-30**

Hanover, 2003-09-15

TÜV CERT Certification Body of TÜV NORD CERT GmbH & Co. KG

VDA A3 07.01 1.500 Lö


FETTE
1232493 1 DIN5472

Important information

Important information

Product range

The entire FETTE catalogue product range with some 15,000 standard items, 1,100 in the hobbing area alone, is subject to continuous improvement. As part of this process, we not only introduce new and therefore technologically superior products into our range, but also take care to remove outdated products from it.

In some cases it could happen that we do not carry in stock the item which you have ordered. In this case you will in general receive products from us technologically better product, but at least an equivalent alternative. In case of doubt, our sales team is available to determine a design that will produce best possible results for you.

By following this procedure, you can be sure that you are always be supplied with tools, which are technologically to the newest standard. For that reason, we do not feel not obliged to supply tools, which are still shown in the catalogue, or which have been cleared from the programme already internally.

Article numbers

To speed up order supply and to avoid confusion, orders should always specify the article numbers listed in this catalogue.

Prices

This catalogue does not contain prices. Prices can be found in the latest price list for standard articles. Please consult us for a quote with regard to semi-standard or special items.

Minimum order value

Orders with a total value of less than DM 200.00 are subject to a processing surcharge of DM 50.00. We trust that you will appreciate the need for this measure.

Tool groups

Our wide range of hobbing tools is divided into tool groups, which are marked in the index at the side of the page and are thus easily located.

Catalogue number index

All catalogue numbers, arranged in numerical order and with the page number, are listed on page 193.

DIN Standard index

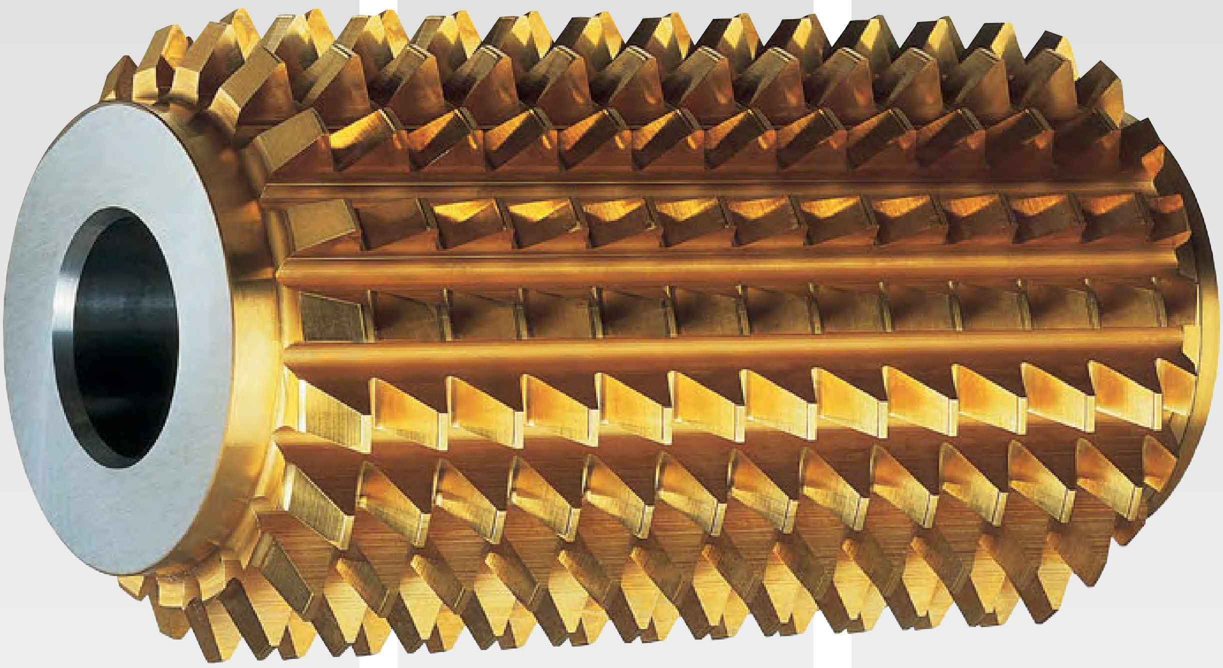
An index on all DIN Standard numbers covered is listed on page 194.

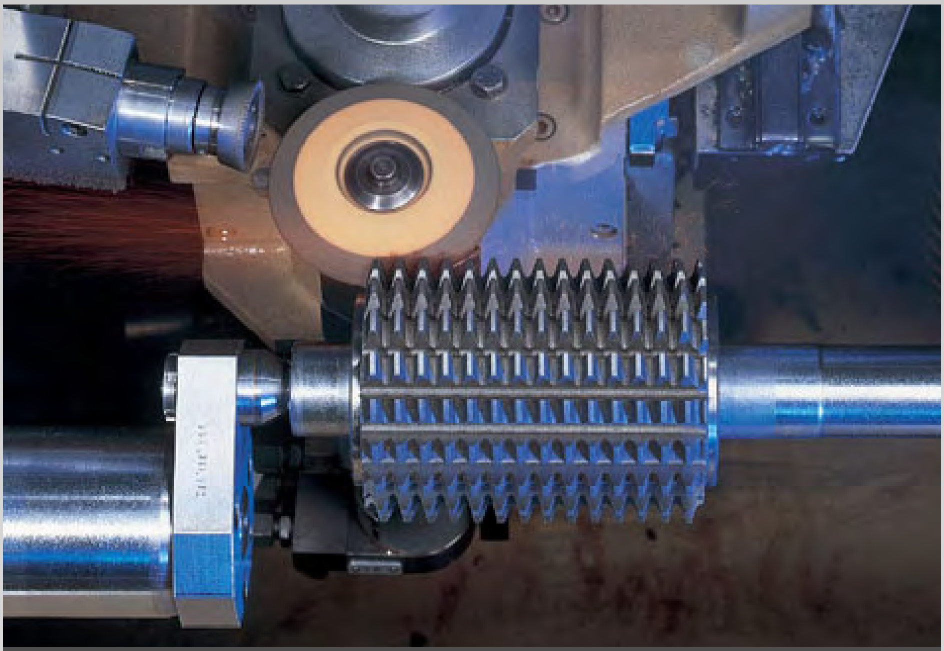
Technical details

Technical application details of a general nature commence on page 125, whereas the specific technical details concerning individual product groups are directly assigned to the section concerned.

Special forms

Should you be unable to find a solution to your machining tasks among the 1,100 items which we stock, special forms are available upon request, including forms manufactured specifically to your drawings.





Grinding Services

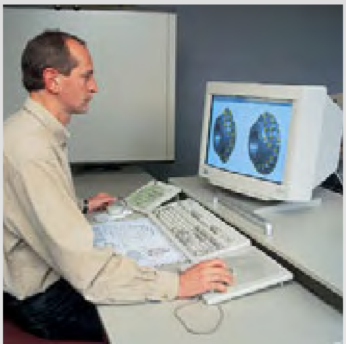
Services

PVD-Coating

FETTE – a brief introduction

Ecology and environment protection are part of the company philosophy, recognizable on the factory grounds

Quality assurance



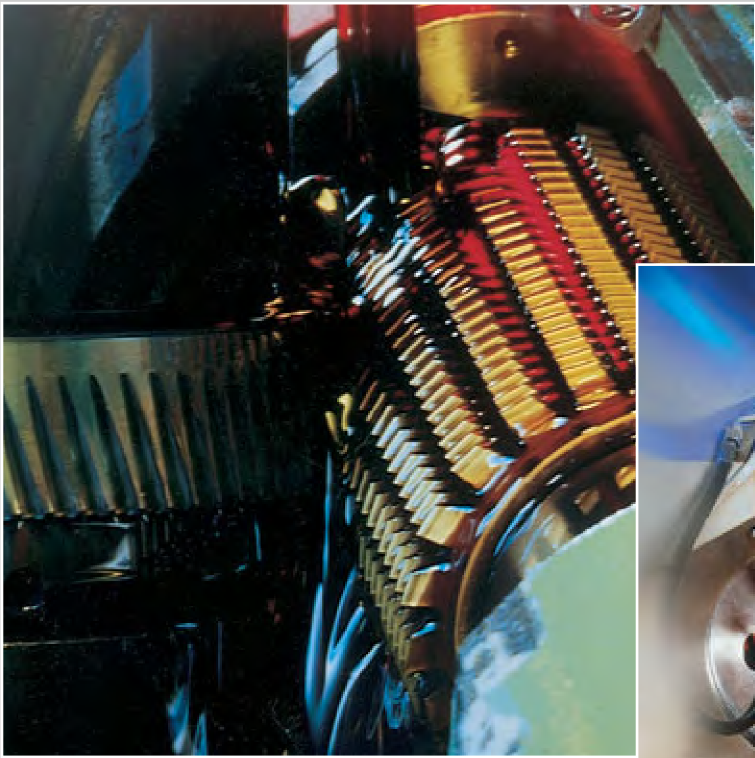
Design and development

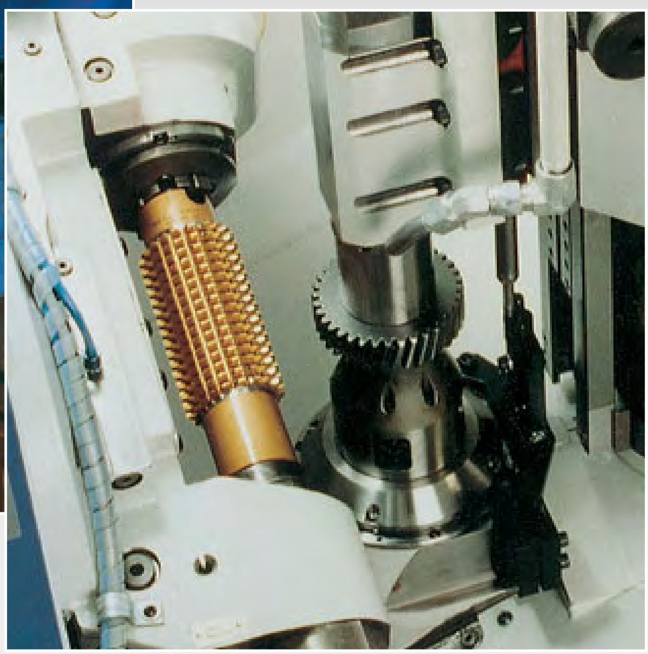
Heat treatment

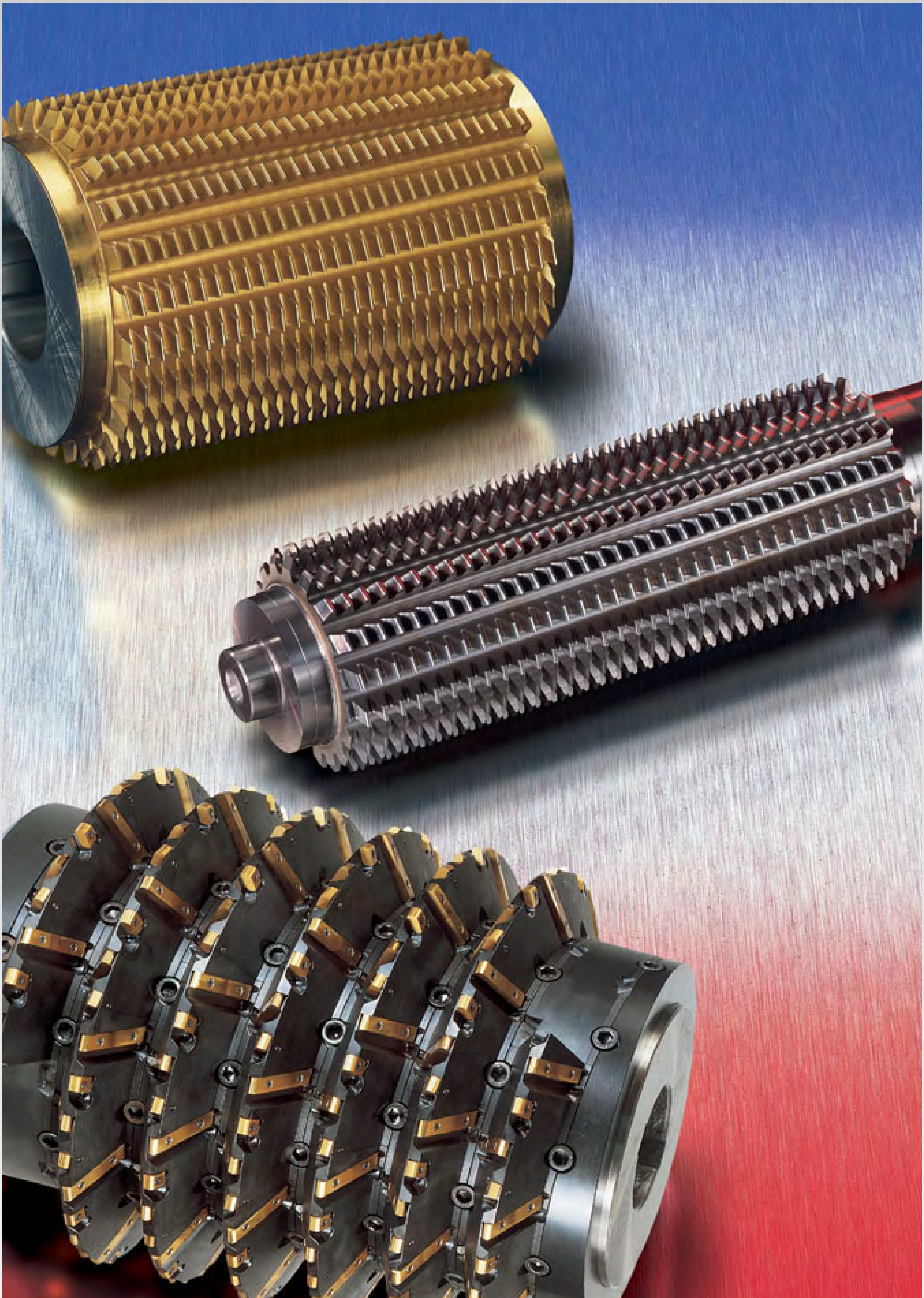
Training

Production on modern machine tools combined with up-to-date CNC technique

Application advice and service







Hobs
for spur gears, straight- or helical tooth, with involute flanks

LMT • FETTE

Hobs for producing straight- and helical-tooth spur gears with involute flanks

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.

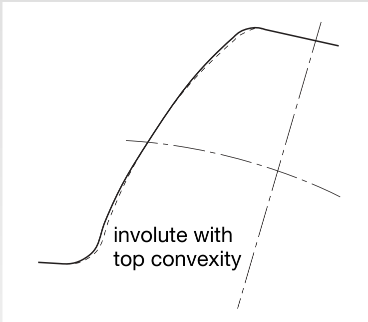
This relieving operation is carried out on machine tools specially developed for this process; it is very time consuming and therefore also expensive. For hobs to moderate accuracy specifications, relief turning is sufficient; for stricter quality requirements the hob is relief ground.

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 µm. E.g. quality class AAA to DIN 3968, item nos. 16 and 17 restricted to 50 % of the tolerance of AA.

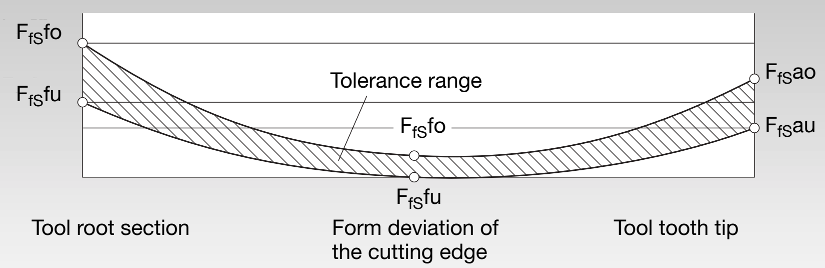
The purpose of hob tolerances is to assign the tools to a quality class according to their accuracy. On the basis of the hob quality classes, the expected gear quality can then be forecast.

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.



Tolerances for hobs with special class tolerance values in 1/1000 millimetres

	Tolerance range \ 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



Notes to the descriptions and size tables for spur gear hobs

Owing to the many different hob versions available, their presentation in a product catalogue must be restricted to a range which is intended as a representative selection. Standardized reference profiles to DIN 3972 or DIN 58412 and size series to DIN 8002 or DIN 58411 were selected for inclusion in the catalogue.

For cutter designs such as broach-tooth type roughing hobs or skiving hobs, the size tables were based upon works standards which maximize usefulness within the constraints of the design criteria.

These standard tools can, however, only cover part of the required hob range, and possible variants are therefore briefly listed below.

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 x 130/138 x 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.

Cutter materials

The standard material is the high-speed EMo5Co5 (material no. 1.3242).

Gear materials whose tensile strength values exceed 1200 N/mm or which are intended for very high cutting speeds and feeds are manufactured from powder metallurgical high-speed steel.

Carbides are increasingly being employed for high-performance hobbing and for skive hobbing.

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 151 and 152 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 pp. 137 to 148.

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.

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.

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 shaving cutter does not machine the tooth root. This prevents stress peaks through grinding- or shaving stages.

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.

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.

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. Normally, one uses right-hand cutters.

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 outside diameter.

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 double-helical teeth, two hobs with chamfer may be necessary, if the distance between the two tooth rows is relatively small.

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.

Rake

Unless otherwise agreed, hobs have a rake of 0°. This does not apply to broaching tooth type roughing hobs, which have a rake of +8°, and indexable insert and skive hobs, which have a rake of -10° to -30°.

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.

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.

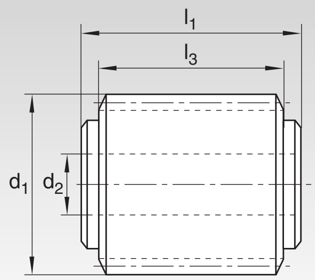
The equations for the conversion into module are:

$$m = 25.4 / DP$$
$$m = 25.4 \cdot CP / 3.1416$$

Solid-type hobs

for spur and helical gears to module pitch

20° pressure angle
basic profile N2 to DIN 58412
quality grade 7 to DIN 58413
single start right-handed
with keyway[1)]



KHSS-E EMo5Co5

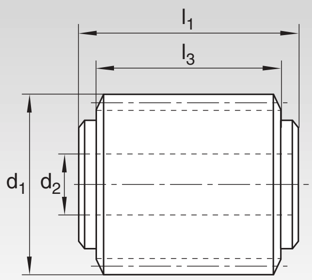
Cat.-No.					**2002** relief ground ■ DIN 58411	
Dimensions in mm					Number of gashes	Ident No.
m	d_1	l_3	l_1	d_2		
0,2	25	6	12	8	8	1193310
0,2	32	12	16	13	10	1202097
0,25	25	6	12	8	8	1202099
0,25	32	12	16	13	10	1193347
0,3	25	10	16	8	8	1193356
0,3	32	12		13	10	1203002
0,35	25	10		8	8	1203004
0,35	32	12		13	10	1193383
0,4	25	10	16	8	8	1193392
0,4	32	12		13	10	1193409
0,45	25	10		8	8	1203006
0,45	32	12		13	10	1193427
0,5	25	10	16	8	8	1193436
0,5	32	12		13	10	1193445
0,6	25	10		8	8	1193454
0,6	32	12		13	10	1193463
0,6	40	20	24	16	12	1193472
0,7	25	14	16[2)]	8	8	1193481
0,7	32	20	24	13	10	1193490
0,7	40			16	12	1193506
0,75	25	14	16[2)]	8	8	1203008
0,75	32	20	24	13	10	1193524
0,75	40			16	12	1193533
0,8	25	14	16[2)]	8	8	1193542
0,8	32	20	24	13	10	1193551
0,8	40			16	12	1193560
0,9	32	20	24	13	10	1193579
0,9	40			16	12	1193588
1,0	32			13	10	1193597
1,0	40			16	12	1193604

1) Standard design: 8 mm bore without keyway
2) This size is only supplied with a single indicator hub.

Solid-type hobs

for spur and helical gears to module pitch

20° pressure angle
basic profile N2 to DIN 58412
quality grade 7 to DIN 58413
single start right-handed
with keyway[1)]



Solid carbide

Cat.-No. **2008 relief ground**

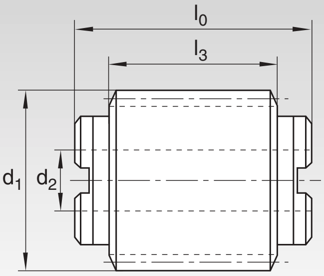
Dimensions in mm					Number of gashes	Ident No.
m	d_1	l_3	l_1	d_2		
0,2	25	7	10	8	12	1193702
0,25						1193704
0,3	25	9	12	8	12	1193706
0,3	32	12	16	13		1193708
0,35	25	9	12	8		1193710
0,35	32	12	16	13		1193712
0,4	25	9	12	8	12	1193714
0,4	32	12	16	13		1193716
0,45	25	9	12	8		1193718
0,45	32	12	16	13		1193720
0,5	25	13	16	8	12	1193722
0,5	32	12		13		1193724
0,6	25	13		8		1193726
0,6	32	12		13		1193728
0,6	40	20	25	16		1193730
0,7	25	15	18	8	12	1193732
0,7	32	20	25	13		1193734
0,7	40		25	16		1193736
0,75	25	15	18	8	12	1193738
0,75	32	20	25	13		1193740
0,75	40		25	16		1193742
0,8	25	15	18	8	12	1193744
0,8	32	20	25	13		1193746
0,8	40			16		1193748
0,9	25	15	18	8	12	1193750
0,9	32	20	25	13		1193752
0,9	40			16		1193754
1,0	25	15	18	8	12	1193756
1,0	32	20	25	13		1193758
1,0	40			16		1193760

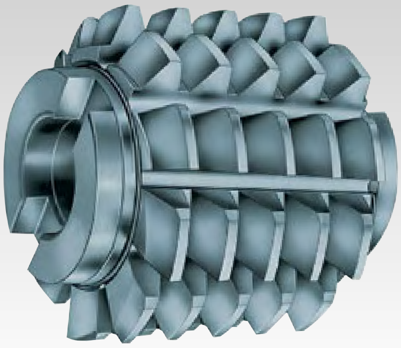
1) Standard design: 8 mm bore without keyway

Solid-type hobs

for spur and helical gears to module pitch

20° pressure angle
basic profile II to DIN 3972
quality grade A to DIN 3968
single start right-handed
with drive slot





KHSS-E EMo5Co5

Cat.-No. **2022** **relief ground ■ DIN 8002 A**

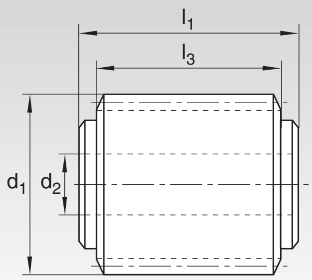
Dimensions in mm					Number of gashes	Ident No.
m	**d_1**	**l_3**	**l_0**	**d_2**		
1	50	25	44	22	14	1202013
1,25						1202015
1,5	56	32	51		12	1202017
1,75						1202019
2	63	40	60	27	12	1202021
2,25	70	50	70			1202023
2,5						1202025
2,75						1202027
3	80	63	85	32	12	1202029
3,25						1202031
3,5						1202033
3,75	90	70	94			1202035
4	90	70	94	32	12	1202037
4,5					10	1202039
5	100	80	104			1202041
5,5						1202043
6	115	100	126	40	10	1202045
6,5						1202047
7						1202049
8	125	130	156			1202051
9						1202053
10	140	160	188	40	10	1202055
11	160	170	200	50	9	1202057
12	170	185	215			1202059
13	180	200	230			1202061
14	190	215	245			1202063
15	200	225	258	60	9	1202065
16	210	238	271			1202067
17	220					1202069
18	230	260	293			1202071
19	240					1202073
20	250	286	319	60	9	1202075
21	260	290	320			1202077
22	270	290				1202079
23	280	310	340			1202081
24						1202083
25	290	310	350	60	9	1202085
26	310	320	360	80		1202087
27	320	330	370			1202089
28						1202091
29	340	340	380			1202093
30						1202095

LMT FETTE

Solid-type hobs

for spur and helical gears to module pitch

20° pressure angle
basic profile II to DIN 3972
single start right-handed
with drive slot



KHSS-E EMo5Co5

Cat.-No.

2031 relief turned ■ Quality grade B/C to DIN 3968 ■ DIN 8002 B
2032 relief ground ■ Quality grade A to DIN 3968 ■ DIN 8002 B

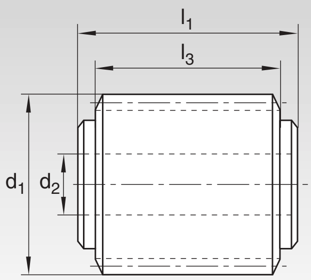
Dimensions in mm					Number of gashes	Ident No. 2031	Ident No. 2032
m	d_1	l_3	l_1	d_2			
0,5	50	16	22	22	14	1203953	2115425
0,75						1203955	2106790
1		25	31			1203951	1205165
1,25	50	25	31	22	14	1203960	1205174
1,5	56	32	38		12	1203979	1205183
1,75						1203957	1205192
2	63	40	46	27	12	1203997	1205209
2,25	70	50	56			1203959	1205218
2,5						2116023	1205227
2,75						1204022	1205236
3	80	63	69	32	12	1204031	1205245
3,25						1204040	1205254
3,5						1204059	1205263
3,75	90	70	78			1204068	1205272
4	90	70	78	32	12	1204077	1205281
4,5					10	1203961	1205290
5	100	80	88			1204095	1205307
5,5						1203963	1205316
6	115	100	108	40	10	1203871	1205325
6,5						2116027	1205334
7						2116028	1205343
8	125	130	138			1204148	1205352
9						1203963	1205361
10	140	160	170	40	10	1203924	1205370
11	160	170	180	50	9	1203933	1205389
12	170	185	195			1203942	1205398
13	180	200	210			2116972	1205405
14	190	215	225			2251076	1205414
15	200	225	235	60	9	2206629	1205423
16	210	238	248			2206630	1205432
17	220					–	2264410
18	230	260	270			2106631	1205450
19	240					–	1203986
20	250	286	296	60	9	2106632	1205478
21	260	290	300			1203967	1203988
22	270					2106633	2105475
23	280	310	320			1203969	1203990
24						1203971	2107384
25	290	320	330	60	9	1203973	2117926
26	310			80		1203975	2251168
27	320	330	340			1203977	1203992
28						1203980	1203994
29	340	340	350			1203982	1203996
30						2106635	2117930

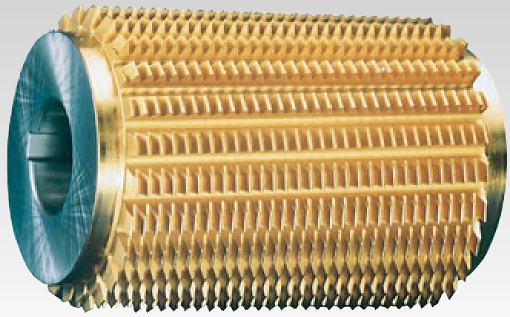
Hobs

For economical production on modern hobbing machines

for spur and helical gears to module pitch

20° pressure angle
basic profile II to DIN 3972
quality grade A to DIN 3968
single start right-handed
with keyway





KHSS-E EMo5Co5 – **TiN-coated**

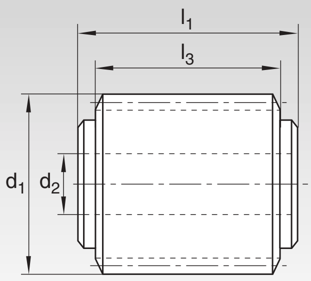
Cat.-No. **2033** **relief ground**

Dimensions in mm					Number of gashes	Ident No.
m	**d_1**	**l_3**	**l_1**	**d_2**		
1	50	44	50	22	15	1205771
2	63	80	90	27		1205773
2,5	70	90	100			1205775
3	80	110	120	32		1205777
4	90	120	130			1205779
5	100	140	150			1205781
6	115			40		1205783
7	125					1205785
8	140	180	190	50		1205787
9					14	1205789
10	160	200	210			1205791

Solid-type hobs

for spur and helical gears to DP (Diametral Pitch)

20° pressure angle
basic profile: $h_{a0} = 1.25 \cdot m$, $\varrho_{a0} = 0.3$ m
quality grade A to DIN 3968
single start right-handed
with keyway

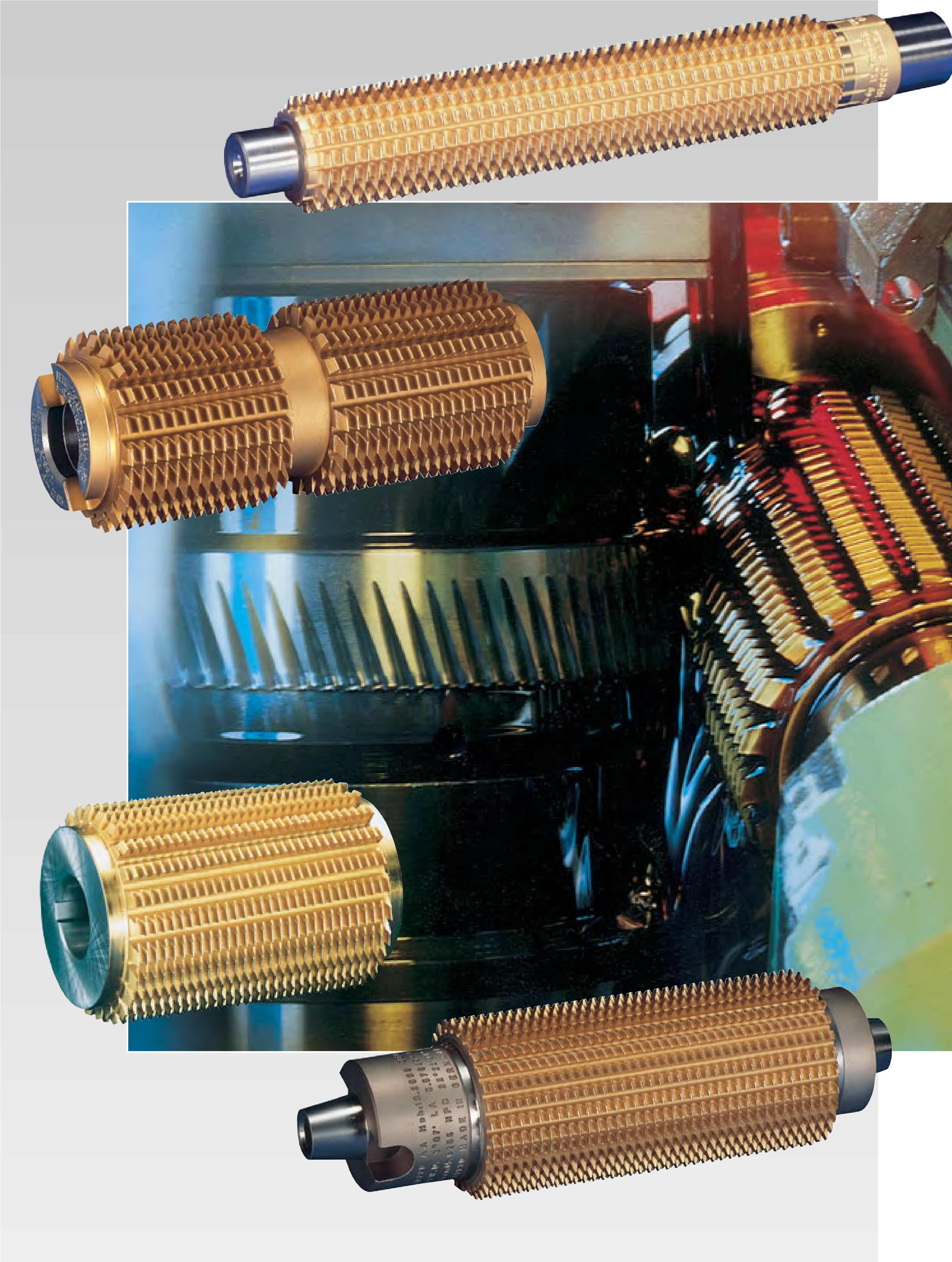


KHSS-E EMo5Co5

Cat.-No. **2042** **relief ground**

DP	Dimensions in mm				Number of gashes
	d_1	l_3	l_1	d_2	
1	290	320	330	60	9
1,25	250	286	296		
1,5	220	238	248		
1,75	200	225	235		
2	180	200	210	50	9
2,5	140	160	170	40	10
3	125	130	138		
3,5	115	100	108		
4	115	100	108	40	10
5	100	80	88	32	
6	90	70	78		
7					12
8	80	63	69	32	12
9					
10	70	50	56	27	
11					
12	63	40	46	27	12
13					
14	56	32	38	22	
15					
16					
17					
18					
19	50	25	31	22	14
20					
21					
22					
23					
24					
25	50	25	31	22	14
26					
27					
28					
29					
30					

Multiple-gash hobs



Coated solid-type hobs with a high number of gashes are ideally suited to high-performance hobbing of straight spur gears. Solid-type hobs are more stable than any type of composite hob. 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.

Compared to conventional hobs, high-performance hobs are required to have:

- A higher tool life quality;
- Shorter machining times;
- At least equal if not superior gear quality.

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.

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 such that the requirements are broadly fulfilled.

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 hobs teeth.

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.

Increased tool life quality

An **increase in the number of gashes** is a design measure with a decisive, positive effect upon the tool life quality. The increase in the number of gashes results in the volume to be machined being distributed over a greater number of cutter teeth, and the tip chip thicknesses being reduced.

Smaller tip chip thicknesses require smaller cutting forces, which reduce the stresses placed upon the cutting edges of the hob and lead to lower wear. Lower tip chip thicknesses enable higher tool life qualities to be achieved.

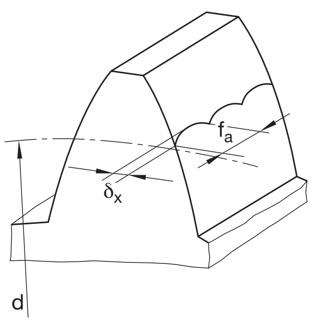
Assuming that the hob diameter remains unchanged, however, an increase in the number of gashes reduces the number of regrinds which are possible. If the number of gashes is selected so that only one to three regrinds are possible, the hob is described as an **super-fine-tooth cutter**.

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

Whether multi-tooth or superfine tooth hobs are the ideal tools for a specific gear hobbing task must be determined by means of a cost analysis. The cost structure and capacity exploitation of the user's installation are also decisive factors.

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

A cutter 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.



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

δ_x [mm] = depth of the feed marking
f_a [mm/WU] = axial feed
β_0 = helix angle
α_n = pressure angle
d_{a0} [mm] = tip circle diameter of the hob

Depth of the feed markings

In order to achieve a high tool life quality, high-performance hobs must be coated. **Titanium nitride (TiN) is generally employed as a coating** at present. The high degree of hardness of the TiN 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.

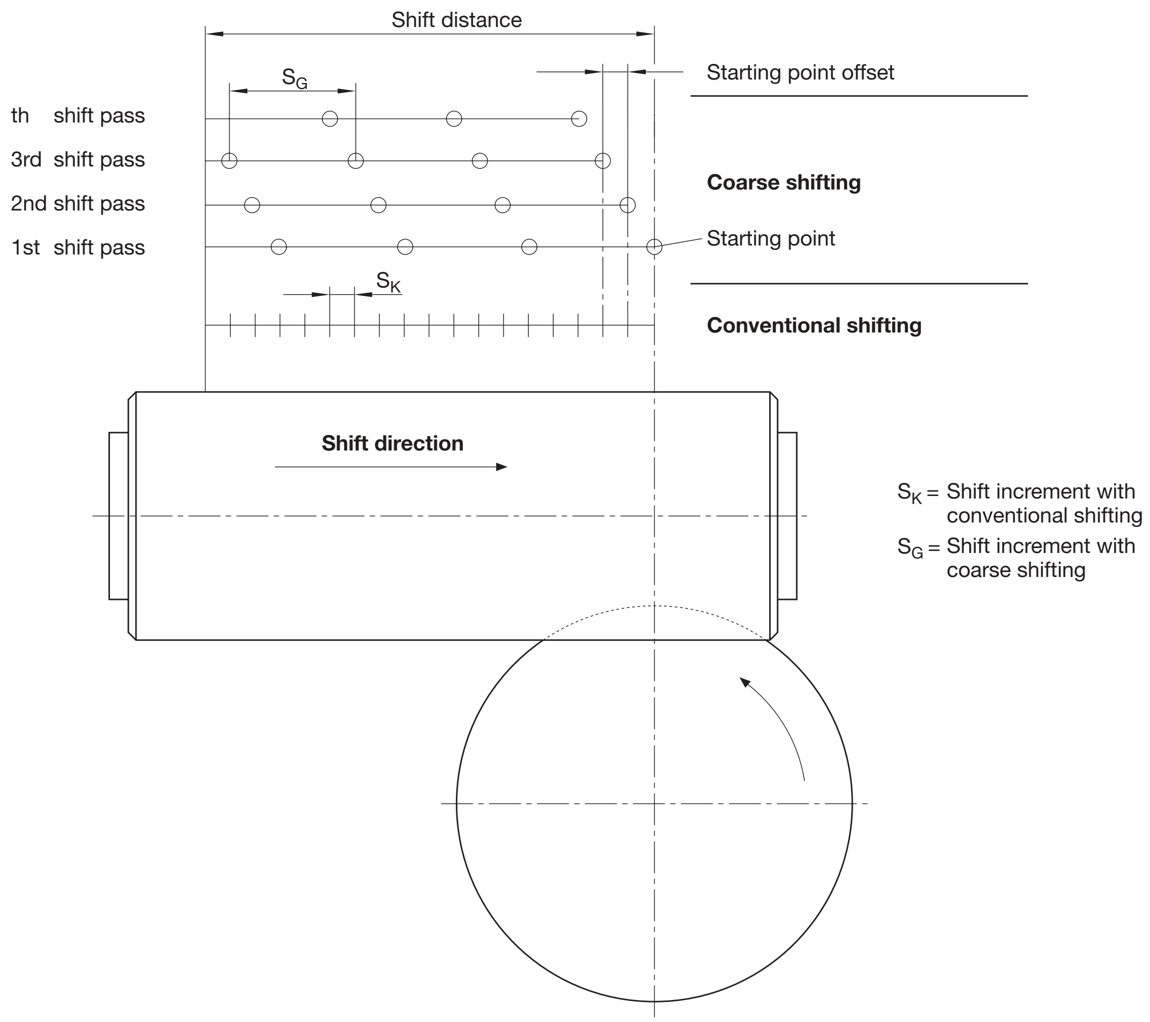
When the hob is sharpened, the TiN coating is removed from the cutting faces. Pitting increases on the now uncoated cutting faces, and the tool life quality is reduced. In order to exploit the high performance potential of these hobs to the full, it follows that hobs for high-performance machining must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

The tool life quality is obviously also increased if the **cutter length** is extended, since the shift distance is extended by the same quantity with which the cutter length is increased.

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 quality is raised considerably if the hob is shifted through several times with an increasing 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.



Shift strategy: coarse shifting

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, and its tensile strength and machineability.

The machining time changes as a function of the **hob diameter**, however. 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 machining distance for axial machining.

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 qualities 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 cutter 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, the increase in which is influenced more strongly by the number of starts than by the increased axial feed.

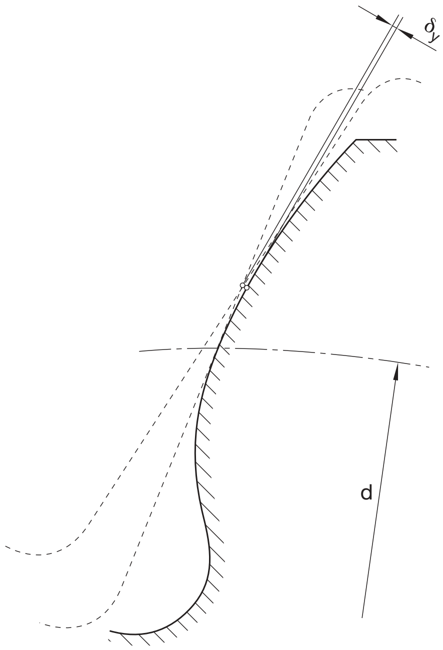
A relatively high feed should be selected, and the number of starts kept as low as possible. This combination produces the lowest tip chip thickness. The two variables are of equal importance for calculation of the machining time, i.e. the machining time is determined by the product of the feed and the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

The number of starts should always be increased when the feed is limited by the depth of the feed markings before the maximum tip chip thickness is reached.
The depth of the feed markings is dependent upon whether the gear is to be finish-hobbed or subsequently shaved or ground.

$$t_h = \frac{z_2 \cdot d_{a0} \cdot \pi \cdot (E+b+A)}{z_0 \cdot f_a \cdot v_c \cdot 1000}$$

t_h [min] = machining time
z_2 = number of teeth of the gear to be machined
d_{a0} [mm] = tip circle diameter of the hob
E [mm] = approach length of the hob
b [mm] = tooth width of the gear to be machined
A [mm] = idle travel distance of the hob
z_0 = number of starts of the hob
f_a [mm/WU] = axial feed
v_c [m/min] = cutting speed

Machining time (production time) for hobbing



δ y [mm] = envelop cut deviation
z_0 = number of starts of the hob
m_n = normal module
α_n = profile angle
z_2 = number of teeth on the gear
i = number of gashes of the hob

$$\delta y\ [\text{mm}] = \frac{\pi^2 \cdot z_0^2 \cdot m_n \cdot \sin\alpha_n}{4 \cdot z_2 \cdot i^2}$$

Envelop cut deviations

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 markings. In consideration of the gear quality produced during finish-hobbing or subsequent processes such as shaving or grinding, the depth of the feed markings and therefore the feed must be limited.

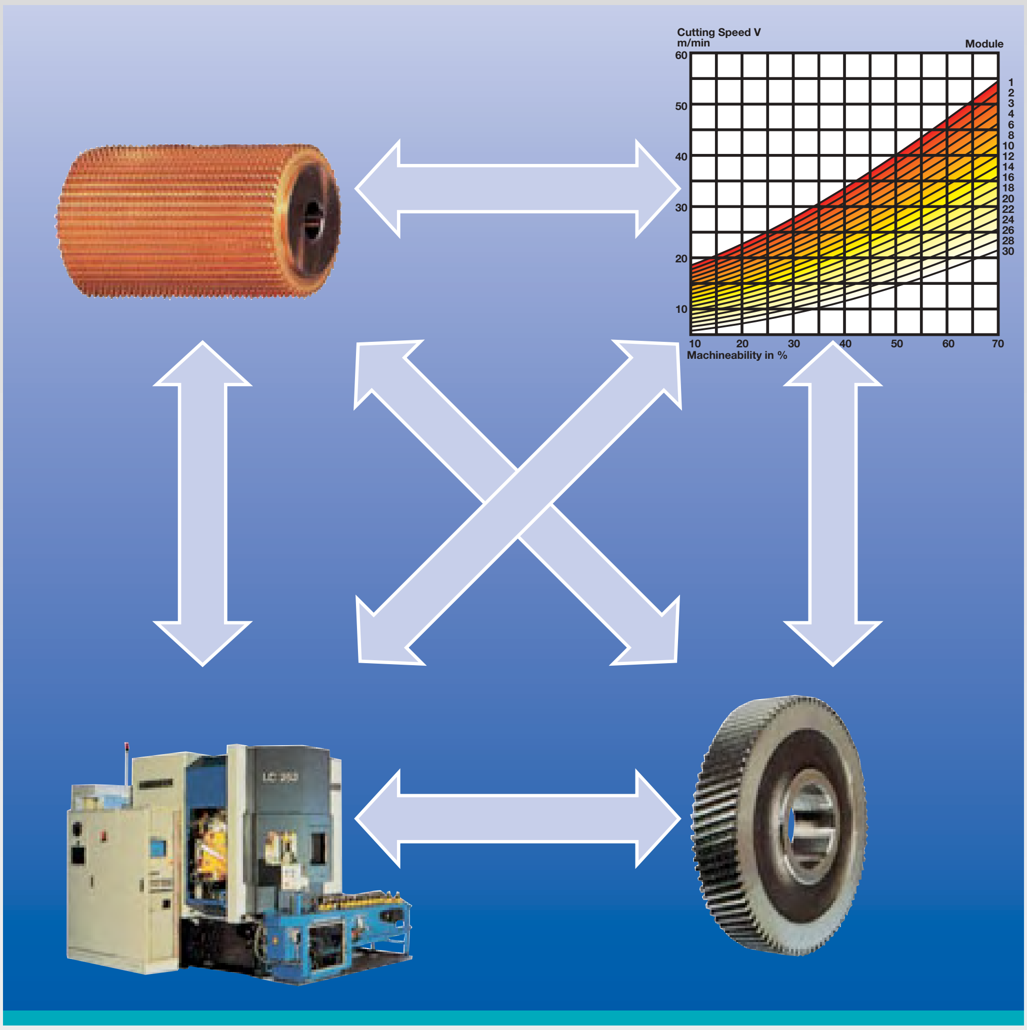
The number of starts and the number of gashes have a bearing upon the magnitude of the enveloping cut deviations. The hob diameter, number of gashes, number of starts, axial feed, and cutting depth are included in the calculation of the tip chip thicknesses, and therefore influence the cutting forces and thereby also the quality of the gear.

With regard to the quality aspects, not only must the correct hob quality to be specified to DIN 3968 or comparable hob standards for each hobbing arrangement; the tip chip thickness, feed markings and enveloping cut deviations must also be checked to ensure that they lie within the specified limits.

Summary

Optimization of the hobbing process must entail 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 gear generating task. The size table shown on Page 25 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.



We can also optimize your hobbing process

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
- Depth of tooth 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

Note when formulating the objectives that measures which are suitable for attainment of, for example, the objective "improvement of the gear quality" influence the machining time and gear generation costs.

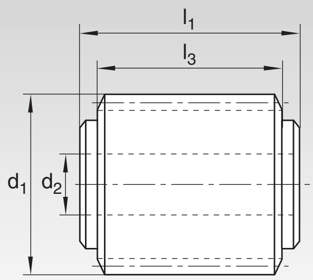
The objective must therefore always be supplemented by a qualitative and quantitative specification of the remaining process results.

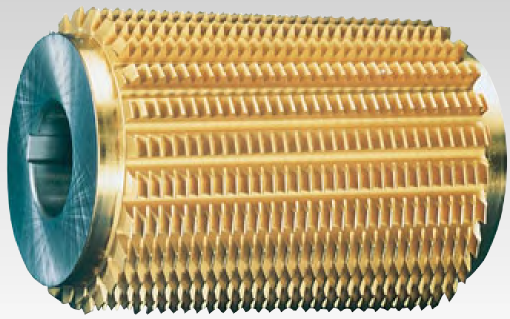
Limit values imposed by the machine must be specified, such as:

- Max. cutter diameter
- Max. cutter length
- Max. cutter spindle and table speed
- Max. shift distance

Multiple-gash hobs

Recommended structural dimensions





KHSS-E EMo5Co5 – **TiN-coated**

Dimensions in mm					Number of gashes
m	d_1	l_3	l_1	d_2	
1 to 4	80	120	130	32	13, 15, 17, 19 or 20
	90				
		140	150		
		170	180		
1 to 6	100	140	150		13, 15, 17, 19 20, 21 or 24
		170	180		
	110	140	150	40	
		200	210		
	120	160	180	32[1]	
		190	210	40	
	125		200		

[1] Or bore diameter 40 mm

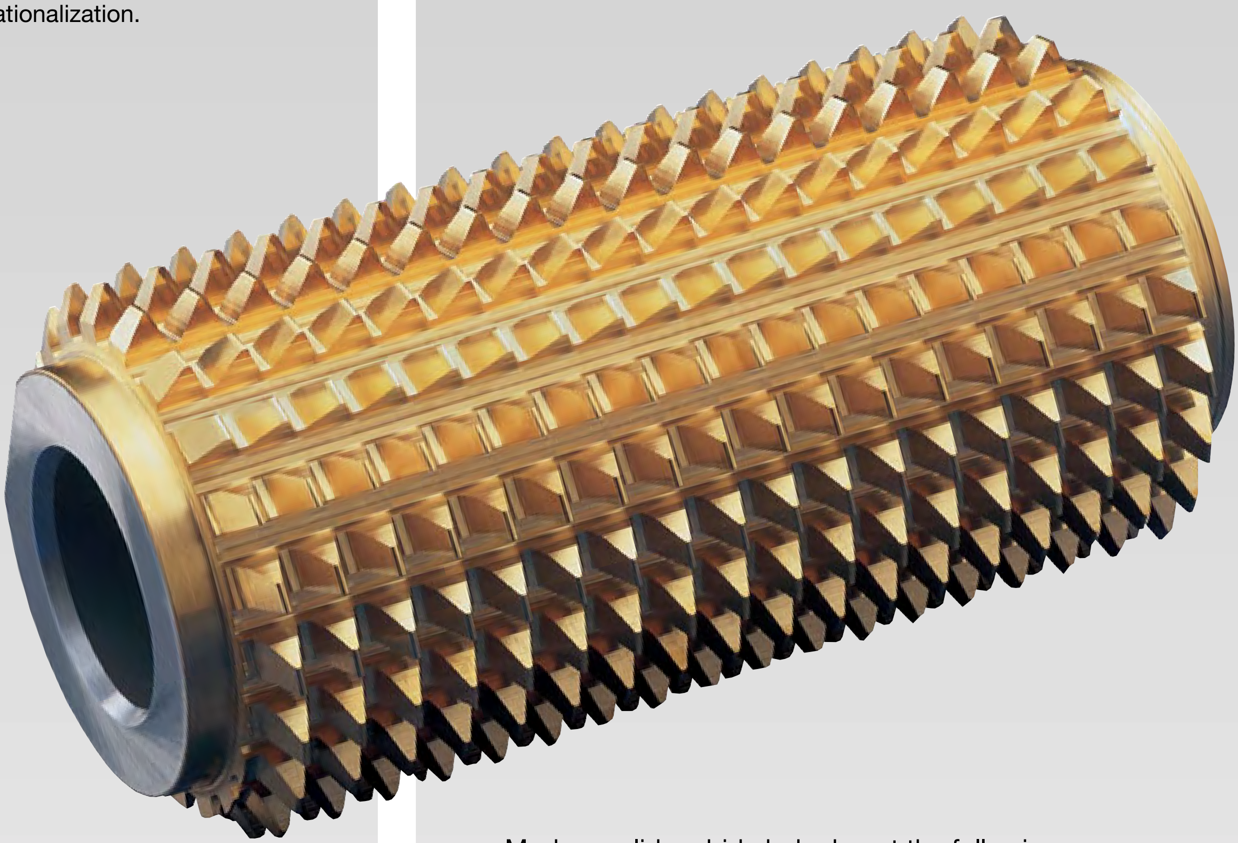
Solid carbide hobs

Introduction

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 solid carbide cutters to be exploited in practical use.

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



Modern solid carbide hobs boast the following characteristics:

- High cutting speeds
- Short machining times
- Long tool life
- High suitability for dry machining
- Re-coating not required for P carbides
- Lower gear generation costs (according to the machining task)

Carbide types and coatings

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.

In addition, P carbides are less sensitive to temperature, and the strong progressive increase in wear which takes effect from a flank wear of approximately 0.2 mm onwards is considerably lower. The substrate reacts more favourably.

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.

TiN, manufactured by means of PVD, continues to be the main substance employed for the hard material layer of hobs. TiN possesses excellent chemical resistance to the hot steel chips. In addition to its hardness of 2200 HV, its relatively high toughness makes it particularly attractive for hobs.

The logistics aspect represents a decisive advantage. TiN is the coating which, owing to its low pressure characteristics, can be re-coated more easily. This is essential following grinding of the cutting face of hobs with a K type substrate.

Newly developed coatings such as TiCN PLUS and ALPLUS (TiAlN) can attain longer tool life travel for a given application, but have yet to be accepted by the market, particularly with regard to the re-coating aspect.

Advantages:	Disadvantages:
● Re-coating not necessary following regrinding ● Low maintenance costs (regrinding only) ● Shorter maintenance times, consequently: ● Fewer tools in circulation (lower capital investment) ● Lower progressive rise in wear when the coating is penetrated, consequently: ● Lower risk of built-up edges	● Shorter tool life in the reground condition, therefore: ● More frequent tool changes required

Use of coated solid carbide hobs with P type substrate
Maintenance process: regrinding (flank coated, cutting face uncoated)

Advantages:	Disadvantages:
● Generally longer tool life, therefore: ● Less frequent tool changing ● Fine-grain grades possible, therefore: ● Greater toughness and greater hardness	● Cannot be employed uncoated, i.e. removal of the coating and re-coating is required, therefore: ● Higher maintenance costs ● Longer maintenance times, therefore: ● More tools in circulation (greater capital investment) ● Strongly progressive increase in wear following penetration of the coating, consequently: ● Greater risk of built-up edges

Use of coated solid carbide hobs with K type substrate
Maintenance process: removal of coating - regrinding - re-coating (flank and cutting face coated)

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.

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.

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.

	Advantages	Disadvantages
Machine	● Supports chip removal ● Lower heating up of the machine	● Aggregates (filters, pumps, etc.), therefore: ● Greater space requirements ● Additional operating expenditure (maintenance, power, etc.)
Tool	● Cooling of the tool ● Lubrication of the friction zones	● Lower tool life owing to the formation of cracks perpendicular to the cutting edge (thermal shock)
Workpiece	● Lower heating ● Lower dimensional deviations ● Protection against corrosion	● Cleaning necessary
Environment	● Binding of graphite dust during cast iron machining	● Health risk
Further costs	● Tempering of the workpiece, thus faster measurement	● Purchasing costs ● Inventory costs ● Contaminated chips, therefore: ● Expensive recycling processes and ● Higher disposal costs

Advantages and disadvantages of the use of cooling lubricant during hobbing

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.

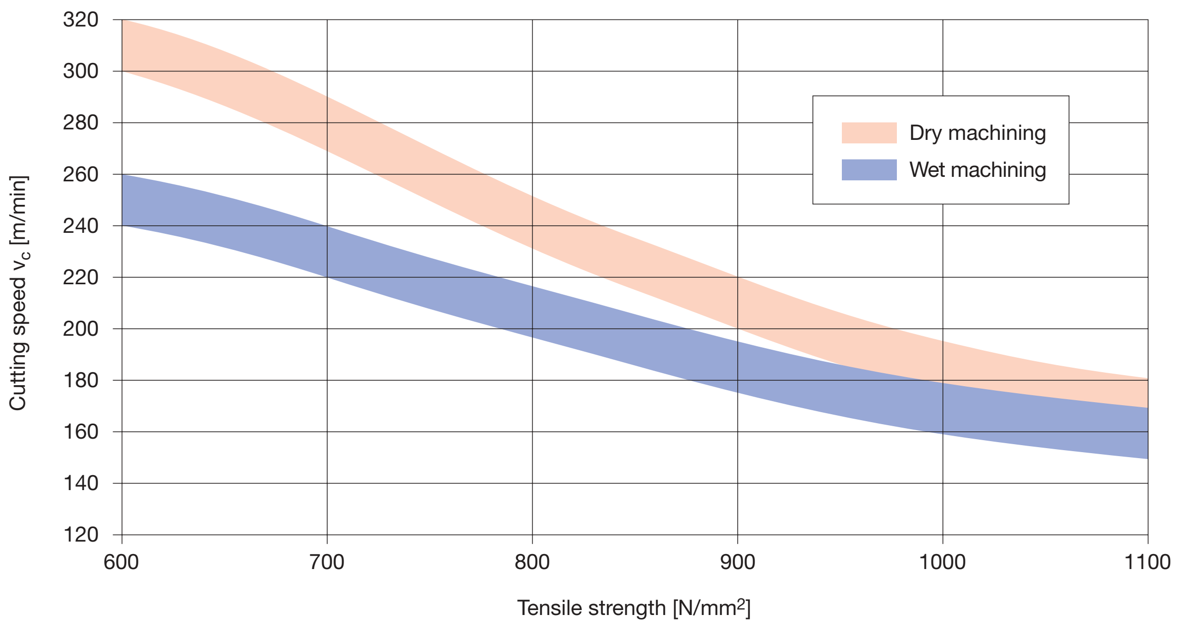
As already mentioned, HSC machining must be considered in conjunction with dry machining. The first studies were performed on HSC hobbing machines in the early 1990s. This process now permits dry machining of gears in a secure process at cutting speeds of up to 350 m/min.

Applications and cutting data

The proven applications for solid carbide tools for gear and pinion manufacture lie in a module range from m = 0.5 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.



Cutting speeds for a range of material tensile strengths, carbide hobbing, dry and wet, module 2

Wear behavior

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

Pitting, which occurs on HSS 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 recoated 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.

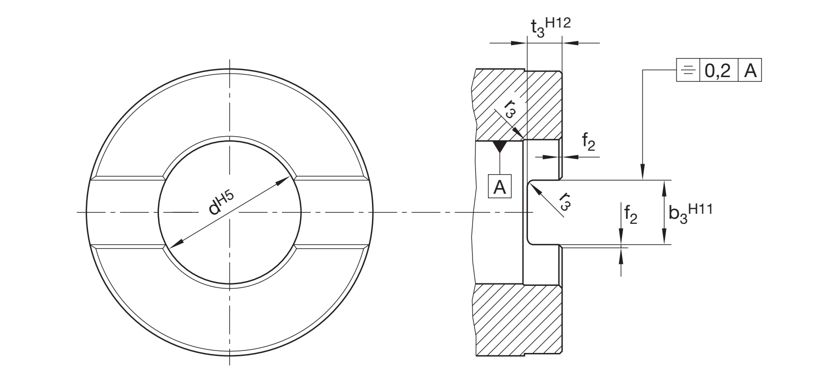
The "de-coating" and "re-coating" processes are required in addition for hobs manufactured from K type carbide.

Further information on the maintenance of solid carbide hobs can be found on Page 168.

Structural dimensions

The size table indicates the hob dimensions for which 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.

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



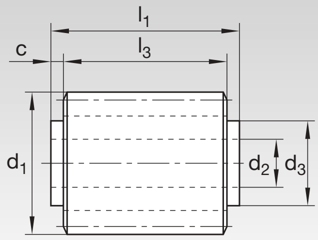
Drive slot dimensions of a carbide hob

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

t_3 = 1/2 depth to DIN 138

Size table for solid carbide hobs

Recommended structural dimensions



d_1 = outside diameter
l_3 = cutting edge length
l_1 = total length
c = shoulder width
d_2 = bore diameter
d_3 = shoulder diameter
h_0 = max. profile height

Dimensions in mm							Number of gashes
d_1	**l_3**	**l_1**	**d_2**	**c**	**d_3**	**h_0**	
Long version							
56	82	100	22	9	42	3	19
63	112	130	27	│	48	4	│
70	160	180	32	10	54	5	│
80	│	│	│	│	│	7	│
90	│	│	40	│	66	8	│
100	180	200	│	│	72	10	│
120	208	230	50	11	80	13	│
Short version							
56	52	70	22	9	42	3	19
63	72	90	27	│	48	4	│
70	100	120	32	10	54	5	│
80	│	│	│	│	│	7	│
90	│	│	40	│	66	8	│
100	120	140	40	│	72	10	│
120	138	160	50	11	80	13	│

Roughing hobs

High cutting capacities are achieved with the heavy duty rouching 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 cutter teeth. This results, particularly when roughing, in an extremely uneven load and wear distribution on the cutter 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 very 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.

These requirements are met perfectly by the FETTE heavy duty roughing hob with its vertically staggered teeth. The cutter 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 16 or 20 flutes on a still practicable cutter diameter.

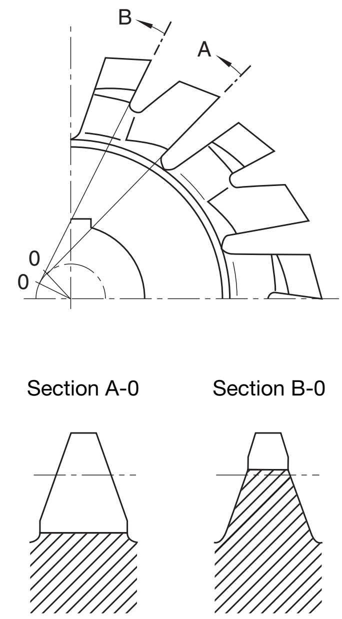
The 8 or 10 complete teeth on the cutter circumference are generally sufficient for producing the profile shape within the required tolerances. The heavy duty roughing hob can therefore also be used as a finishing cutter.

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

For roughing, the cutter 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 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.

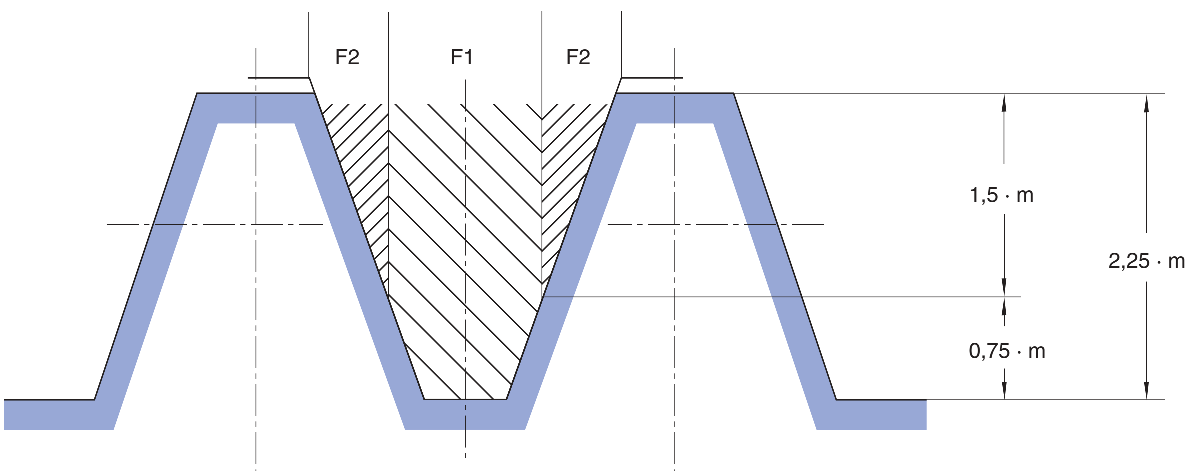


Face plane of a roughing hob

Metal removal areas on the cutter tooth:

tooth tip corresponds to area F 1 ≈ 75 %
tooth root corresponds to area F 2 ≈ 25 %

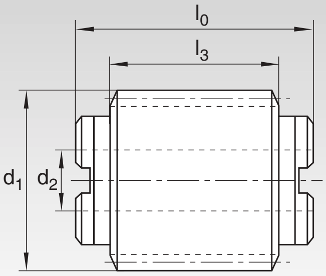
tooth gash volume = 100 %

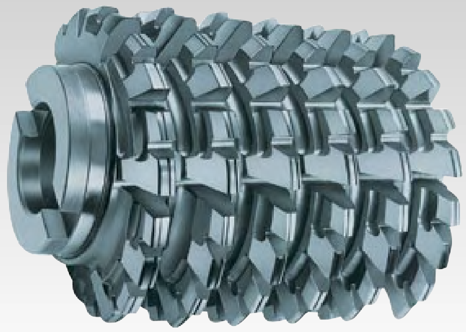


Heavy duty roughing hobs

(roughing type hobs)
for spur and helical gears to module pitch

20° pressure angle
basic profile III to DIN 3972
with positive rake (undercut)
optionally with chip breaker grooves
single start right-handed
with drive slot





KHSS-E EMo5Co5

Cat.-No.

2051	**relief turned**	**Quality grade B/C to DIN 3968**	**with 20 gashes**
2053	**relief ground**	**Quality grade A to DIN 3968**	**with 20 gashes**
2055	**relief turned**	**Quality grade B/C to DIN 3968**	**with 16 gashes**
2057	**relief ground**	**Quality grade A to DIN 3968**	**with 16 gashes**

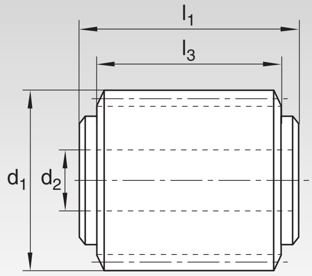
Dimensions in mm

m	d_1	l_3	l_0	d_2
6	150	108	140	50
7		126	158	
8	160	144	176	
9		162	194	
10	170	180	214	60
11	180	198	232	60
12	190	216	250	
13	200	234	268	
14	210	252	286	
15	230	270	310	80
16	240	288	330	
18	260	318	360	
20	290	360	406	100
22	300	396	442	100
24	310	432	478	
27	330	486	532	
30	340	540	586	

Heavy duty roughing hobs

(roughing type hobs)
for spur and helical gears to module pitch

20° pressure angle
basic profile III to DIN 3972
with positive rake (undercut)
optionally with chip grooves
single start right-handed
with keyway



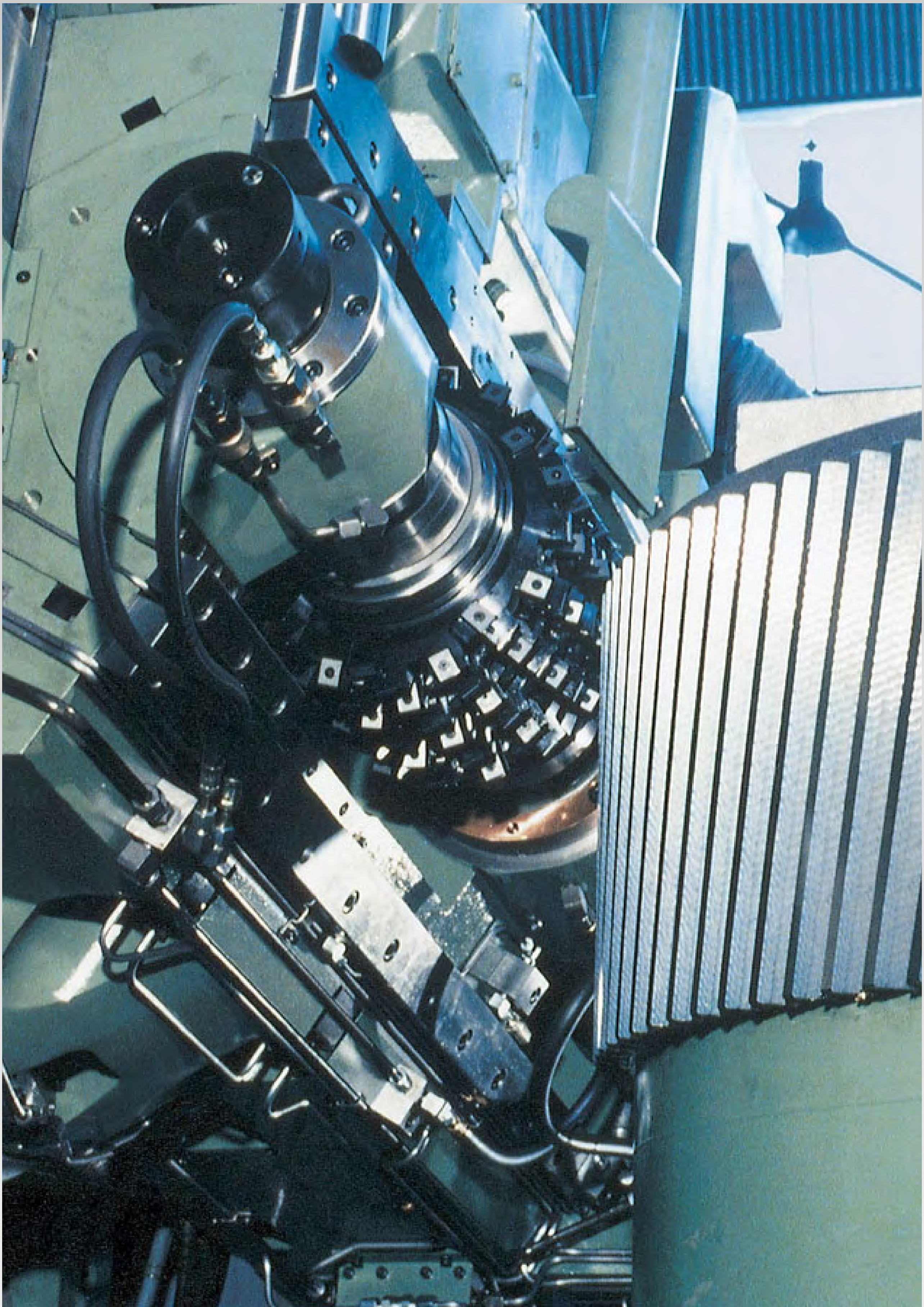
KHSS-E EMo5Co5

Cat.-No.			
	2061 relief turned	■ Quality grade B/C to DIN 3968	■ with 20 gashes
	2063 relief ground	■ Quality grade A to DIN 3968	■ with 20 gashes
	2065 relief turned	■ Quality grade B/C to DIN 3968	■ with 16 gashes
	2067 relief ground	■ Quality grade A to DIN 3968	■ with 16 gashes

Dimensions in mm					Ident No.	Ident No.	Ident No.	Ident No.
m	**d_1**	**l_3**	**l_0**	**d_2**	**2061**	**2063**	**2065**	**2067**
6	150	108	118	50	1208017	1208053	1209205	1209023
7		126	136		1208019	1208055	1209214	1209025
8	160	144	154		1208021	1208057	1209223	1209028
9		162	172		1208023	1208059	1209232	1209030
10	170	180	190	60	1208025	1208061	1209241	1209032
11	180	198	208	60	1208027	1208063	1209250	1209034
12	190	216	226		1208029	1208065	1209269	1209037
13	200	234	244		1208031	1208067	1209278	1209039
14	210	252	262		1208033	1208069	1209287	1209041
15	230	270	280	80	1208035	1208071	1209296	1209043
16	240	288	300		1208037	1208073	1209303	1209046
18	260	318	330		1208039	1208075	1209312	1209048
20*	287				1208041	1208077	1209321	1209050
20	290	360	372	100	1208043	1208079	1209011	1209052
22	300	396	408	100	1208045	1208081	1209013	1209055
24	310	432	444		1208047	1208083	1209015	1209057
27	330	486	498		1208049	1208085	1209017	1209059
30	340	540	552		1208051	1208087	1209019	1209061

* For hobbing machines with max. capacity = 290 mm dia. and for max.cutter lenght = 330 mm.

Roughing hobs with indexable carbide inserts



Roughing hob with indexable carbide inserts in operation

The rough hobbing of gears form module 5 onwards can be carried out extremely economically with this modern tool.

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 indexable inserts, only those inserts need be turned 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 form the machine. This results in short hobbing machine downtimes.

Changing the indexable 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.

Construction

FETTE 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.

Cutter body

Tooth segment

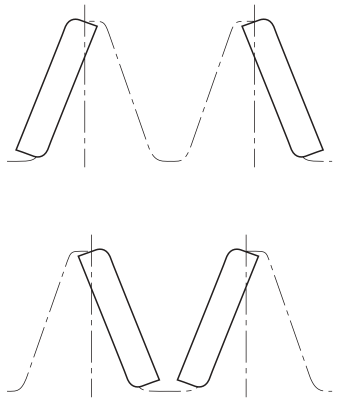
The parts of the ground cylindrical shell which remain between the groove windings act as support surfaces for the tooth segments. Two cylindrical pins arranged in the tooth segments are guided in the groove and determine the position of the segments.
The segments are fixed to the cutter body by inhex 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.

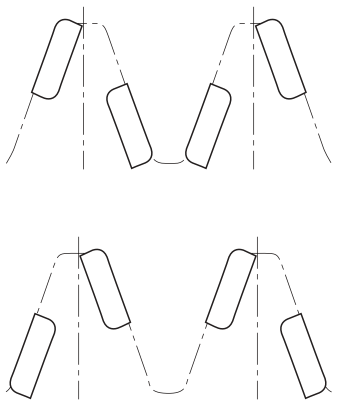
The indexable carbide inserts must completely cover the cutting edges of the cutter tooth. The necessary number of indexable inserts and their arrangement depend on the dimensions of the inserts and on the size of the gear. To render the pre-cutting of the gear optimal for skive hobbing or grinding,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

In the range from module 5 to module 10 each cutter tooth only holds **one** insert, which covers the entire flank length.

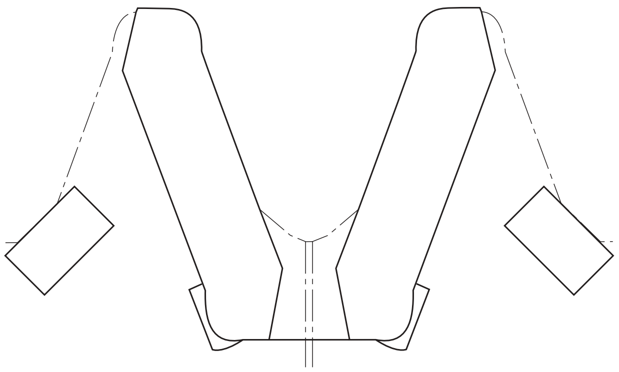
From module 11 onwards, each flank is fitted with an indexable insert offset to the opposite flank. In special cases, versions with a single insert covering each flank are also possible with these module sizes.



Cutting edge construction module 5–10



Cutting edge construction module 11–20

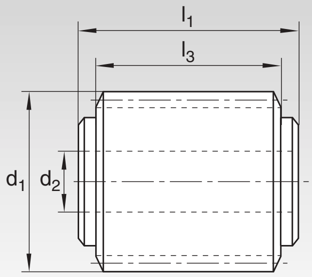


Profile design with protuberance and chamfer

Roughing hobs

with indexable carbide inserts
for spur and helical gears
to module pitch

20° pressure angle
basic profile by arrangement
single start right-handed
with keyway



Carbide - TiN-coated

Cat.-No. **2163**

Dimensions in mm					Number of tooth rows	Number of segments	Number of indexable inserts[1)]	Ident No.
m	**d_1**	**l_3**	**l_1**	**d_2**				
5	190	95	144	60	19	24	96	–
6		114	165					1224206
7	210	133	185					–
8		152	206					1224215
9		171	227					–
10		190	248					1224224
11	280	209	269	80	19	24	192	–
12		229	289					1224233
13		248	310					–
14		267	331					1224242
15	280	286	352	80	19	24	192	–
16	300	305	373					1224251
17		324	394					–
18		343	415					1224260
19		362	436					–
20	300	382	457	80	19	24	192	1224279

Spare parts and indexable inserts: design on request.

1) The number of indexable inserts may change according to the basic profile.

Carbide skiving hobs

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 down to the necessary grinding allowance. Grinding times and costs are reduced while gaining additional grinding capacity.

The tool

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.

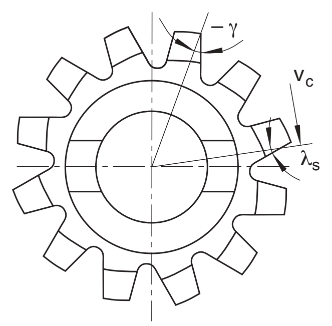
Tool material

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.

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
  FETTE Cat. no. 2028
- Brazed-on carbide tips
  for modules above 4
  FETTE Cat. no. 2129
- Indexable carbide inserts
  for modules from 5 upwards
  FETTE Cat. no. 2153



$-\gamma$ = tip rake angle
λ_s = back rake of the flank cutting edge
v_c = cutting speed

Fig. 2

Fig. 1

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 cutter 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.

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).

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

Preparation for skive hobbing

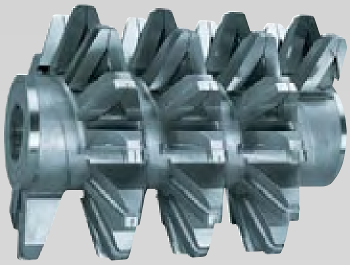
The machining allowance depends on the module size and the hardening distortion. Experience has shown that for the module range 2 to 10 it lies between 0.15 and 0.30 mm/flank.

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

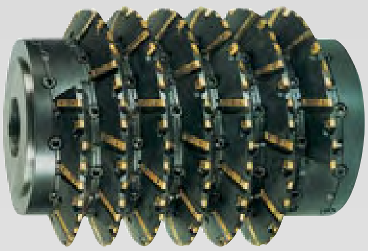
We recommend hobs protuberance, e.g. FETTE Cat. no. 2026.

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

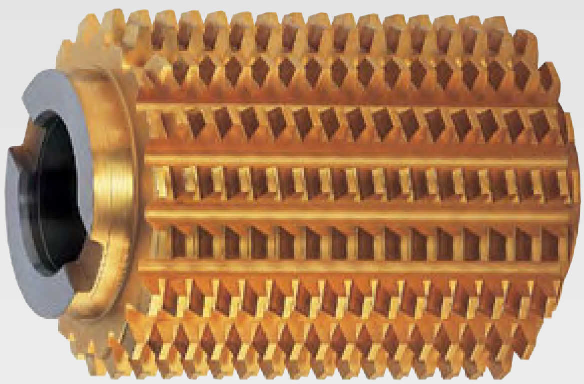
Skiving hob with brazed-on carbide tips



Skiving hob with brazed-on carbide strips



Skiving hob with indexable carbide inserts



Solid-carbide skiving hob

Cutting conditions

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 quoted for module 30 and of 110 m/min for module 2.

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.

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.

Feed

The structure of surfaces machined with hobs is affected by the depth of the feed markings. 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.

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

Climp hobbing method

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

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.

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.

Wear and tool life values

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

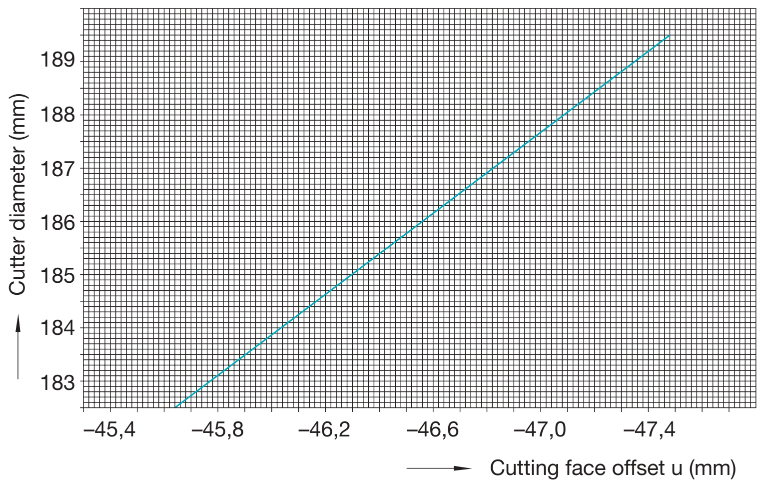
The gear quality when skive hobbing depends on the interaction of a large number of components and parameters, such as:

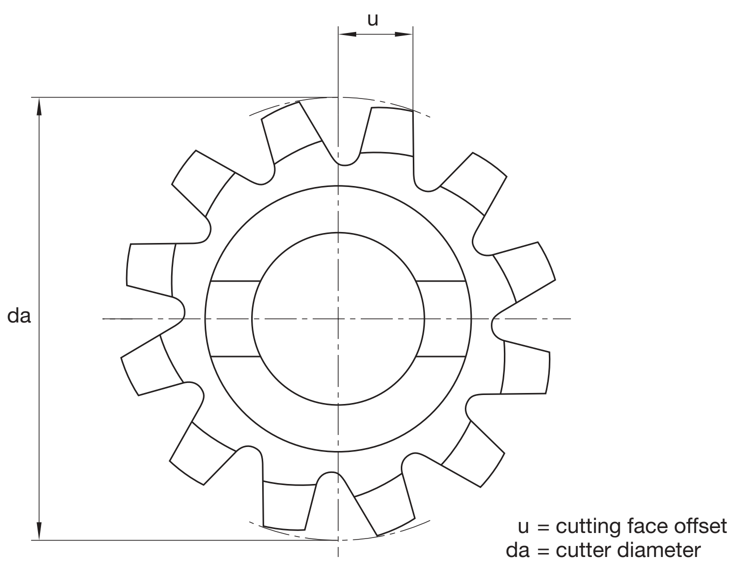
- skiving hob (cutting material, correctly sharpened, sufficent accuracy)
- rigid hobbing machine
- accurate and stable clamping of hob and workspiece
- hob aligned with an absolute minimum of runout
- accurate centering
- correct selection of cutting speed, feed and metal removal per flank
- adherence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

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 1to2 µm.





Cutting face regrinding diagram for carbide skiving hobs

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

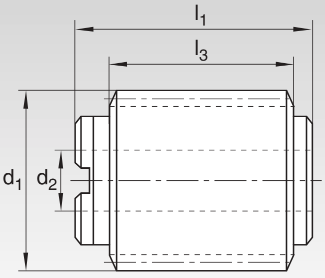
The skiving hob should be sharpened when the wear mark has reached a width of 0.15 mm. Diamond wheels are used for grinding with the traverse grinding or the deep grinding process.
Because of the negative tip rake angle, the grinding wheel must be set off-centre. The measurement for the setting of the 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.

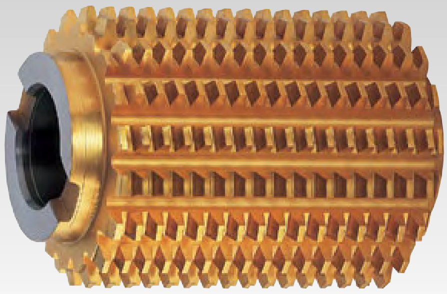
Skiving hobs

Solid carbide

for finishing hardened (highly tempered) spur and helical gears to module pitch

20° pressure angle
basic profile: $h_{a0} = 1.15 \cdot m$, $\varrho_{a0} = 0.1 \cdot m$
quality grade AA nach DIN 3968
single start right-handed
with keyway





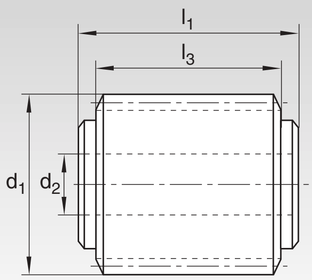
Carbide – TiN coated

Cat.-No.					**2028** relief ground	
Dimensions in mm					Number of gashes	Ident No.
m	**d_1**	**l_3**	**l_1**	**d_2**		
2	80	100	120	32	15	2352890
2,5						2352891
3	90			40		2352892
3,5	100	120	140			2352893
4						4021516

Skiving hobs

with brazed-on carbide inserts
for finishing hardened (highly tempered)
spur and helical gears to module pitch

20° pressure angle
basic profile: $h_{a0} = 1.15 \cdot m$, $\varrho_{a0} = 0.1 \cdot m$
quality grade AA nach DIN 3968
single start right-handed
with keyway



Carbide

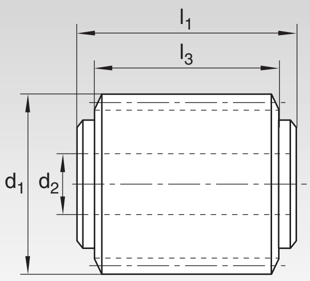
Cat.-No. **2129** **relief ground**

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

Skiving hobs

with indexable carbide inserts
for finishing hardened (highly tempered)
spur and helical gears to module pitch

20° pressure angle
basic profile: h_{a0} = 1.15 · m,
depth of cut 2.15 · m
quality grade AA to DIN 3968
single start right-handed
with keyway or drive slot



Carbide

Cat.-No. **2153**

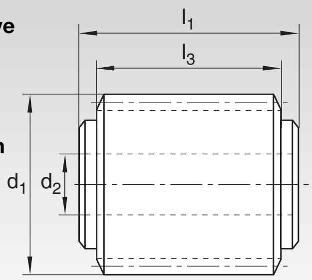
Dimensions in mm						Number of tooth rows	Number of segments	Number of index inserts	Ident No.
m	d_1	l_3	l_1	l_1 1)	d_2				
5	160	79	127	147	50	19	19	76	–
6		94	145	165					1224000
7	190	110	163	183					–
8		126	180	200					1224019
9		142	197	217					–
10		158	215	235					1224028
11	220	173	232	256	60	21	21	84	–
12		189	250	274					1224037
13	250	205	267	291		23	23	92	–
14		220	285	309					1224046
15	250	236	302	326	60	23	23	92	–
16		252	320	344					1224055
17	280	268	337	365	80				–
18		284	355	383					1224064
19		299	373	401					–
20	280	315	390	418	80	23	23	92	1224073

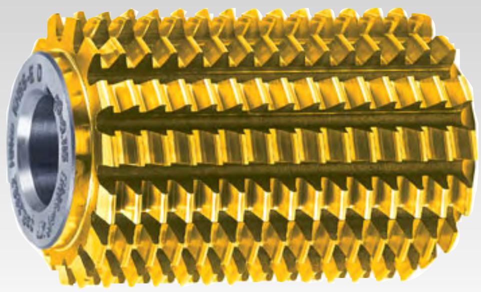
1) with drive slot
Spare parts and indexable inserts: design details on request.

Solid-type hobs

for straight spur gears with straight and helical teeth
to module
with protuberance
for rough hobbing prior to grinding or skive hobbing

20° pressure angle
basic profile: $h_{a0} = 1.4 \times m$, $\varrho_{a0} = 0.4 \times m$
allowance per flank: $q_{P0} = 0.09 + 0.0125 \times m$
protuberance value:
$pr_{P0} = 0.129 + 0.0290 \times m$ up to module 7
$pr_{P0} = 0.181 + 0.0235 \times m$ above module 7
quality grade A to DIN 3968
single-start
with keyway





KHSS-E EMo5Co5 **– TiN-coated**

Cat.-No. **2026**

Dimensions in mm					Number of gashes	Ident No. Right-handed	Ident No. left-handed
m	**d_1**	**l_3**	**l_1**	**d_2**			
1	70	50	56	27	17	1223334	1223344
2		90	100		15	1223326	1223346
3	80	110	120	32		1223338	1223348
4	90	120	130		14	1223340	1223350
5	100	140	150			1223343	1223352
6	140			40		1223345	1223355
7	150					1223347	1223357
8	160	160	170	50		1223349	1223359
9	170					1223351	1223361
10	180	180	190			1223353	1223363
12	200	200	210	60	12	1223356	1223365

Hobs
for internal gears, with straight or helical teeth, involute flanks

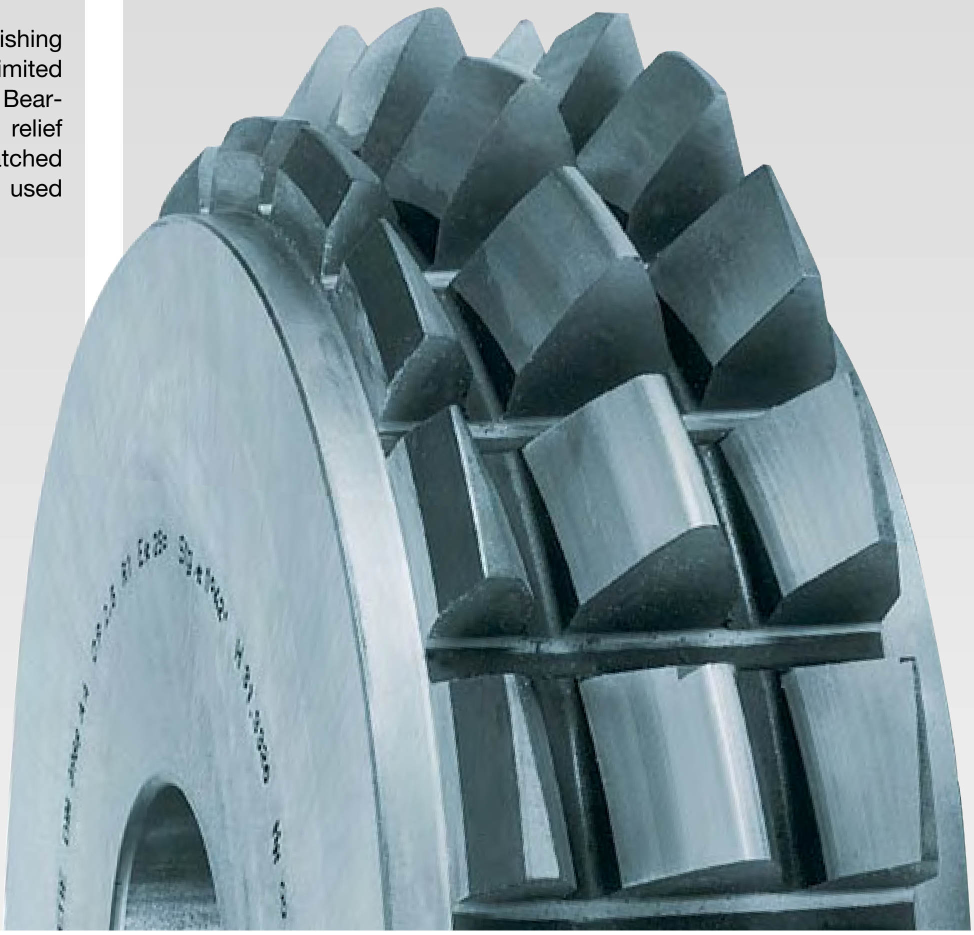
Explanatory notes

Hobs for internal gears are designed for a specific gear. The measurements for the maximum and the minimum cutter diameter and the maximum cutter width must then be taken into account, for which the internal hobbing head is dimensioned.

In the case of internal gears with large profile displacement, the maximum permissible cutter width may be insufficient for cutting the complete teeth, if the hob is dimensioned in the usual way. It is then necessary to fix the module and the pressure angle of the hob differently from those of the internal gear.

On the hob, one tooth is defined as a "setting tooth" and marked accordingly. The cutter must be positioned on the hobbing machine so that the setting tooth is when new placed in the "machine centre". Although the setting tooth will shift in the axial direction when the hob is reground, it is not necessary to correct the position of the hob determined in the new condition and fixed by spacers.

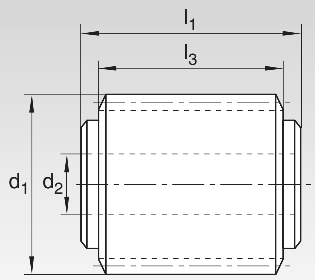
The hobs offered for finishing internal gears are only to a limited extent suitable for roughing. Bearing in mind the tool costs, relief turned hobs with a lead matched to the workpiece should be used for roughing.



Solid-type hobs

for internal gears to module pitch
straight or helical teeth

20° pressure angle
basic profile II to DIN 3972
quality grade AA to DIN 3968
single start right-handed
with keyway



KHSS-E EMo5Co5

Cat.-No.			**2082** relief ground		
Dimensions in mm					Number of gashes
m	**d_1**	**l_3**	**l_1**	**d_2**	
5	360	45	65	100	30
6		52	72		
8		66	86		24
10		80	90		22
12		94	104		
14		108	118		
16		122	132		20
18		136	146		18
20		150	160		16

The structural dimensions listed are approximate values, which can be changed according to the size of the internal hobbing head and the tooth data of the gear.

For internal hobs greater than module 20, workpiece drawings and dimensions of the internal hobbing head must be submitted, so that the structural dimensions of the hob can be determined accordingly.

Hobs
for compressor rotors and pump spindles

Hobs for compressor rotors

Rotors are the multi-thread feed screws of a screw compressor, which are arranged in pairs inside a housing. The meshing screw threads have a symmetrical or an asymmetrical profile.

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

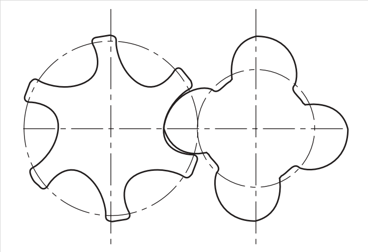
The advantages of hobbing produce favourable results in rotor manufacture:

- 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.

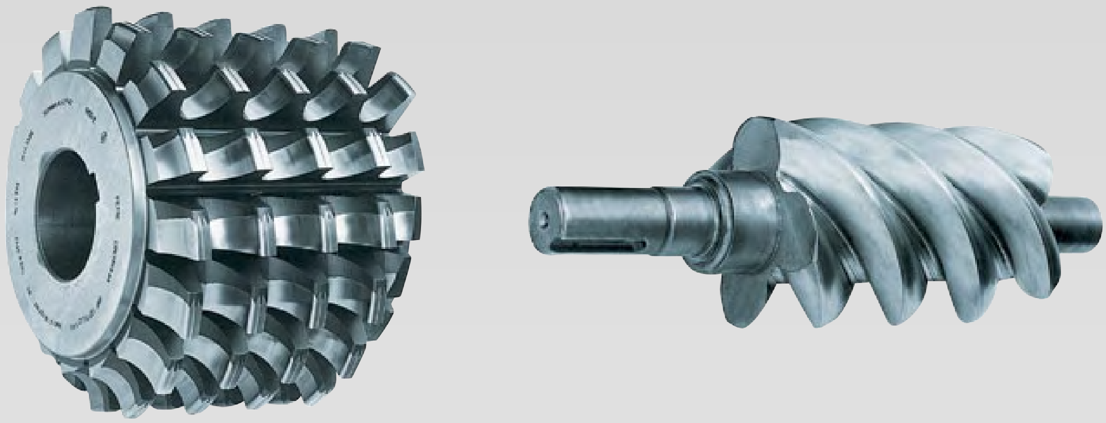
The use of this technology for rotor manufacture requires the development of the required analysis programs for rotor and hob profiles and high standards of manufacturing in the area of precision hobs.

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

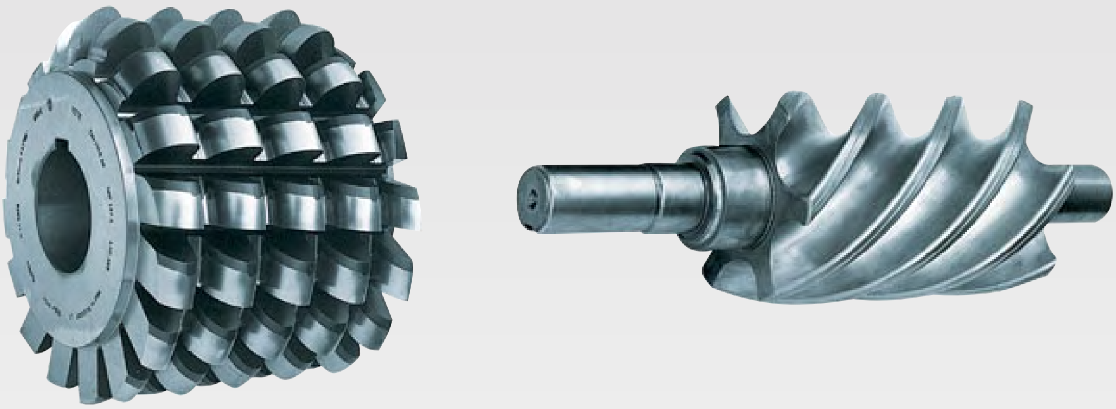
The successful use of hobs also depends on the degree to which the tool manufacturer on the one hand and the rotor producer or -designer on the other hand communicate with each other about the production constraints imposed on profile shape, amount of play and play distribution. This process then does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



Rotors: face plane view



Male rotor

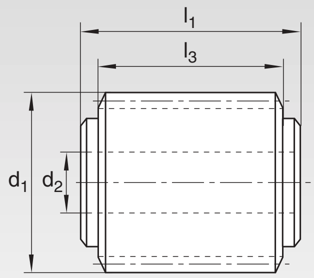


Female rotor

Rotor hobs, for roughing

for screw compressors
for male and female rotors
as heavy-duty roughing hobs
with 16 flutes
axially parallel gashes

single start
with keyway



for male rotors

for female rotors

KHSS-E EMo5Co5

Cat.-No. **2091** **relief turned**

Dimensions in mm

Rotor dia.	m	Profile height	Cutter dimensions			
			d_1	**l_3**	**l_1**	**d_2**
47/44,5	≈ 5,2	≈ 10,2	112	90	106	40
81,6	≈ 9,1	≈ 17,5	140	154	170	50
102	≈ 11,4	≈ 22	170	184	200	60
127,5	≈ 14,2	≈ 27,5	212	234	250	|
163,2	≈ 18,2	≈ 35,5	265	299	315	80
204	≈ 22,7	≈ 44	305	319	335	100
204	≈ 22,7	≈ 44	335	|	|	|

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

When ordering, workpiece drawings of the rotors and data abaut 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.
FETTE played a leading part in the introduction of the hobbing process for the manufacture of rotors. 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:

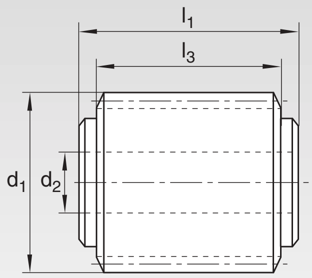
- Quick and trouble-free production of rotors with good surfaces and accurate profiles and pitch.
- The sealing strips on the tooth tip and the sealing grooves in the tooth root of the rotors can be generated in one operation with the flanks.
- Hobbed rotors can be exchanged at any time, thanks to their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

Rotor hobs, for finishing

for screw compressors
for male and female rotors

quality grade AA restricted to DIN 3968
axially parallel flutes

single start
with keyway



for male rotors

for female rotors

KHSS-E EMo5Co5

Cat.-No.			**2092** relief ground			
Dimensions in mm						
			Cutter dimensions			
Rotor dia.	**m**	Profile height	**d_1**	**l_3**	**l_1**	**d_2**
47/44,5	≈ 5,2	≈ 10,2	140	74	90	60
81,6	≈ 9,1	≈ 17,5	190	124	140	80
102	≈ 11,4	≈ 22	236	154	170	
127,5	≈ 14,2	≈ 27,5	265	196	212	100
163,2	≈ 18,2	≈ 35,5	300	249	265	
204	≈ 22,7	≈ 44	305	299	315	
204	≈ 22,7	≈ 44	335			

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

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

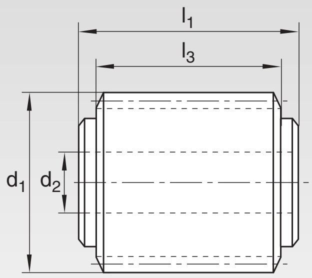
When ordering, workpiece drawings of the rotors and data about the profile at the face plane (list of coordinates) must be made available.

Hobs

for screw pumps
for drive or trailing spindle

quality grade AA restricted to DIN 3968
single start
with keyway

Hob for drive spindle



Hob for trailing spindle

KHSS-E EMo5Co5

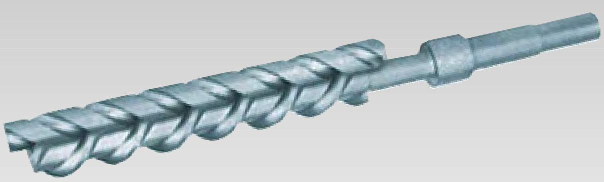
Cat.-No. **2094 relief ground**

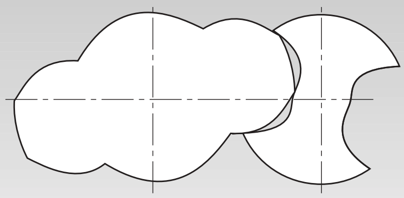
Drive spindle D x d1)	Trailing spindle D x d1)	Dimensions in mm Hob dimensions				Number of gashes
		d_1	l_3	l_1	d_2	
18 x 10,8	10,8 x 3,6	100	52	60	32	16
20 x 12	12 x 4		55	63		
30 x 18	18 x 6	112	72	80		
35 x 21	21 x 7	118	82	90		
38 x 22,8	22,8 x 7,6	125	87	95	40	
45 x 27	27 x 9	140	98	106		18
52 x 31,2	31,2 x 10,4	150	104	112	50	
60 x 36	36 x 12	160	110	118		
70 x 42	42 x 14	180	122	132		

1) D = Outside diameter, d = inside diameter

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 quoted: 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.





Drive and trailing spindles


KHSS-E

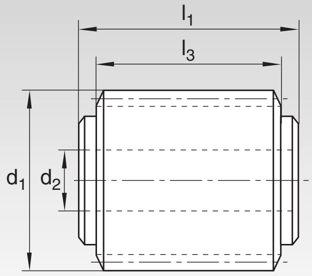
Hobs

for sprockets, timing belt pulleys and splines

Hobs

for sprockets to DIN 8196
for roller and barrel chains
to DIN 8187, 8188

basic profile to DIN 8197
single start right-handed
with keyway



KHSS-E EMo5Co5

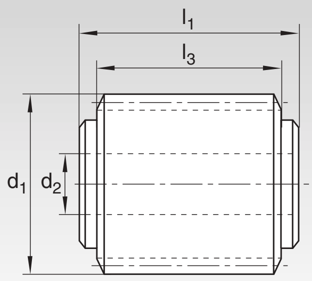
Cat.-No. **2301** **relief turned**

Dimensions in mm					Number of gashes	Ident No.
Chain		Hob dimensions				
Pitch	Roller/barrel dia.	d_1	l_1	d_2		
5,0	3,2	56	38	22	12	1226204
6,0	4					1226213
8,0	5	63		27		1226231
9,525	6,35	70	46			1226268
12,7	7,92	80	56	32		
	7,75					1226286
	7,77					
12,7	8,51					1226295
15,875	10,16	90	69		10	1226302
19,05	11,91	100	88			1226320
	12,07					
25,4	15,88	110	108	40		1226339
31,75	19,05	125	133			1226357
38,1	22,23	140	150			1226366
	25,4					1226375
44,45		160	170	50	9	1226384
	27,94					1226393
50,8	28,58	170	190			2111640
	29,21					1226419
63,5	39,37	190	235			2110189
	39,68					
76,2	47,63	225	290	60		2110188
	48,26					2108994

Hobs

for sprockets for Gall's chains (heavy)
to DIN 8150

single start right-handed
with keyway



KHSS-E EMo5Co5

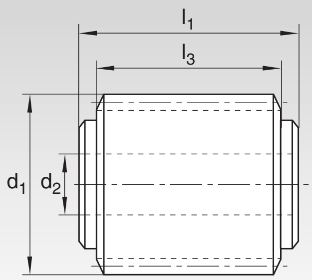
Cat.-No. **2311** **relief turned**

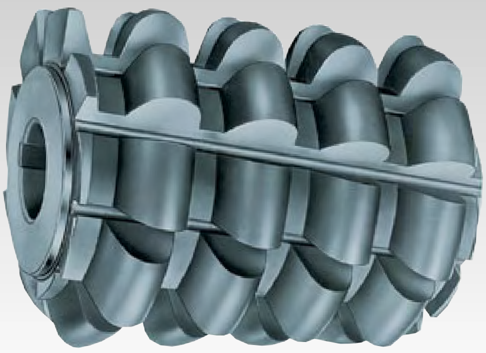
Dimensions in mm					Number of gashes	Ident No.
Chain		Hob dimensions				
Pitch	Roller dia.	d_1	l_1	d_2		
3,5	2	50	31	22	12	2110190
6	3		38			1226829
8	3,5	56				2110191
10	4		51			1226847
15	5	63	69	27		1226856
20	8	80	98	32		1226865
25	10	90	108		10	1226874
30	11	100	133			1226883
35	12		150			2110192
40	14	110	170	40		2110193
45	17	125	190			2110194
50	22	140	210			1226909
55	24					1226911
60	26	160	235	50	9	1226913
70	32	180	290			1226915
80	36	190				1226917
90	40	210	325	60		1226919
100	45	220	365			1226921
110	50	240	410			1226923
120	55	250				1226925

Hobs

for sprockets for barrel chains
to DIN 8164

single start right-handed
with keyway





KHSS-E EMo5Co5

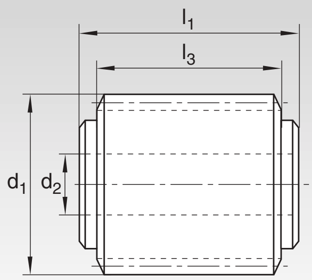
Cat.-No. **2331** **relief turned**

Dimensions in mm					Number of gashes	Ident No.
Chain		Hobs dimensions				
Pitch	Roller dia.	**d_1**	**l_1**	**d_2**		
15	9	90	69	32	12	1227317
20	12	100	98		10	1227329
25	15	110	108	40		1227338
30	17	125	133			1227347
35	18		150			1227349
40	20	140	170			1227365
45	22		190			1227374
50	26	160	210	50	9	1227376
55	30	170				1227378
60	32	180	235			1227380
65	36	190	260			1227382
70	42	210	290	60		1227384
80	44	220				1227386
90	50	240	325			1227388
100	56	250	365			1227390

Hobs

for sprockets with involute flanks
with tip relief

30° pressure angle
quality grade A to DIN 3968
single start right-handed
with keyway



KHSS-E EMo5Co5

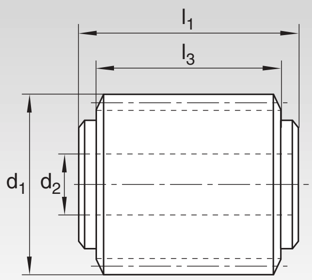
Cat.-No. **2341** **relief ground**

Pitch Inch	Dimensions in mm				Number of gashes	Ident No.
	d_1	l_3	l_1	d_2		
5/16	70	63	69	27	16	1227506
3/8	80			32		1227515
1/2	90	70	78			1227524
5/8		80	88		14	1227533
3/4	100	92	100			1227542
1	110	120	130		12	1227551
1 1/2	150	160	170	50		1227560
2	190	215	225			1227579

Hobs

for synchroflex timing belt pulleys
topping cutter

quality grade A to DIN 3968
single start right-handed
with keyway



KHSS-E EMo5Co5

Cat.-No. **2342 relief ground**

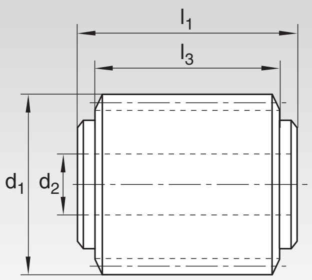
Pitch	Tooth number range	Dimensions in mm				Number of gashes	Ident No.
		d_1	**l_3**	**l_1**	**d_2**		
T 2,5 se	12– 20	50	25	31	22	14	1228006
T 2,5	21– 45						1228015
T 2,5	46– 80						1228024
T 5 se	10– 14	56	32	38	22	14	1228033
T 5 se	15– 20						1228042
T 5	21– 50						1228051
T 5	51–114						1228060
T 10 se	12– 15	70	50	56	27	14	1228079
T 10 se	16– 20						1228088
T 10	21– 45						1228097
T 10	46–114						1228104
T 20 se	15– 20	90	80	88	32	14	1228113
T 20	21– 45						1228122
T 20	46–119						1228131

The "se" tooth gap form is applied up to 20 teeth incl., over 20 teeth = normal profile

Hobs

for timing belt pulleys
with involute flanks to DIN/ISO 5294
topping cutter

quality grade A to DIN 3968
single start right-handed
with keyway



KHSS-E EMo5Co5

Cat.-No. **2352** **relief ground**

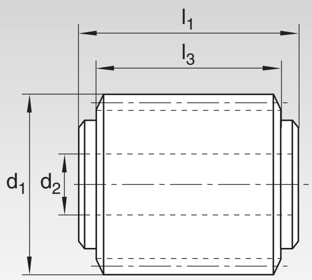
Pitch	Tooth number range	Dimensions in mm				Number of gashes	Ident No.
		d_1	**l_3**	**l_1**	**d_2**		
0,08 MXL	10 up to 23	50	25	31	22	14	1203010
	from 24						2257398
1/8 XXL	from 10						1203012
1/5 XL	from 10	56	32	38			1228300
3/8 L	from 10	70	50	56	27		1228319
1/2 H	14–19		63	69			1228328
1/2 H	from 20						1228337
7/8 XH	from 18	100	80	88	40		1228346
1 1/4 XXH	from 18	115	100	108			1228355

Hobs for timing belt pulleys with straight flanks to DIN/ISO 5294 on request.
Our range also includes hobs for timing belt pulleys with special profiles.

Hobs

for spline shafts

quality grade A to DIN 3968
single start right-handed
with keyway



KHSS-E EMo5Co5

Cat.-No. **2402** **relief ground** / **2412** **relief ground**

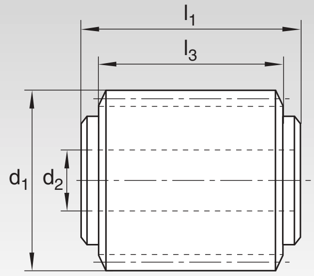
Dimensions in mm			Number of splines	Dimensions in mm					Number of gashes	Ident No.
Spline shaft nominal dimesions				For shldr. dia.	Hob dimensions					
I.d. g 6	O.d. a 11	Wdth of spl. h 9			**d_1**	**l_3**	**l_1**	**d_2**		
2402 For spline shafts to DIN ISO 14 – light series ■ Cutting to shoulder, with 2 lugs and chamfer										
23	26	6	6	29	56	30	36	22	12	1229461
26	30			33	63	34	40	27		1229470
28	32	7		35						1229489
32	36	6	8	39		39	45			1229498
36	40	7		43						1229504
42	46	8		50						1229513
46	50	9		54	70	44	50			1229522
52	58	10		62		50	56			1229531
56	62			66						1229540
62	68	12		73						1229559
72	78		10	83		57	63			1229568
82	88			93	80			32		1229577
92	98	14		103	90	65	71			1229586
102	108	16		113	100					1229595
112	120	18		126		72	80			1229602
2412 For spline shafts to DIN ISO 14 – medium series ■ Cutting to shoulder, with 2 lugs and chamfer										
11	14	3	6	16	56	26	32	22	12	1230217
13	16	3,5		18						1230226
16	20	4		22		30	36			1230235
18	22	5		25		34	40			1230244
21 [1)]	25			28	63			27		1230253
23 [2)]	28	6		31		39	45			1230262
26 [3)]	32			35						1230271
28 [4)]	34	7		37		44	50			1230280
32	38	6	8	41						1230299
36	42	7		45						1230306
42	48	8		52	70	50	56			1230315
46	54	9		58						1230324
52	60	10		64		57	63			1230333
56	65			69	80			32		1230342
62	72	12		77		65	71			1230351
72	82		10	87	90					1230360
82	92			97		72	80			1230379
92	102	14		107	100					1230388
102	112	16		117	112			40		1230397
112	125	18		131		82	90			1230404

[1)], [2)], [3)], [4)] This hob is absolutely identical with the hob marked with the same index number under Cat.-No. 2442.

Hobs

for spline shafts

quality grade A to DIN 3968
single start right-handed
with keyway



KHSS-E EMo5Co5

Cat.-No. **2422** **relief ground** / **2432** **relief ground**

Dimensions in mm: Spline shaft nominal dimesions: I.d. g 6	O.d. a 11	Wdth of spl. h 9	Number of splines	Dimensions in mm: For shldr. dia.	Hob dimensions: d_1	l_3	l_1	d_2	Number gashes	Ident No.
2422 **For spline shafts to DIN 5464** ■ Cutting to shoulder, with 1** lug and chamfer										
16	20	2,5	10	22	56	30	36	22	12	1230994
18	23	3		25	63	34	40	27		1231001
21	26			28						1231010
23	29	4		31		39	45			1231029
26	32			34						1231038
28	35			37	70	44	50			1231047
32	40	5		43						1231056
36	45			48	80	50	56	32		1231065
42	52	6		55						1231074
46	56	7		59		57	63			1231083
52	60	5	16	63						1231092
56	65			68						1231109
62	72	6		75	100	65	71			1231118
72	82	7		85						1231127
82	92	6	20	95		72	80			1231136
92	102	7		105						1231145
102	115	8		119	112	82	90	40		1231154
112	125	9		129						1231163
2432 **For spline shafts to DIN 5471** ■ Cutting to shoulder, with 2 lugs and chamfer										
11	15	3	4	17	63	34	40	27	14	1231662
13	17	4		19						1231671
16	20	6		23		39	45			1231680
18	22			25						1231699
21	25	8		29	70	50	56			1231706
24	28			32						1231715
28	32	10		36						1231724
32	38			42	90	57	63	32		1231733
36	42	12		47						1231742
42	48			53	100	65	71		16	1231751
46	52	14		57						1231760
52	60			65	125	72	80	40		1231779
58	65	16		70						1231788
62	70			75						1231797
68	78			83	140	82	90			1231804

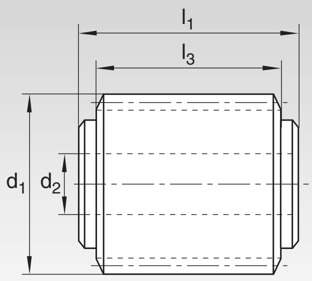
** Hobs may have 2 lugs for some spline shaft dimensions with 10 splines

LMT • FETTE

Hobs

for spline shafts

quality grade A to DIN 3968
single start right-handed
with keyway



KHSS-E EMo5Co5

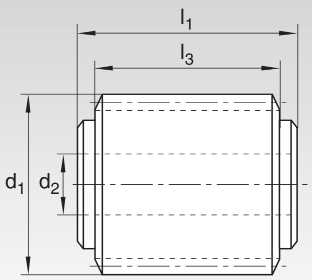
Cat.-No.					**2442** relief ground					
Dimensions in mm			Number of splines	Dimensions in mm					Number of gashes	Ident No.
Spline shaft nominal dimesions				For shldr. dia.	Hob dimensions					
I.d. g 6	O.d. a 11	Wdth of spl. h 9			**d1**	**l3**	**l1**	**d2**		
2442 For spline shafts to DIN 5472 ■ Cutting to shoulder, with 2 lugs and chamfer										
21 1)	25	5	6	28	63	34	40	27	12	1232420
23 2)	28	6		31		39	45			1232439
26 3)	32			35						1232448
28 4)	34	7		37		44	50			1232457
32	38	8		42	70	50	56			1232466
36	42			46						1232475
42	48	10		52	90	57	63	32	14	1232484
46	52	12		57						1232493
52	60	14		65	100	65	71			1232509
58	65			70						1232518
62	70	16		75						1232527
68	78			83	112	72	80	40		1232536
72	82			87						1232545
78	90			95	140	82	90		16	1232554
82	95			100						1232563
88	100			105						1232572
92	105	20		111		92	100			1232581
98	110			116						1232590
105	120			126	160	102	110	50		1232607
115	130			136						1232616
130	145	24		151						1232625

1), 2), 3), 4) This hob is absolutely identical with the hob marked with the same index number under Cat.-No. 2412.

Hobs

for p.t.o. shafts to DIN 9611

quality grade A to DIN 3968
single start right-handed
with keyway



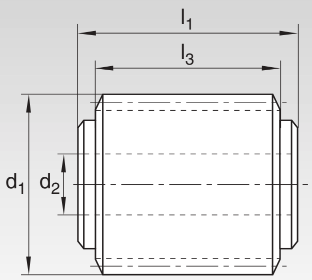
KHSS-E EMo5Co5

Cat.-No.	**2444 relief ground**					
P.t.o. shafts	Dimensions in mm Hob dimensions				Number of gashes	Ident No.
	d_1	**l_3**	**l_1**	**d_2**		
Form 1 28.91 ± 0.05 x 34.79 ± 0.06 x 8.69 $^{-0.09}_{-0.16}$ 6 splines with 2 lugs and chamfer	63	50	56	27	12	1232689
Form 2 DP 16, EW 30°, d_a = 34.67 21 teeth with chamfer	56	32	38	22	14	1232661
Form 3 DP 12, EW 30°, d_a = 44.33 20 teeth with chamfer	63	40	46	27	14	1232670

Hobs

for spline shafts with involute flanks
to DIN 5480

30° pressure angle
quality grade A to DIN 3968
single start right-handed
with keyway



KHSS-E EMo5Co5

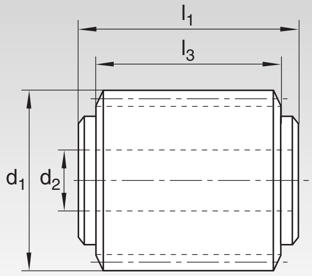
Cat.-No. **2472** **relief ground**

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

Hobs

for spline shafts with involute flanks
previously DIN 5482

30° pressure angle
quality grade A to DIN 3968
single start right-handed
with keyway



KHSS-E EMo5Co5

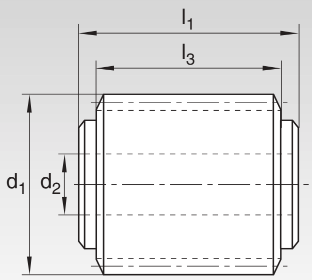
Cat.-No. **2452** **relief ground**

	Dimensions in mm					Number of gashes	Ident No.
Spl. shaft nom. size	m	d_1	l_3	l_1	d_2		
15 x 12	1,6	56	32	38	22	12	1233018
17 x 14							
18 x 15							
20 x 17							
22 x 19							
25 x 22							
28 x 25	1,75						1233027
30 x 27							
32 x 28							
35 x 31							
38 x 34	1,9	63	40	46	27		1233036
40 x 36							
42 x 38							
45 x 41	2						1233045
48 x 44							
50 x 45							
52 x 47							
55 x 50							
58 x 53							
60 x 55							
62 x 57	2,1						1233054
65 x 60							
68 x 62							
70 x 64							
72 x 66							
75 x 69							
78 x 72							
80 x 74							
82 x 76	2,25	70	50	56			1233063
85 x 79							
88 x 82							
90 x 84							
92 x 86							
95 x 89							
98 x 92							
100 x 94							

Hobs

for serrated shafts to DIN 5481
with staight flanks for involute flank
form on the component

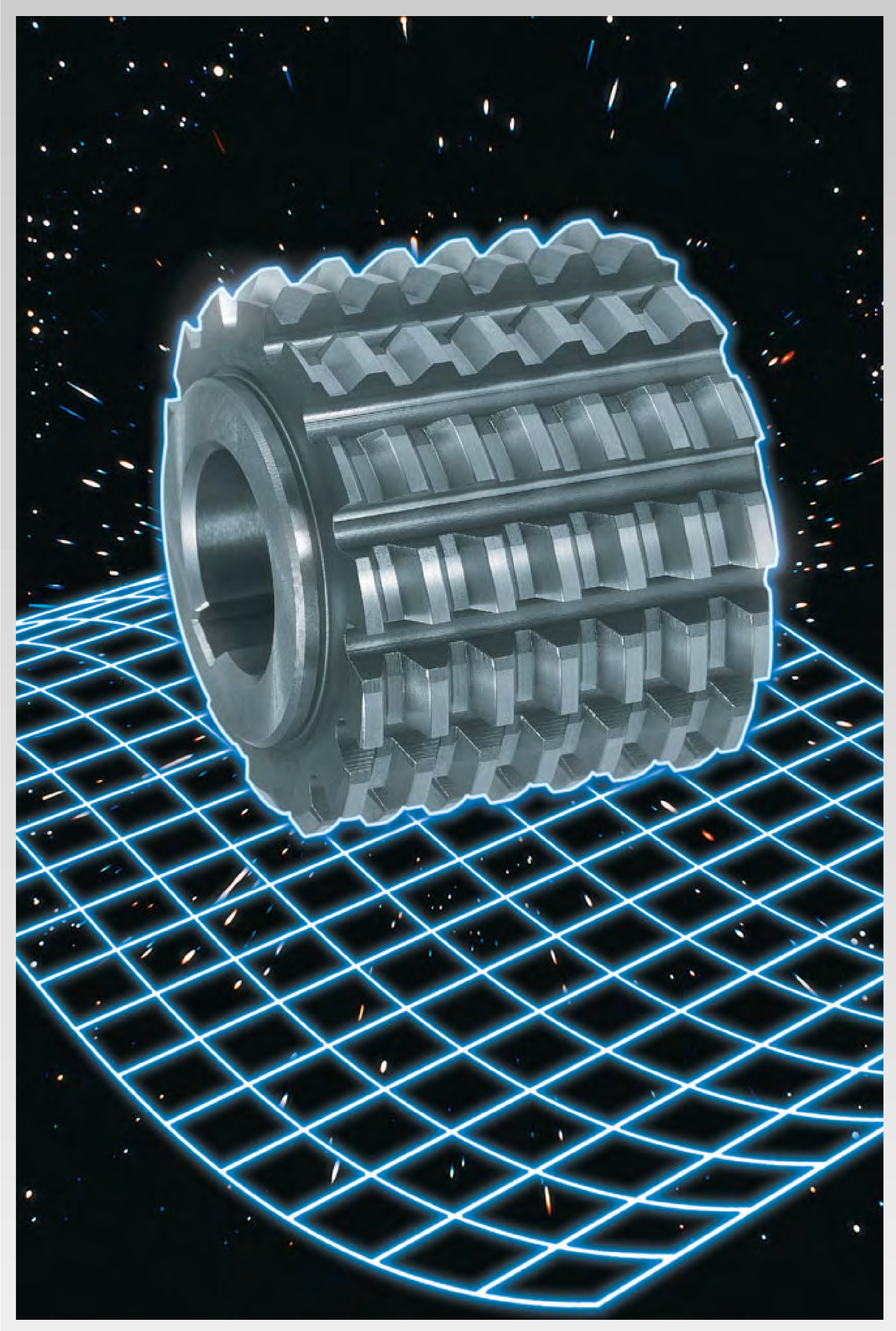
quality grade A to DIN 3968
single start right-handed
with keyway



KHSS-E EMo5Co5

Cat.-No.		**2462** relief ground					
		Dimensions in mm				Number of gashes*	Ident No.
Serr. sh. nom. size	Pitch	d_1	l_3	l_1	d_2		
7 x 8	0,842	50	25	31	22	16	1233410
8 x 10	1,010						1233429
10 x 12	1,152						1233438
12 x 14	1,317						1233447
15 x 17	1,517						1233456
17 x 20	1,761	56	32	38			1233465
21 x 24	2,033						1233474
26 x 30	2,513						1233483
30 x 34	2,792						1233492
36 x 40	3,226						1233508
40 x 44	3,472	63	40	46	27		1233517
45 x 50	3,826						1233526
50 x 55	4,123						1233535
55 x 60	4,301						1233544
60 x 65	4,712	70	50	56			
65 x 70							
70 x 75							
75 x 80							
80 x 85							
85 x 90							
90 x 95							1233553
95 x 100							
100 x 105							
105 x 110							
110 x 115							
115 x 120							
120 x 125							

* Hobs will be supplied with 12 gashes whilst stocks last.



Hobs
for worm gears

Hobs for worm gears

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

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 regrinding. 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.

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

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.

- 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.

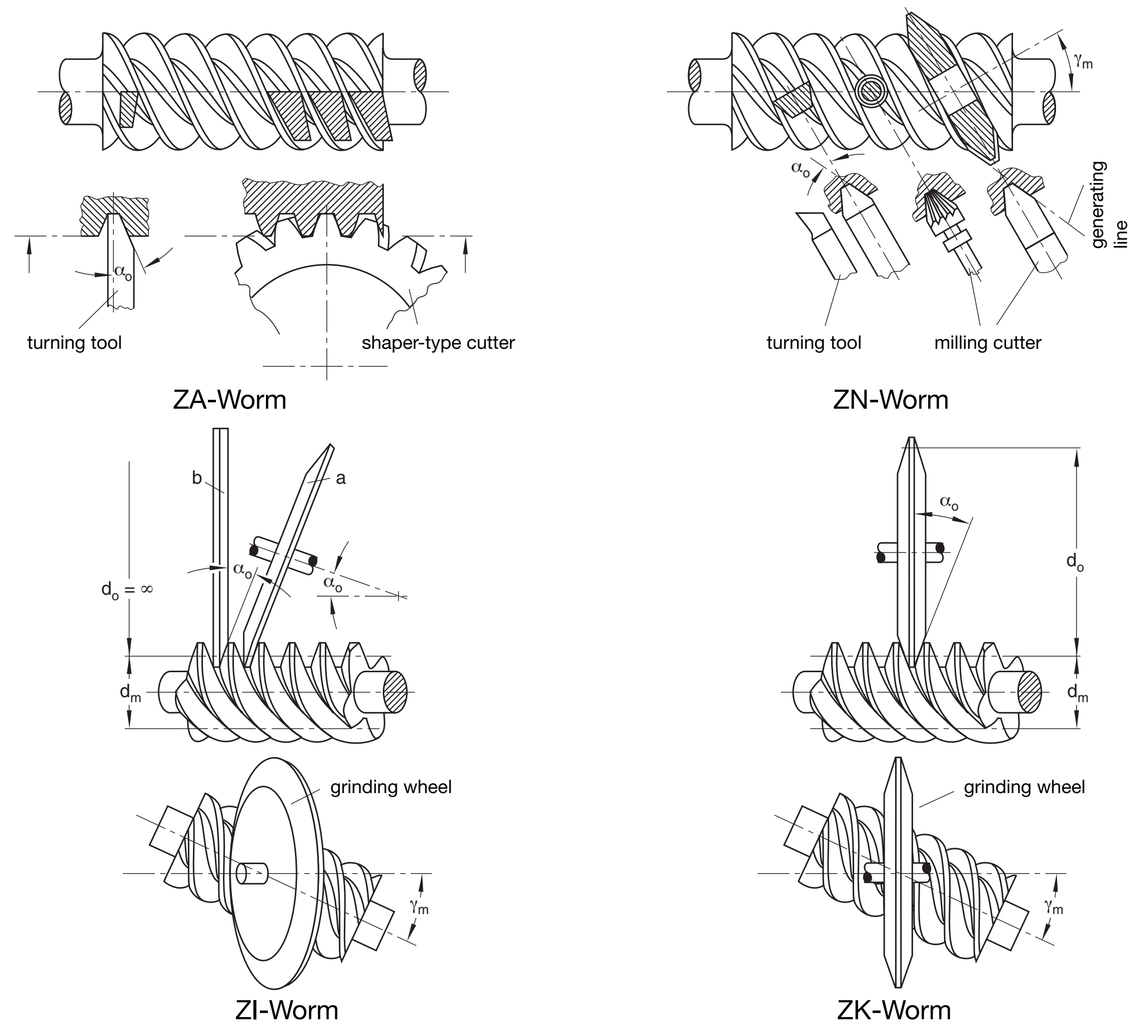
- The **ZN worm** has a straight-line flank profile in its normal plane. This flank form is achieved when a trapezoidal turning tool set at axis height is applied so that its cutting edges lie in the plane inclined by the mean lead angle and the worm profile is generated in this setting.

- 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 mean 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 mean 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.

Apart from the standardized flank forms, there are special forms, of which the follow 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.

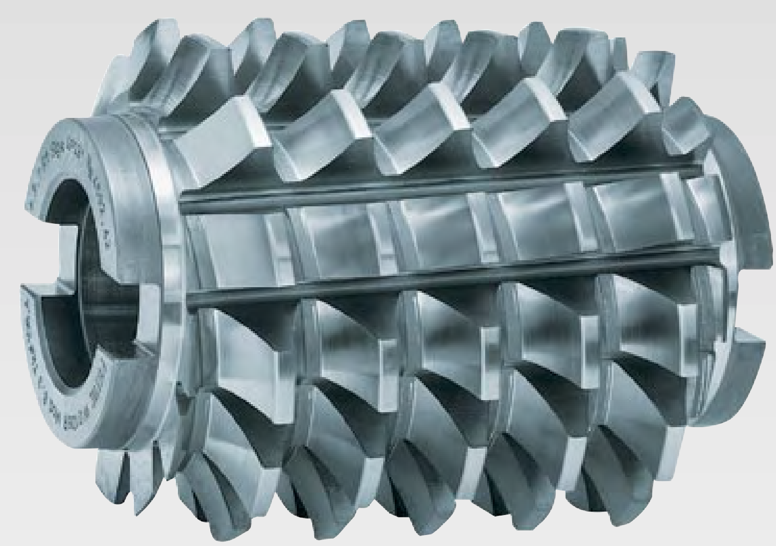


Processes and designs

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

Radial method

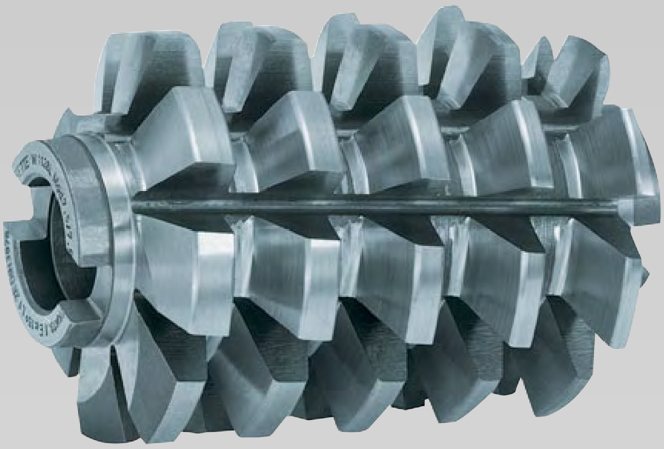
Cylindrical hobs are employed for this method. The hob enters the worm radially to full tooth depth, and can be displaced tangentially by a small distance in order to improve the enveloping cut on the flanks. This hobbing method has the shortest machining time and is generally employed for worm gear 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.



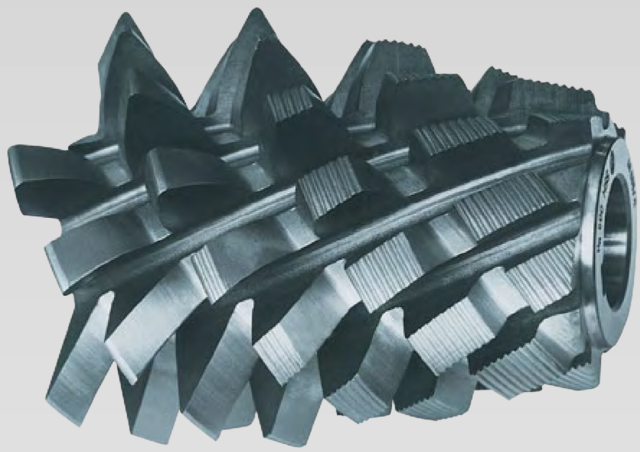
Bore-type hob with drive slot for radial hobbing

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.

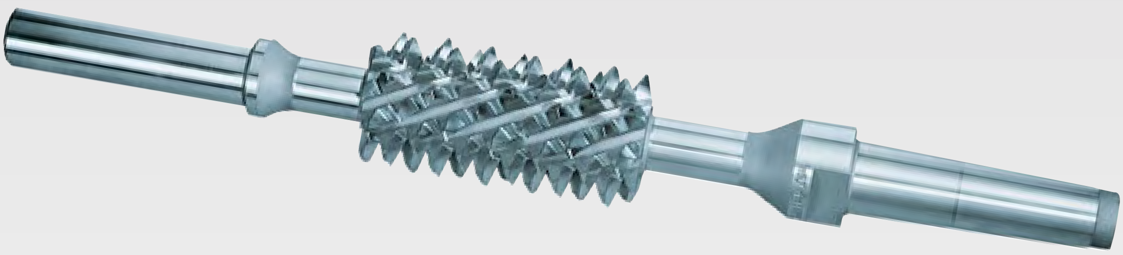
The simplest forms of worm gear hob for tangential hobbing are the single- or multi-start fly-cut hobs. Fly-cut hobs are hobs with only one cutting tooth per start. They are relatively simple and low-cost tools, but they also have the lowest metal removal capacity.



Duplex worm gear hob



Worm gear hob for tangential hobbing



Shank-type worm gear hob for radial hobbing

Shaving worms
For high-precision worm gears, shaving worms are also employed for finish profiling of rough-hobbed worm gears. Shaving worms have lift allowances 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.

Radial Method

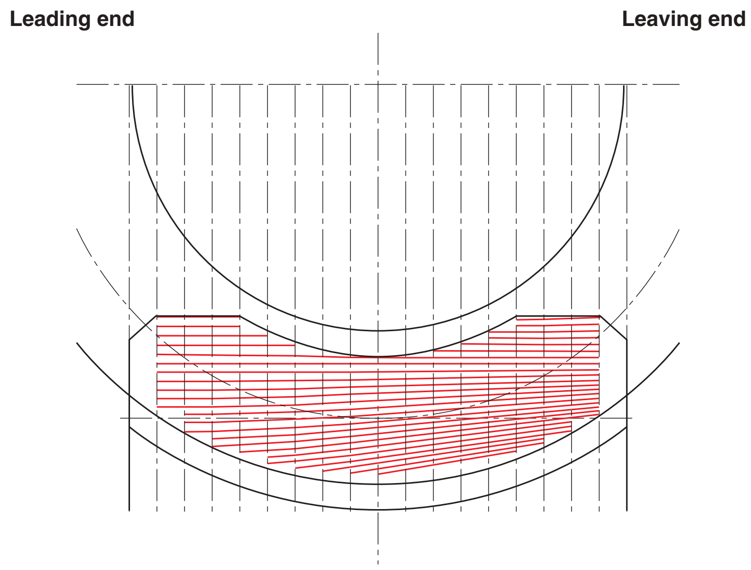
with constant centre distance

The use of modern CNC hobbing machines has enabled 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.

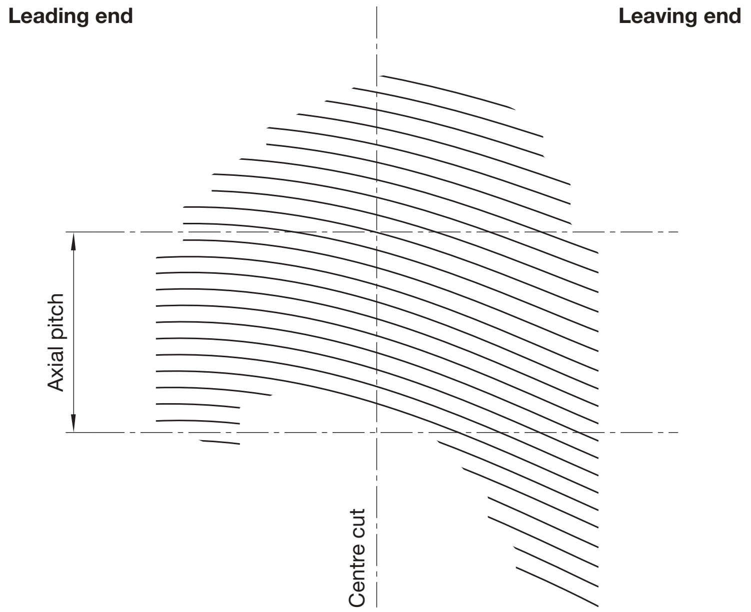
In the new method, cylindrical radial hobs are employed the flanks of which are axially relief-machined. The usual tangential hobbing is thus replaced at higher helix angles (>8°). The tool setting can be calculated as for the new condition. The setting is optimized when the tool is first used, and the 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.



Contact lines on the worm gear flank

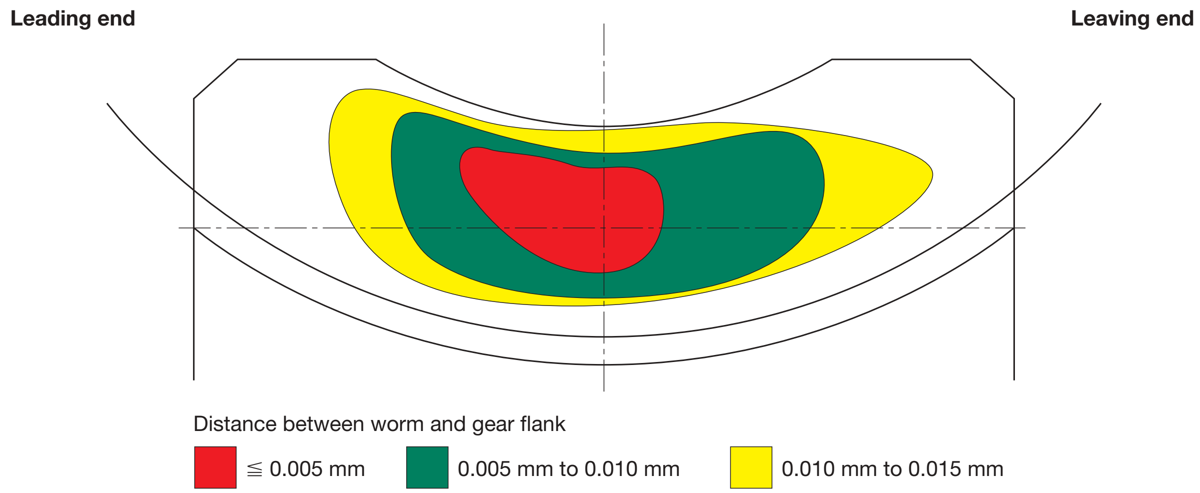


Engagement area

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 helix.
The complex computation of the engagement conditions in the worm gear can now be performed very precisely by means of powerful PCs.

In practice, bearing contact patterns with a percentage contact area of 50-70% are desirable.
The 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 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.



Topography of the worm gear flank

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 latter 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.

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.

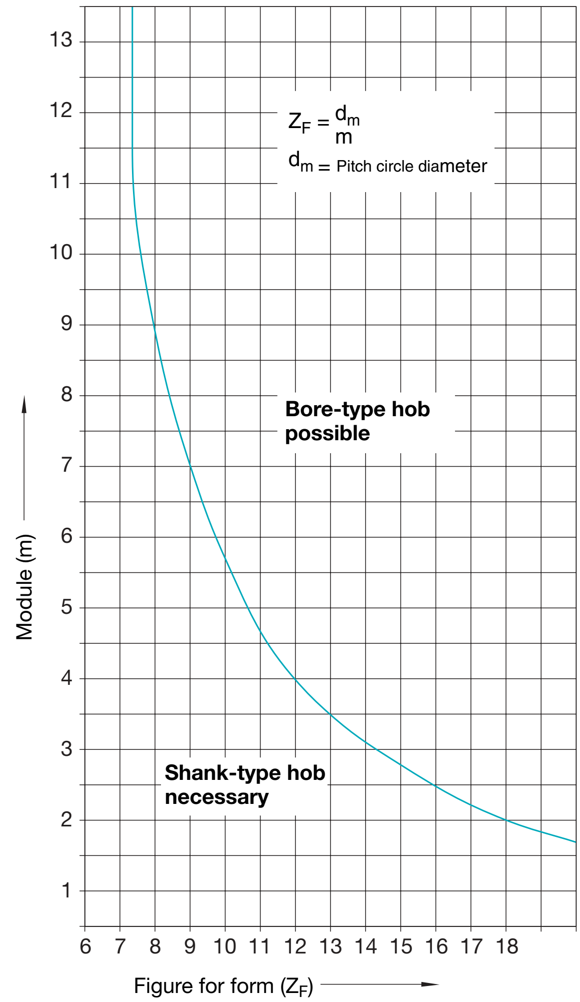
The following information is required for manufacture of these hobs:

- 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)

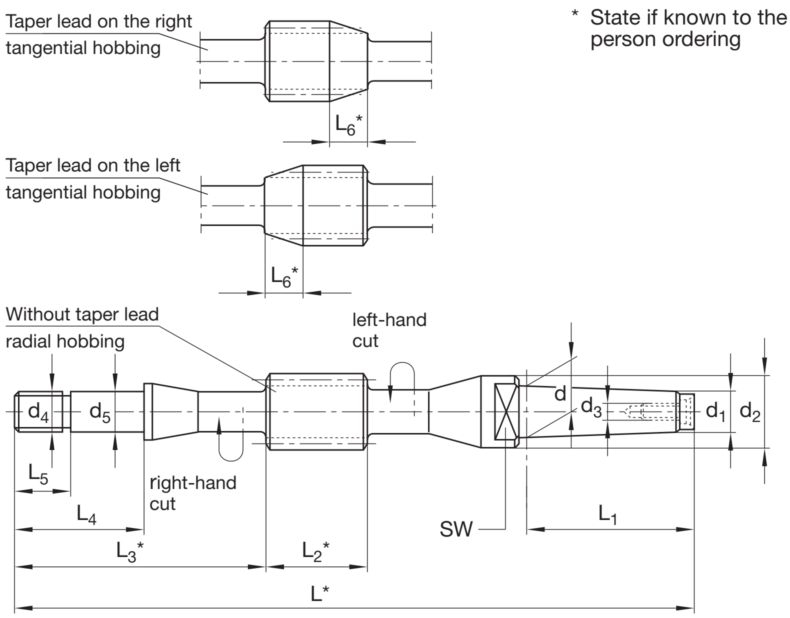
The above data can of course also be supplied in the form of worm and worm gear drawings.

Unless otherwise specified, the hobs are designed as follows:

- Addendum = 1.2 x m
- Depth of tooth = 2.4 x 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°



Bore-/shank-type hob



Shank dimensions

Hobs
for special profiles

Special and single-position hobs

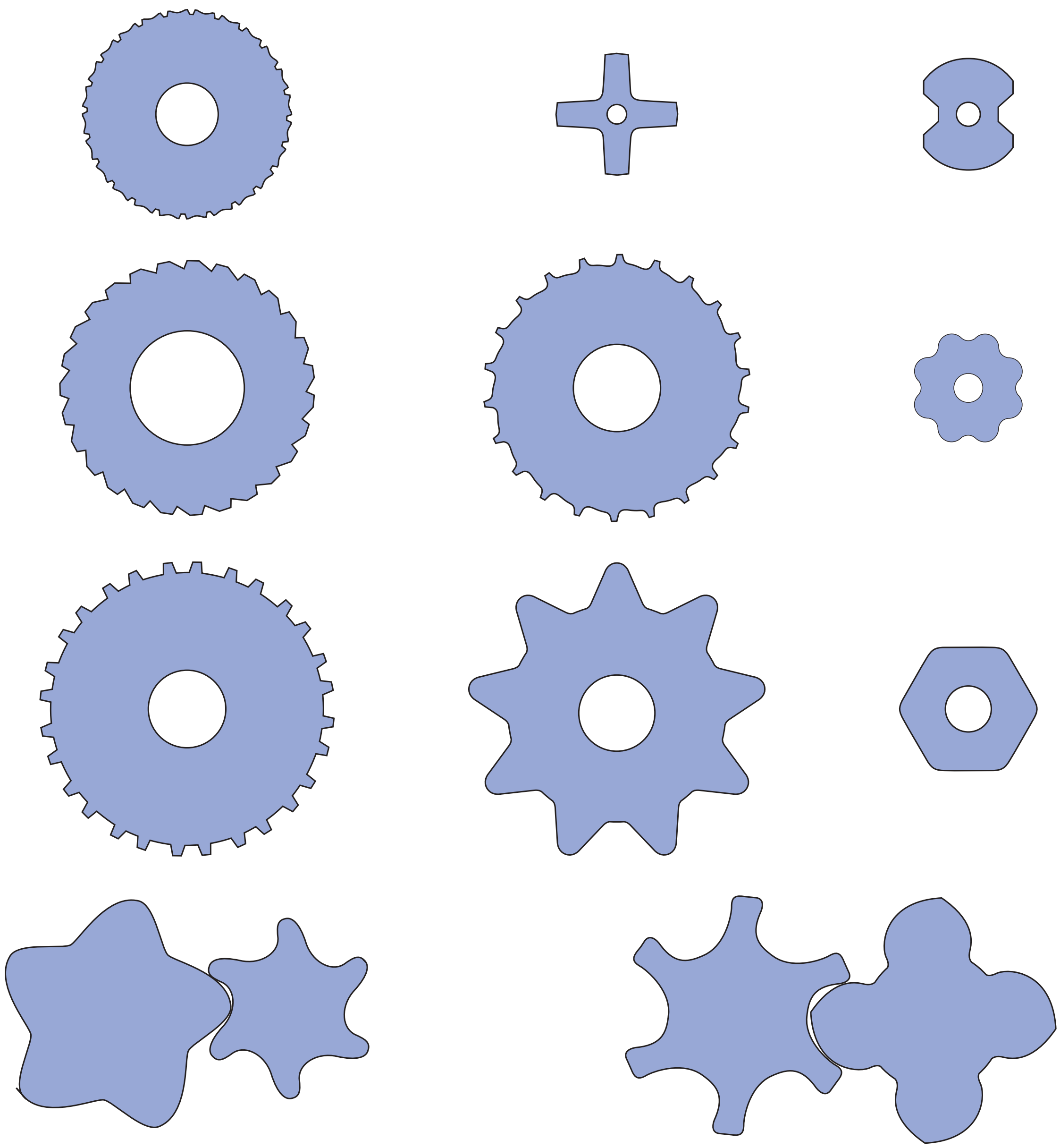
The hobbing process with its well-known advantages is, in addition to the standard operating- and slip gears as well as gears for belt and chain pulleys, also suitable for a large number of special profiles, of which a few examples are shown here. Hobs for particularly frequently used special profiles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

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.

Provided that the profile standard allows this, single-position hobs can be manufactured for several setting positions and with a longer effective length, to improve economy.



Examples of special profiles which can be generated by hobbing

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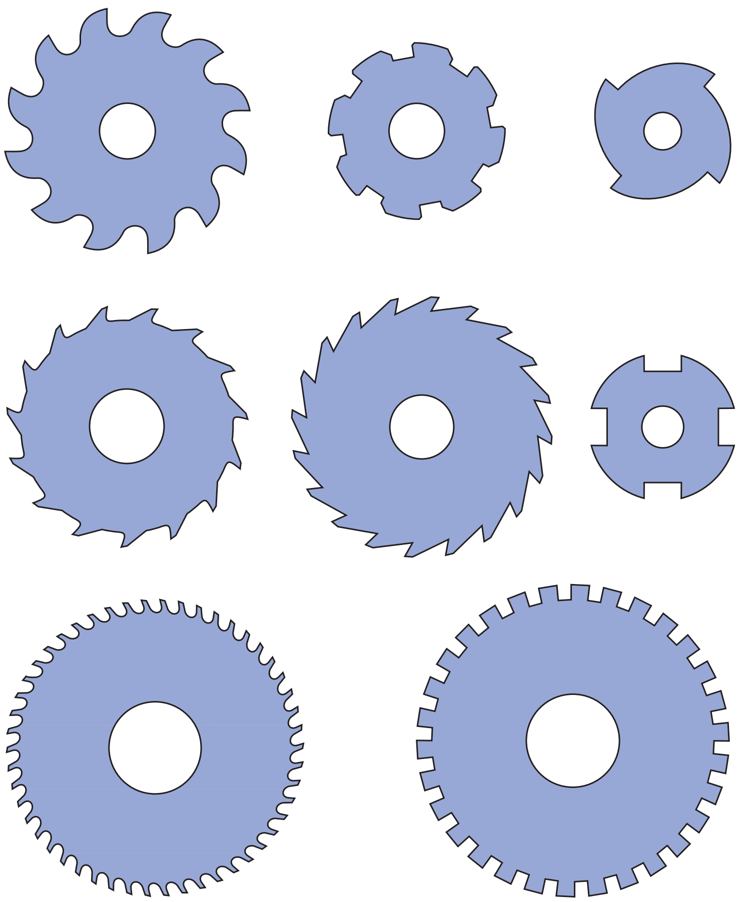
Multi-start single-position fly-cut hob for ratchets of various pitches

Special hops for pump wheels with orbit gears



Example of profiles which can be hobbed with single-position hobs

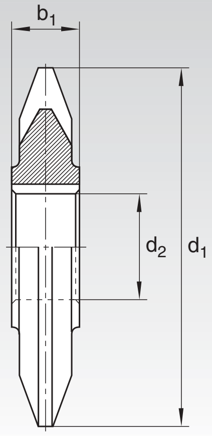

FETTE
m4/20° HSS W 1234534

Gear milling cutters
for racks and worms

Worm thread milling cutters

for module pitch

20° pressure angle
basic profile I to DIN 3972
with offset teeth
and one tooth for checking



HSS

Cat.-No. **2500** **straight tooth, milled, with ground lands**

Dimensions in mm				Ident No.
m	**d_1**	**b_1**	**d_2**	
1	70	8	22	1234419
1,5				1234437
2				1234455
2,5				1234473
3	80	10		1234491
3,5				1234516
3,75		12		–
4,5		13		1234543
5,5	100	15	27	–
6,5		18		–
8		22		1234605
10	125	27	32	1234623

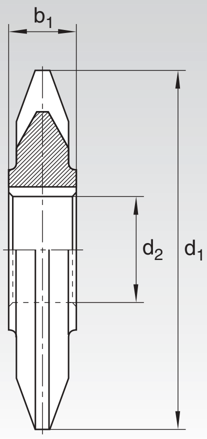
This design can also be used as a gear milling cutter for roughing and as a rack tooth cutter.

We also manufacture: worm thread milling cutters of larger dimensions with different basic profiles,
also available as trapezoidal thread milling cutters with millimetre pitch.

Rack and worm milling cutters

module pitch

20° pressure angle
basic profile I to DIN 3972
with one tooth for checking



KHSS-E EMo5Co5

Cat.-No. **2512** **staggered tooth, milled, with ground lands**

Dimensions in mm				Ident No.
m	**d_1**	**b_1**	**d_2**	
1	140	8	40	1235212
1,5				1235221
2		10		1235230
2,5				1235249
3				1235258
3,5		12		1235267
4				1235276
4,5		14		1235285
5				1235294
6	145	16		1235301
7		19		1235310
8		22		1235329
9	150	25		1235338
10		27		1235347

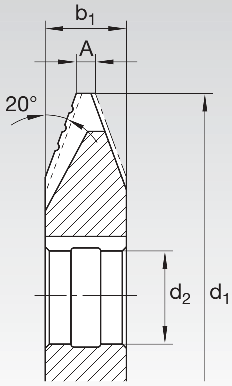
We also manufacture: rack milling cutters with larger dimensions,
different basic profiles and with 10° inclined profile.

LMT · FETTE

Worm milling cutters for roughing

for roughing gears, tooth racks and worms of module pitch

20° pressure angle, straight flanks
basic profile IV to DIN 3972
without tooth for checking
staggered chip breakers form module 10



KHSS-E EMo5Co5

Cat.-No. **2513** **staggered tooth, milled, with ground lands**

Dimensions in mm

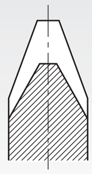
m	d_1	b_1	d_2	A
5	140	13	40	2,56
5,5		14		2,86
6	145	15		3,17
6,5		17		3,48
7		18		3,79
7,5		19		4,10
8		20		4,41
9	150	23		5,04
10		25		5,67
11		28		6,30
12		30		6,93
13	155	34		7,56
14	160	36		8,20
15	165	38		8,83
16	170	40		9,47
17	180	43	50	10,11
18	190	46		10,75
19	195	48		11,39
20	200	50		12,03

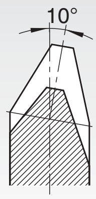
These milling cutters are designed for the straight flank roughing of gears, racks and worms.
They are manufactured without a tooth for checking, to achieve a high cutting rate. They are sharpened by tracing the profile at the backed-off surfaces. The tooth tip width A given in the table can be used as a checking dimension.

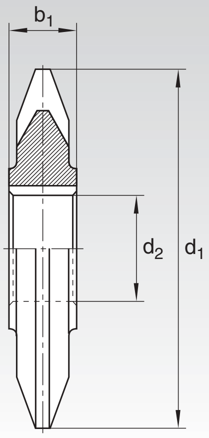
Rack milling cutters/worm milling cutters

module pitch

20° pressure angle
basic profile I to DIN 3972
form A: with straight profile
form B: with 10° inclined profile*







KHSS-E EMo5Co5

Form A

Form B

Cat.-No. **2521** **straight tooth, relief turned**

Dimensions in mm				Ident No. Form A	Ident No. Form B
m	**d1**	**b1**	**d2**		
1	140	8	40	1235711	1235855
1,5				1235720	1235864
2				1235739	1235873
2,5		10		1235748	1235882
3				1235757	1235891
3,5				1235766	1235908
4				1235775	1235917
4,5		11		1235784	1235926
5		13		1235793	1235935
6	145	15		1235800	1235944
7		17		1235819	1235953
8		20		1235828	1235962
9	150	22		1235837	1235971
10		25		1235846	1235980

* Only available until stock is depleted

Unless otherwise specified, we supply form A.

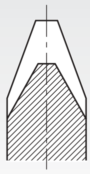
We also manufacture: rack milling cutters with larger dimensions and different basic profiles.

Rack milling cutters/worm milling cutters

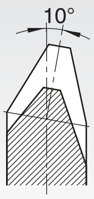
module pitch

20° pressure angle
basic profile I to DIN 3972
form A: with straight profile
form B: with 10° inclined profile*

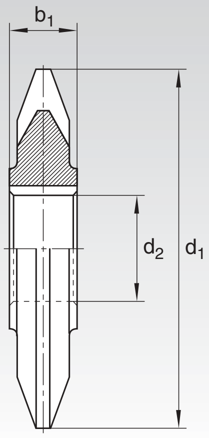
KHSS-E EMo5Co5



Form A



Form B



Cat.-No. **2522** **straight tooth, relief ground**

Dimensions in mm				Ident No. Form A	Ident No. Form B
m	**d_1**	**b_1**	**d_2**		
1	140	8	40	1236319	2125816
1,5				1236328	2254679
2				1236337	1236471
2,5		10		1236346	1236480
3				1236355	1236499
3,5				1236364	1236505
4				1236373	1236514
4,5		11		1236382	2222348
5		13		1236391	1236532
6	145	15		1236408	1236541
7		17		1236417	1236550
8		20		1236426	1236569
9	150	22		2120452	1236578
10		25		1236444	1236587

* Only available until stock is depleted

Unless otherwise specified, we supply form A.

We also manufacture: rack milling cutters with larger dimensions and different basic profiles.

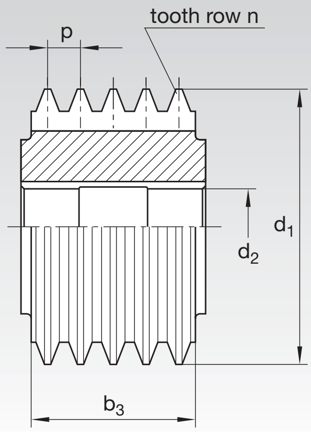
LMT · FETTE

Rack tooth gang cutters

with several tooth rows
for racks to module pitch

20° pressure angle
basic profile I or II to DIN 3972

m = module
p = pitch = m · π
n = number of tooth rows
b_3 = cutter width = m · π · n
z = number of gashes



KHSS-E EMo5Co5

Cat.-No. **2560** **relief ground**

Dimensions in mm

m	Z = 14		Z = 18		Z = 22	
	d_1	d_2	d_1	d_2	d_1	d_2
1	70	27	100	32	125	40
1,25						
1,5						
1,75						
2	90	32	125	40	160	50
2,25						
2,5						
2,75						
3	110		140		180	
3,25						
3,5						
3,75						
4	125	40	160	50	200	60
4,25						
4,5						
4,75						
5						

(Number of gashes)

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 cutters are recommended. See cat. no. 2561.

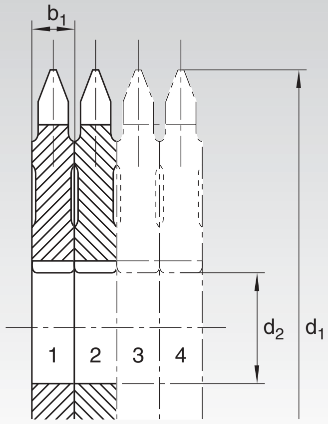
Unless otherwise specified, we supply with basic profile I to DIN 3972.

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

High-precision rack tooth gang cutters

for tooth racks to module pitch

20° pressure angle
basic profile I to DIN 3972
with additional grinding slots,
with offset keyways



KHSS-E EMo5Co5

consecutively numbered as: cutter no. 1, 2, 3, 4

Cat.-No. **2561** **relief ground**

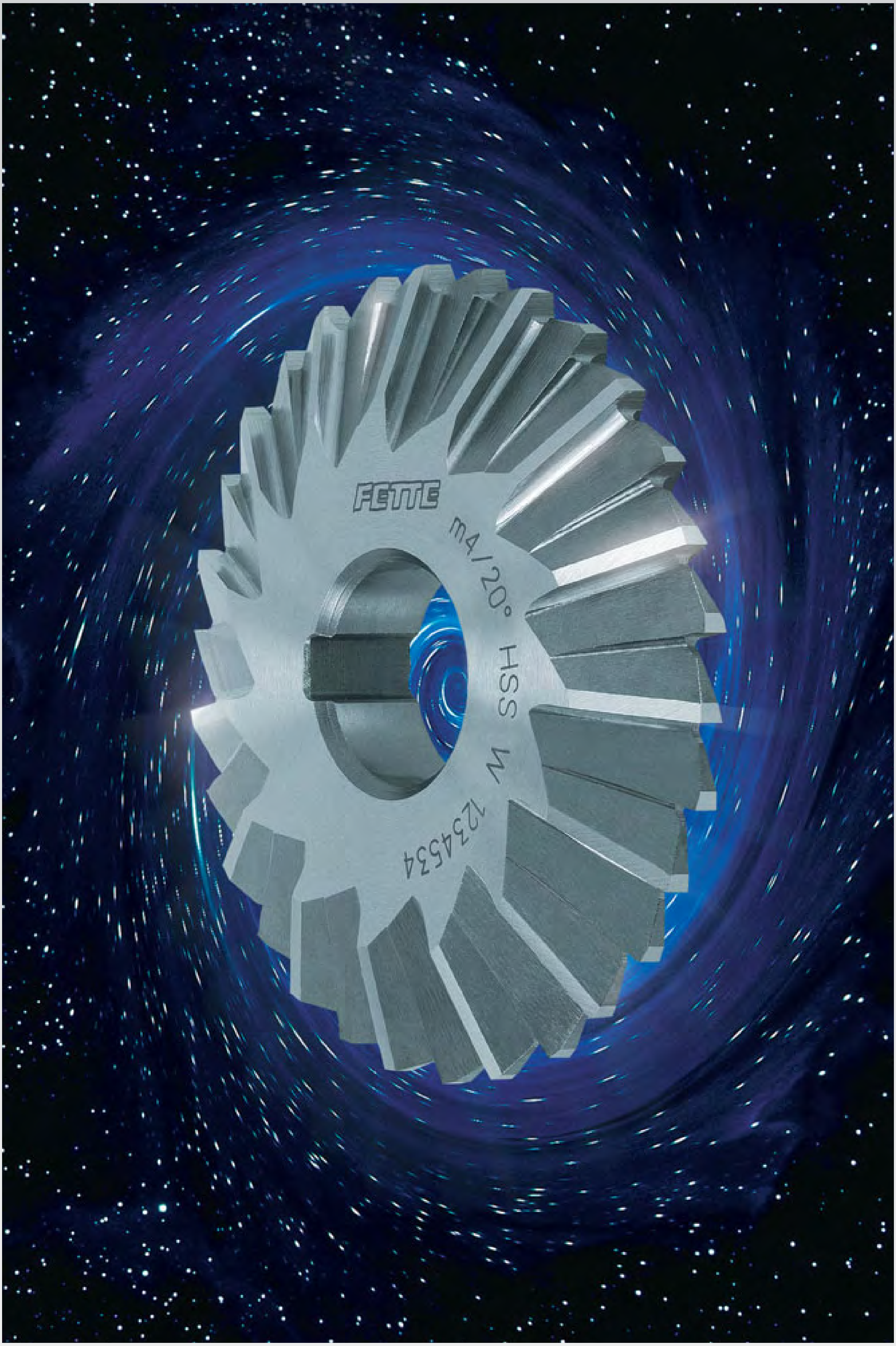
Dimensions in mm				Number of gashes
m	**d_1**	**b_1**	**d_2**	
3	140	9,425	40	20
3,25		10,210		
3,5		10,995		18
3,75		11,781		
4	150	12,556		
4,5		14,137		
5		15,708		16
5,5		17,279		
6		18,849		
6,5	160	20,420	50	
7		21,991		
8		25,133		
9		28,274		14
10		31,416		

Rack tooth gang cutters for the simultaneous machining of several tooth gaps are made up of several single-profile circular-type milling cutters. Through the continual offsetting of the gashes in relation to the drive slot the individual cutters are successively coming (helically) to the point of cutting addition.
This feature particularly promotes quiet running of the milling machine under heavy chip loads.

To allow regrinding combined in a gang, the individual cutters are provided with an additional closely tolerated keyway (grinding slot), so that an axially parallel position of the cutting faces on the arbor is guaranteed.

Rack tooth gang cutters are profile relief ground with parallelly flat lapping of the contact faces.
To improve tool life, these milling cutters are made exclusively of cobalt alloyed super high speed steel.

For extreme precision requirements the tolerances for pitch, flank form, gash spacing, cutting face position as well as cutting edge concentricity lie within quality grade AA to DIN 3968.


FETTE
m4/20°
HSS
W
1234534


m1.5/20° Nr2

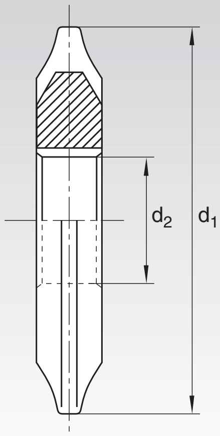
Gear milling cutters
for spur gears

LMT FETTE

Involute gear cutters

for spur gears to module pitch

20° pressure angle
basic profile I to DIN 3972



HSS* / KHSS-E EMo5Co5

Cat.-No. **2601** **relief turned**

Specification of Sets		
from module 0.3 to module 10 in sets of 8 units		
Cutter No. 1	for	12– 13 teeth
Cutter No. 2	for	14– 16 teeth
Cutter No. 3	for	17– 20 teeth
Cutter No. 4	for	21– 25 teeth
Cutter No. 5	for	26– 34 teeth
Cutter No. 6	for	35– 54 teeth
Cutter No. 7	for	55–134 teeth
Cutter No. 8	for	135– ∞ teeth
from module 11 to module 20 in sets of 15 units		
Cutter No. 1	for	12 teeth
Cutter No. 1 1/2	for	13 teeth
Cutter No. 2	for	14 teeth
Cutter No. 2 1/2	for	15– 16 teeth
Cutter No. 3	for	17– 18 teeth
Cutter No. 3 1/2	for	19– 20 teeth
Cutter No. 4	for	21– 22 teeth
Cutter No. 4 1/2	for	23– 25 teeth
Cutter No. 5	for	26– 29 teeth
Cutter No. 5 1/2	for	30– 34 teeth
Cutter No. 6	for	35– 41 teeth
Cutter No. 6 1/2	for	42– 54 teeth
Cutter No. 7	for	55– 79 teeth
Cutter No. 7 1/2	for	80–134 teeth
Cutter No. 8	for	135– ∞ teeth

* Available only while stocks last.

If required, we also supply involute gear cutters above module 10 in sets of 8 units.

Involute gear cutters are supplied in complete sets as well as singly. When ordering single gear cutters, the cutter number or the number of teeth to be cut must be specified.

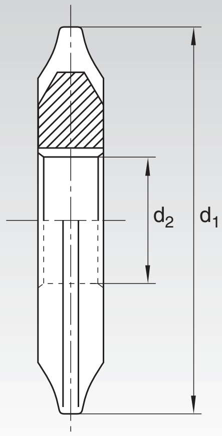
We also manufacture:
Involute gear cutters with other pressure angles or to CP. Involute gear cutters for cutting spur gears with less than 12 teeth.

Dimensions in mm		
m	**d_1**	**d_2**
0,3	35	13
0,4		
0,5	40	16
0,6		
0,7		
0,75		
0,8		
0,9	50	
1		
1,25		
1,5	60	22
1,75		
2		
2,25		
2,5	65	
2,75	70	27
3		
3,25	75	
3,5		
3,75	80	
4		
4,25	85	
4,5		
4,75	90	
5		32
5,5	95	
6	100	
6,5	105	
7		
7,5	110	
8		
8,5	115	
9		
9,5	120	
10		
11	135	40
12	145	
13	155	
14	160	
15	165	

Involute gear cutters

for spur gears to module pitch

20° pressure angle
basic profile I to DIN 3972



HSS* / KHSS-E EMo5Co5

Cat.-No. **2601** **relief turned**

Dimensions in mm		
m	**d_1**	**d_2**
16	170	40
17	180	50
18	190	
19	195	
20	205	

Specification of Sets		
from module 0.3 to module 10 in sets of 8 units		
Cutter No. 1	for	12– 13 teeth
Cutter No. 2	for	14– 16 teeth
Cutter No. 3	for	17– 20 teeth
Cutter No. 4	for	21– 25 teeth
Cutter No. 5	for	26– 34 teeth
Cutter No. 6	for	35– 54 teeth
Cutter No. 7	for	55–134 teeth
Cutter No. 8	for	135– ∞ teeth
from module 11 to module 20 in sets of 15 units		
Cutter No. 1	for	12 teeth
Cutter No. 1 1/2	for	13 teeth
Cutter No. 2	for	14 teeth
Cutter No. 2 1/2	for	15– 16 teeth
Cutter No. 3	for	17– 18 teeth
Cutter No. 3 1/2	for	19– 20 teeth
Cutter No. 4	for	21– 22 teeth
Cutter No. 4 1/2	for	23– 25 teeth
Cutter No. 5	for	26– 29 teeth
Cutter No. 5 1/2	for	30– 34 teeth
Cutter No. 6	for	35– 41 teeth
Cutter No. 6 1/2	for	42– 54 teeth
Cutter No. 7	for	55– 79 teeth
Cutter No. 7 1/2	for	80–134 teeth
Cutter No. 8	for	135– ∞ teeth

* Available only while stocks last.

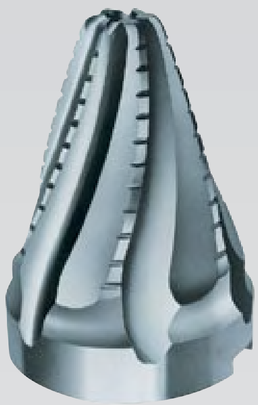
If required, we also supply involute gear cutters above module 10 in sets of 8 units.

Involute gear cutters are supplied in complete sets as well as singly. When ordering single gear cutters, the cutter number or the number of teeth to be cut must be specified.

We also manufacture:
Involute gear cutters with other pressure angles or to CP. Involute gear cutters for cutting spur gears with less than 12 teeth.

Gear cutters for large-size gears

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.



End mill type gear cutter
(for roughing) Cat.-No. 2620

Gear milling cutter for roughing, Cat.-No. 2667, with indexable carbide inserts

Gear milling cutter for roughing,
stepped-up type, Cat.-No. 2630

Gear finishing cutter, Cat.-No. 2675, with indexable carbide inserts, involute profile

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 (Cat.-No. 2630). We supply end mill type gear cutters (Cat.-Nos. 2620 and 2621) for large modules, for example for machining gear segments on boring mils. For gear cutting machines with powerful motor milling heads, we manufacture milling cutters with carbide-tipped blades (Cat.-Nos. 2675 and 2667).

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.

Profile roughing cutter for rotary pistons (Roots blower)
2-section, 312 mm dia. x 260 x 120 dia., 92 indexable inserts

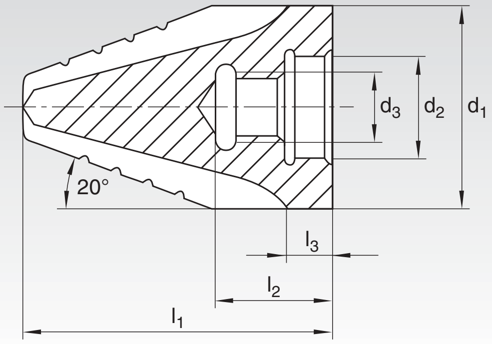
End mill type gear cutter (roughing cutter) m 48-stub, 20° p.a., 150 dia. x 180 mm length, 22 indexable inserts

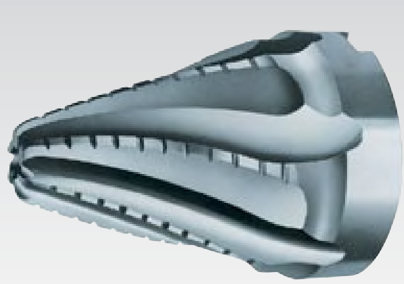
Circular-type gear profile cutter
m 50, 20° p.a., 11 teeth, without roof radius, 295 mm dia. x 190 x 80 dia., 136 indexable inserts

End mill type gear cutter (roughing cutters)

for gears and racks

20° pressure angle,
basic profile IV to DIN 3972
with straight flanks, spiral fluted,
with female thread and centring,
for screw-on, 2 spanner flats



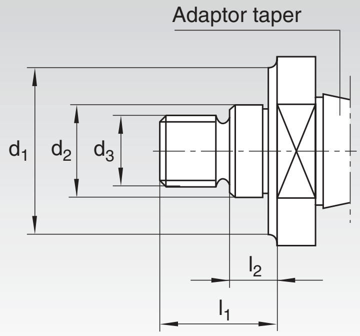


KHSS-E EMo5Co5

Cat.-No.				**2620** milled and ground			
Dimensions in mm					Dimensions in mm		
Overall cutter dimensions					Adapter dimensions		
m	d_1	l_1	Z	d_3 (inches)	d_2	l_2	l_3
20	60	120	4	1 1/4	36	45	10
22	65	125					
24							
26	70	130					
28	75	135		1 1/2	42		
30	80						
32	85	140					
34	90	145					
36	95			2	56	50	12
38	100	150					
40	105	155					
42	110						
44	115						
46	120	160	6	2 1/2	70		
48	125						
50	130						

This cutter version is also supplied as a finishing cutter for racks with basic profile I or II to DIN 3972.

Adaptor tapers optionally
Morse taper DIN 1806
Morse taper DIN 2207
Metric taper DIN 1806
Steep taper DIN 2080



Mounting dimensions for adaptor mandrels

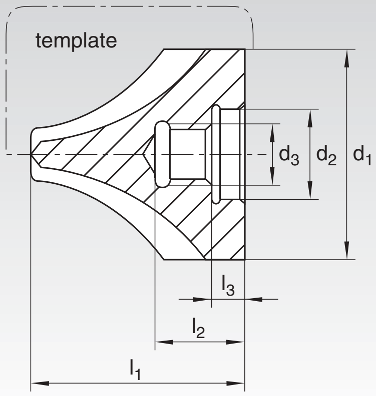
d_3 (inches)	Dimensions in mm			
	d_2	d_1	l_1	l_2
BSW 1 1/4 – 7 Gg	36	70	40	9,5
BSW 1 1/2 – 6 Gg	42	90		
BSW 2 – 4 1/2 Gg	56	115	45	11,5
BSW 2 1/2 – 4 Gg	70	130		

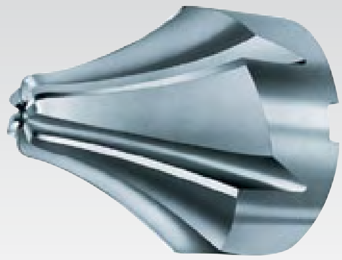
LMT · FETTE

End mill type gear cutters (finishing cutters)

involute profile

20° pressure angle,
basic profile I or II to DIN 3972
straight fluted, with female thread and centre bore, for screw-on, 2 spanner flats





KHSS-E EMo5Co5

Cat.-No. **2621** **relief turned ■ with ground profile lands**

Dimensions in mm

	Number of teeth range								Adaptor dimensions			
	12 … 16		17 … 25		26 … 54		55 … ∞					
m	d_1	l_1	d_1	l_1	d_1	l_1	d_1	l_1	d_3 (Zoll)	d_2	l_2	l_3
20	70	115	66	115	62	120	60	120	1 1/4	36	45	10
22	76		72	120	66	125	62	125				
24	84	120	78		74		68					
26	90		84		78		72	130				
28	98		90		84		78	135	1 1/2	42		
30	104		98	125	90		82					
32	110	125	104		96	130	88	145				
34	118		110		102		94					
36	124	130	116	130	108	135	98	145	2	56	50	12
38	130	135	122	135	114	140	104	150				
40	136		128	140	120	145	110	155				
42	144	140	134	145	126	150	116					
44	150	150	140	155	130	155	120					
46	156		146		136	160	125	160	2 1/2	70		
48	164	160	152		142		130					
50	170		160	160	148		135					

End mill type gear cutters with involute profiles are generally not designed for a number of teeth range but vor special gear operations with a specific numer of teeth.

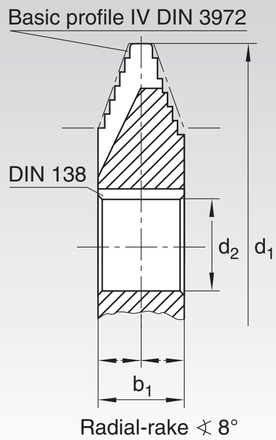
When ordering, therefore, please provide workpiece drawings or precise gear data.

To achieve high profile accuracy and surface quality, the cutters are ground with a profile land. For maintenance we supply, if required, checking gauges and grinding templates for tool grinding machines: Studer-Oerlikon, Aldridge or Schuette.
The referende cylinder for checking the profile is the ground outside diameter of the cutter.

Circular type gear roughing cutters

stepped-up type

20° pressure angle
alternate cutting
with keyway



KHSS-E EMo5Co5

Cat.-No. **2630** **relief turned**

Dimensions in mm				Number of gashes	Ident Nr.
m	**d_1**	**b_1**	**d_2**		
		Series I cutter			
12	145	28	40	16	2122085
14	160	32			2129266
16	170	37			2125036
18	180	42	50		2125037
20	200	46			2125005
22	210	50			2125006
24	220	54			2125007
26	240	58	60		2129268
28	250	63			2121680
30	260	68			2129276
		Series II cutter			
12	160	28	50	18	2125874
14	175	32			2129267
16	190	37			2121701
18	210	42	60		2126898
20	225	46			2122883
22	240	50			2127500
24	250	54			2127501
26	275	58	80		2129269
28	290	63			2129275
30	300	68			2129277

Stepped-up pre-machining is a process well-tried in practice for gear sizes above 10 module. An advantage of this cutter design is the relatively low power requirement as the chips are at the steps only formed in the direction of the circumference and hardly any lateral loads are occurring. Another feature is the relatively simple maintenance by tool face grinding.

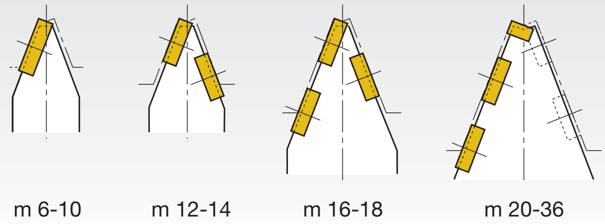
When enough machine power is available, these cutters can also be used as gang cutters for simultaneous machining of two adjacent tooth gaps.

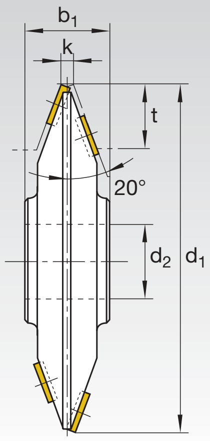
Two overall dimension series have been established in practice for stepped-up roughing cutters. Special dimensional requirements can however also be taken into account with these cutters.

Gear roughing cutters

with indexable carbide inserts

20° pressure angle
basic profile IV to DIN 3972
with keyway to DIN 138
optionally with drive slot

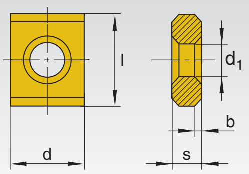




Cat.-No. **2667 staggered tooth**

Dimensions in mm							Number of indexable inserts				Clamping screws
	Overall dimensions				Profile		Form				
m	d_1	b_1	d_2	z	k	t	1	2	3	3.1.	Cat.-No.
6	160	50	50	12	3,14	17			12		1150-86
	220		60	16					16		
	280		80	20					20		
8	180		50	12	4,41	23				12	
	220		60	16						16	
	280		80	20						20	
10	180	60	50	12	5,67					12	
	220		60	16						16	
	280		80	20						20	
12	200		50	12	6,93	33		18			
	250		60	16				24			
	320		80	20				30			
14	200		50	12	8,20			18			1150-80
	250		60	16				24			
	320		80	20				30			
16	200	70	50	12	9,47	49		24			
	250		60	16				32			
	320		80	20				40			
18	200		50	12	10,75			24			
	250		60	16				32			
	320		80	20				40			
20	220	80	60	12	12,03		6	18			
	280		80	16			8	24			
	360		100	20			10	30			
22	250		60	12	13,32	65	6	24			
	300		80	16			8	32			
	360		100	20			10	40			
24	250		60	12	14,61		6	24			
	300		80	16			8	32			
	360		100	20			10	40			
26	320	100	80	16	15,89		8	32			
	400		100	20			10	40			
28	320		80	16	17,18		8	32			
	400		100	20			10	40			
30	320		80	16	18,46	80	8	40			
	400		100	20			10	50			
32	340		80	16	19,76		8	40			
	420		100	20			10	50			
34	340		80	16	21,05	95		56			
	420		100	20				70			
36	340		80	16	22,35			56			
	420		100	20				70			

Indexable inserts precision ground indexable 4 times



Form	Cat.-No.	l	s	d	b	d_1
1	1185-11	12,7	6,35	14,3	0,78	5,3
2	1185-31	19,05	6,35	14,3	0,78	5,3
3	1185-33	25,4	5	14,3		5,5
3.1.	1185-32	25,4	5	14,3	1,1	5,5
4*	1185-15	15,88	7,94	12,7		5,4
5*	1185-35	19,03	6,35	14,3		5,8

* For round tip forms

Circular-type gear profile cutters with form indexable inserts, Cat.-No. 2675

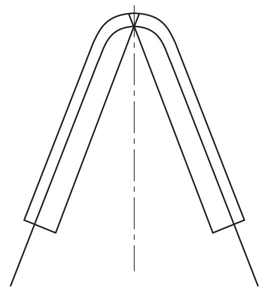
These gear milling cutters are high-performance tools for finish-milling. A double negative cutter geometry combined with a high number of blades produces good cutting behaviour (peeling cut). Indexable inserts with high accuracy and surface finish quality produce clean gear flanks. In addition, long service life is ensured by additional hard material coatings.

Example: external gear

Module 16
$\alpha_0 = 20°$
z = 89

Cutter diameter: 300
Bore diameter: 80
Form indexable inserts: 24

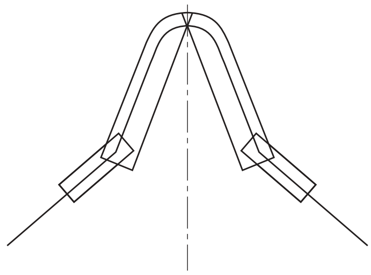
For rough-hobbing
we recommend
gear roughing cutters
FETTE Cat.-No. 2667.



Example: internal gear

Module 10
$\alpha_0 = 20°$
z = 94

Cutter diameter: 380
Bore diameter: 80
Form indexable inserts: 30
Indexable inserts for chamfer: 10

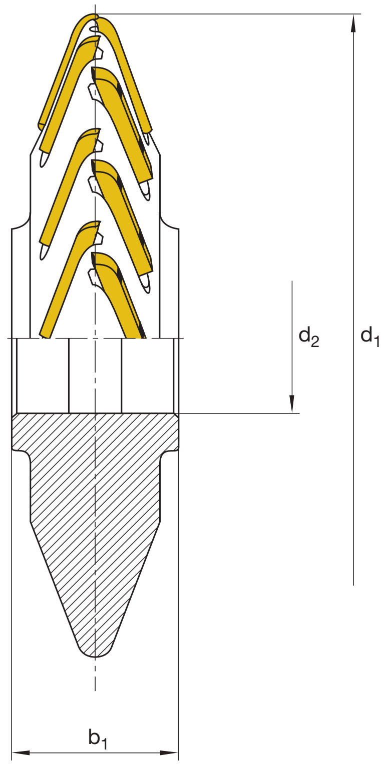


Gear finishing cutter

- With carbide form indexable inserts
- Involute profile
- For external or internal gears
- Alternate cutting
- With keyway or drive slot to DIN
- Pressure angle 20°
- z = number of blades

Module	z = 24	z = 28	z = 32
8			
10	d_1 300	350	420
12	b_1 70	80	100
14	d_2 80	80	100
16			
18			
20			
22			
24			
26			

The range shows guide values for high numbers of gear teeth. The cutter diameters are determined by the number of cutting edges. Alternative structural dimensions are possible.



Carbide form indexable inserts

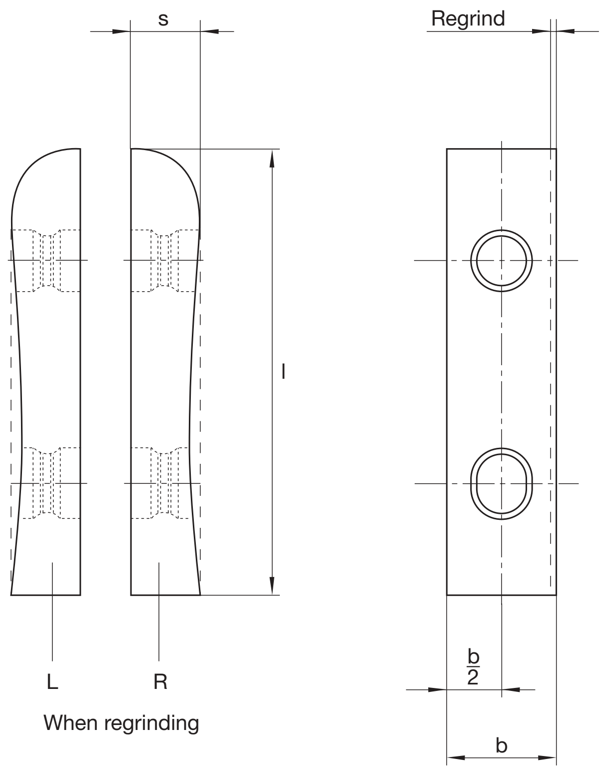
- Involute profile
- For external or internal gears
- Ground on all faces
- 2 cutting edges
- Supplied in sets
  1 set = z off

Module	l	b	s
8	25,40		5,00
10	31,75		6,35
12	31,75		6,35
14	38,10		7,14
16	44,45	14,30	7,94
18	50,80		7,94
20	57,15		8,73
22	66,68		9,53
24	66,68		9,53

These form indexable inserts have two cutting edges in the new condition. They can be employed on both the right-hand and left-hand sides.

The indexable inserts can be reground. Regrinding entails surface grinding of the cutting faces, but on one side only.

When regrinding sets, note the difference between right-hand and left-hand indexable inserts.




FETTE
HART METALL
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HART METALL

Gear milling cutters

for multi-start worm gears and conveyor screws (rotors)

Profile milling cutters for coarse-pitch worms and conveyor screws with special profiles

In addition to the usual worm milling cutters with straight flanks (Cat.-Nos. 2500, 2512, 2521, 2522), 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, see also Cat.-No. 2690.

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.:

1. the lead of the screw H
2. the coordinates in the face planer r, ϱ, α_S or axial plane coordinates r, a, α_A

Coordinates in the axial plane are found with the equation

$a = \text{arc}\ \varrho \cdot H/2\pi$

$\tan \alpha_A = \tan \alpha_S \cdot H/2r\pi$

Fig. 3

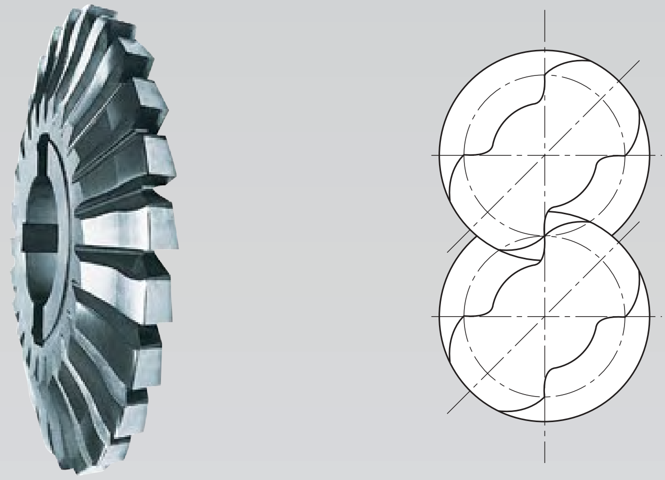


Fig. 1

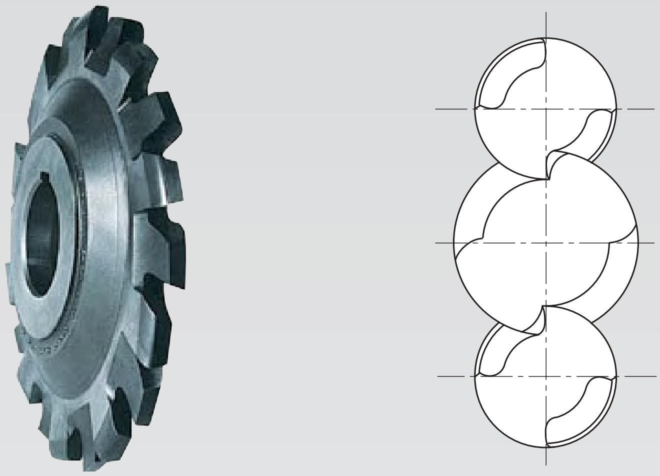


Fig. 2

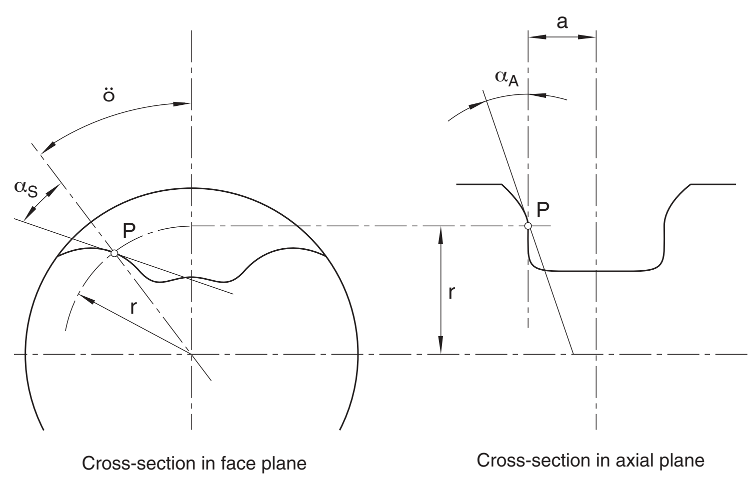
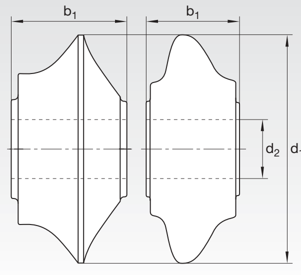


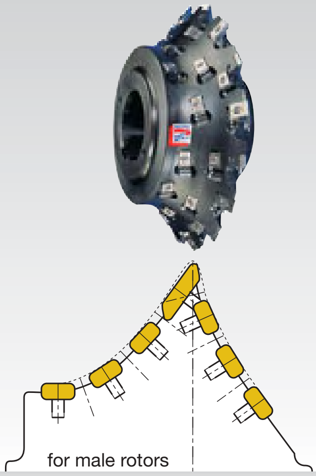
Fig. 4

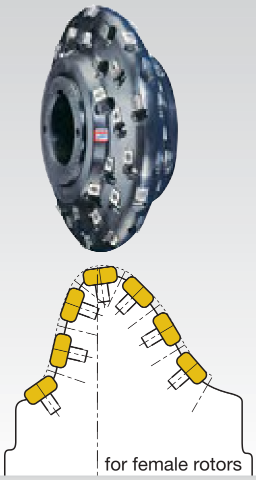
Roughing cutters for rotors

with indexable carbide inserts
for screw compressors

HL = male rotor
NL = female rotor
indexable inserts arranged tangentially
with keyway to DIN 138







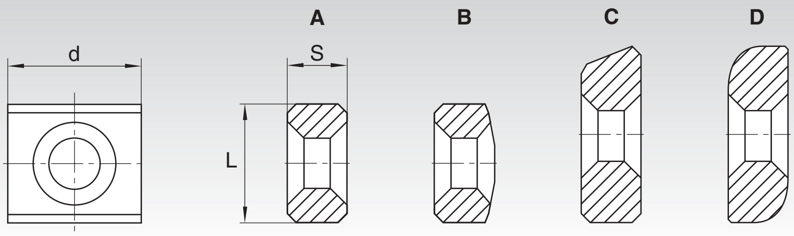
Cat.-No. **2695**

Dimensions in mm						Number of inserts
Rotor measurements			Cutter measurements (variable)			
Outside diameter	Profile height	Type	d_1	b_1	d_2	
100	22	HL	220	60	60	25– 36
│	│	NL	│	│	│	
127,5	27,5	HL	250	70	80	32– 45
│	│	NL	│	│	│	
163,2	35,5	HL	│	80	│	40– 56
│	│	NL	│	│	│	
204	44	HL	300	100	100	50– 70
│	│	NL	│	│	│	
255	55	HL	320	125	│	63– 85
│	│	NL	│	100	│	
318	70	HL	350	160	│	70–100
│	│	NL	│	125	│	

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.

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.
For rotors in stainless chromium alloys or for machines with low drive power, the tools can be fitted optionally with KHSS indexable inserts with ridges.

Indexable insert forms



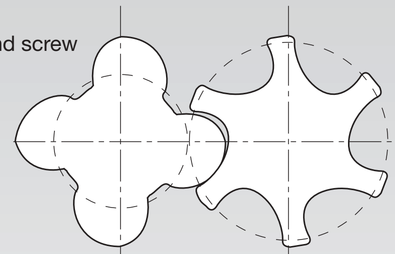
Form	Dimensions in mm			Designation	Clamping screw
	L	S	d		
A	12,70	6,35	14,29	1185-11	1150-80
	│	7,94	15,88	1185-15	
	15,88	│	│	M4-21764	
	19,05	6,35	14,29	1185-31	
B	12,70	│	│	M4-20859	
	│	7,94	15,88	M4-19730-2	
C	19,05	6,35	14,29	M4-21056	
D	25,40	│	│	M4-20924	
	19,05	│	│	1185-35	

Rotor profile cutters

for screw compressors
for male rotors or female rotors
with inserted blades
blades radially and axially resettable
blade clamping by chucking wedge and screw
with keyway

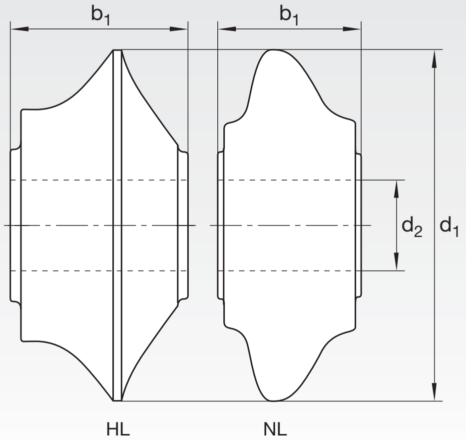
A
Roughing cutter
with profile undersize
staggered chip breakers
positive rake angle + 10° radial,
+ 10° axial

B
Finishing cutter
rake angle 0° radial,
0° axial



Male rotor Female rotor

Cutter for male rotor



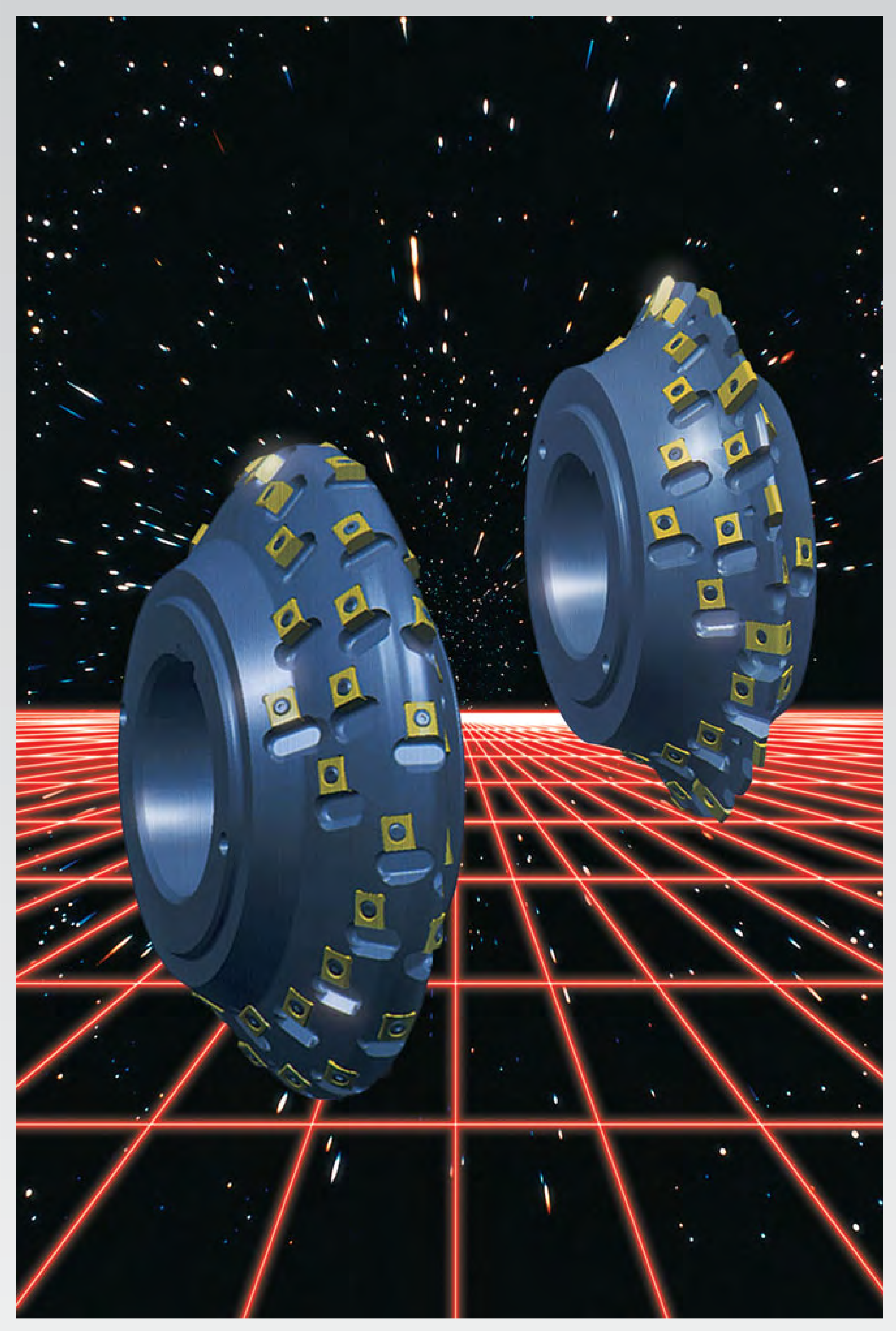
Cutter for female rotor

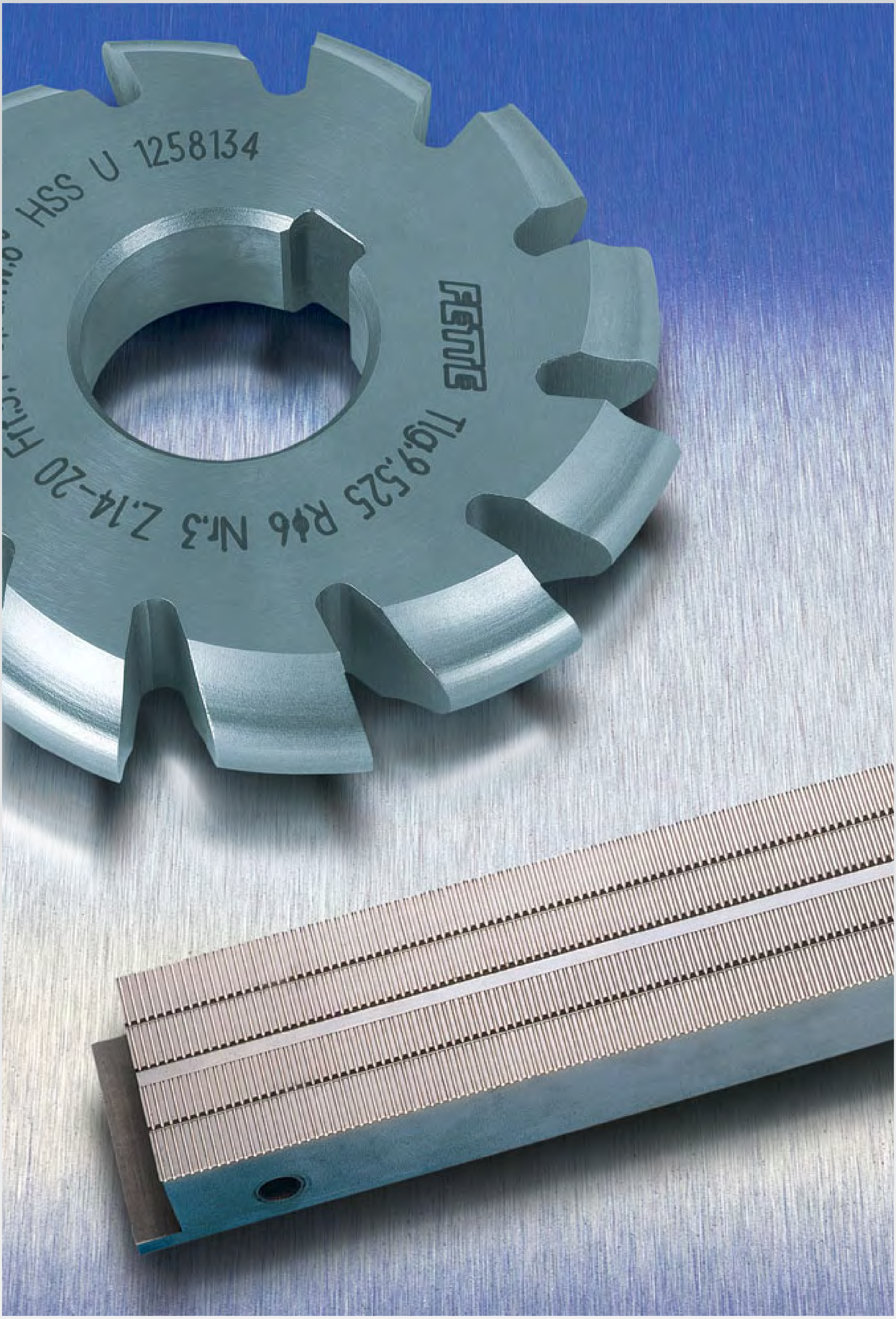
KVHSS-E EV4Co

Cat.-No.		**2690** staggered teeth ■ with profile ground lands				
Dimensions in mm						Number of blades
Rotor dimensions		Cutter dimensions				
Outside diameter	Profile height	d_1	b_1 male rot.	b_1 female rot.	d_2	
127,5	27,5	210	70	50	60	16
163,2	35,5	220	85	65	│	│
204,0	44,0	235	105	80	│	│
255,0	55,0	290	125	100	80	│
│	│	340	│	│	100	20
318,0	70,0	360	160	125	│	│
400,0	86,0	380	200	160	│	│

Circular type cutters for rotors must be kept in close limits as regards their outside diameter, since changes in diameter will affect the generated screw profile. This is why these tools are ground by the land grinding method. The blades are radially adjusted by means of set screws, the width adjustment is made possible by the staggered serrations in steps of 0.25 mm. The cutting profiles top the rotor o.d. and generate the entire gap profile including tip radii and sealing strips. To deal with enquiries, we need workpiece drawings with profile data. We carry out the computation of the cutter profiles.

Replacement blades are pre-machined with grinding allowance on the profile and are ground on the cutting faces.

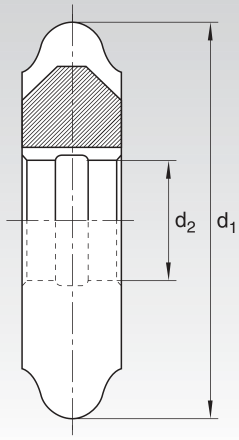



HSS U 1258134

Gear milling cutters
for sprockets, timing belt pulleys and slip-on gears

Form milling cutters

for sprockets
for roller- and barrel chains
to DIN 8187, 8188



HSS* / KHSS-E EMo5Co5

Cat.-No. **2701 relief turned**

Specification of sets in sets of 5 units

Cutter no. 1 for 8– 9 teeth
Cutter no. 2 for 10–13 teeth
Cutter no. 3 for 14–20 teeth
Cutter no 4 for 21–34 teeth
Cutter no. 5 for 35– ∞ teeth

Pitch		Roller/barrel diameter		d_1	d_2
mm	inches approx.	mm	inches approx.	mm	mm
6	15/64	4	5/32	63	22
6,35	1/4	3,3			
8	5/16	5	3/16		
9,525	3/8			70	
		6	15/64		
		6,35	1/4		
12,7	1/2	7,75	5/16		
		7,93			
		8,51			
15,875	5/8	10,16		90	27
19,05	3/4	11,9	15/32		
		12,07	1/2		
25,4	1	15,88	5/8	100	
30	1 1/4			105	32
31,75		19,05	3/4	110	
38,1	1 1/2	22,22	7/8	125	
		25,4	1		
44,45	1 3/4			140	40
		27,94			
50,8	2	28,57	1 1/8		
		29,21			
57,15	2 1/4	35,71	1 13/32	150	
63,5	2 1/2	39,37		170	50
		39,68	1 9/16		
76,2	3	47,62	1 7/8	190	
		48,26			

* Only available until stock is depleted

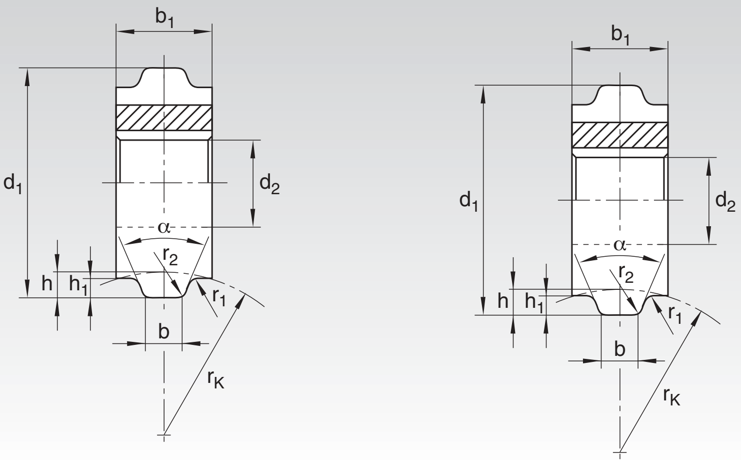
Form milling cutters for sprockets are supplied both in complete sets and singly.
When ordering single cutters, please specify the cutter number or the number of teeth to be cut.

We also manufacture:
Form milling cutters for sprockets with other or larger dimensions or with inserted blades, for sprockets to match Gall's chains to DIN 8150 and 8151, barrel chains to DIN 8164, SAE chains, Renold chains and for sprockets of other systems.

Form milling cutters

for timing belt pulleys
semi-topping
positive rake angle

r_K = ext. radius
b = gap width
α = gap angle
h = depth of cut
h_1 = height of tooth on cutter
r_1 = tooth tip radius
r_2 = tooth root radius



KHSS-E EMo5Co5

Cat.-No. **2742** **relief turned**

Specifications of sets for metric pitches to DIN 7721	**T**	**z**	Dimensions in mm / Cutter dimensions **d_1**	**b_1**	**d_2**
Cutter no. 1 for 10–13 teeth Cutter no. 2 for 14–20 teeth Cutter no. 3 for 21–34 teeth Cutter no. 4 for 35–71 teeth Cutter no. 5 for 72–∞ teeth	T 2,5 SE	to 20	63	5	22
	T 2,5 N	over 20			
	T 5 SE	to 20		6	
	T 5 N	over 20			
	T 10 SE	to 20		9	
	T 10 N	over 20			
	T 20 SE	to 20	70	18	27
	T 20 N	over 20			

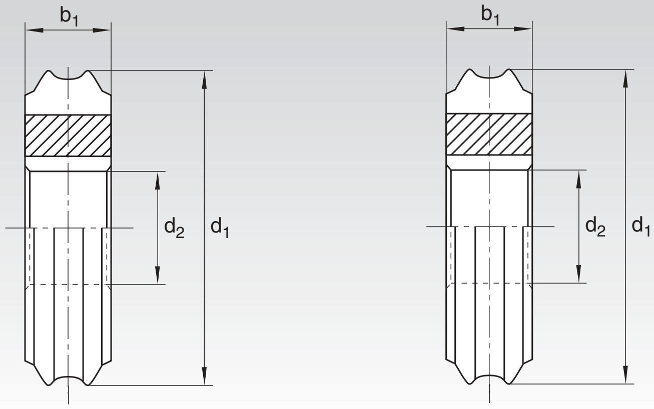
Specifications of sets for inch pitches to DIN ISO 5294	**T**	Symbol	Dimensions in mm / Cutter dimensions **d_1**	**b_1**	**d_2**
Cutter no. 1 for 10–13 teeth	5,08 = 1/5"	XL	63	5	22
Cutter no. 2 for 14–20 teeth	9,525 = 3/8"	L		8	
Cutter no. 3 for 21–34 teeth	12,70 = 1/2"	H		10	
Cutter no. 4 for 35–71 teeth	22,225 = 7/8"	XH	80	18	32
Cutter no. 5 for 72–∞ teeth	31,75 = 1 1/4"	XXH	90	26	

When cutting timing belt pulleys using the single indexing method, the tooth tip radius r_1 is semi-topped. The profile height h_1 on the cutter therefore depends on the number of teeth to be cut. This number must also be quoted to facilitate order processing.

For gears with different belt pitches or with special profiles we require dimensional data as shown in the figure above.

Form milling cutters

for spline shaft profiles



KHSS-E EMo5Co5

Cat.-No. **2730** **relief turned or relief ground**

Dimensions in mm

Spline shaft dimensions		Cutter dimensions		
DIN ISO 14 - light series Nominal dimension*	Number of splines	**d_1**	**b_1**	**d_2**
23 x 26 x 6	6	63	10	22
26 x 30 x 6			12	
28 x 32 x 6			13	
32 x 36 x 6	8		11	
36 x 40 x 7			12	
42 x 46 x 8			13	
46 x 50 x 9		70	14	27
52 x 58 x 10			16	
56 x 62 x 10			18	
62 x 68 x 12				
72 x 78 x 12	10		16	
82 x 88 x 12		80	19	32
92 x 98 x 14			20	
102 x 108 x 16			21	
112 x 120 x 18			23	
Spline shaft dimensions		Cutter dimensions		
DIN ISO 14 - medium series Nominal dimension*	Number of splines	**d_1**	**b_1**	**d_2**
11 x 14 x 3	6	56	6	22
13 x 16 x 3,5				
16 x 20 x 4			8	
18 x 22 x 5				
21 x 25 x 5		63	9	
23 x 28 x 6			10	
26 x 32 x 6			12	
28 x 43 x 7			13	
32 x 38 x 6	8		11	
36 x 42 x 7			12	
42 x 48 x 8			13	
46 x 54 x 9		70	14	27
52 x 60 x 10			16	
56 x 65 x 10			18	
62 x 72 x 12				
72 x 82 x 12	10		16	
82 x 92 x 12		80	19	32
92 x 102 x 14			20	
102 x 112 x 16			21	
112 x 125 x 18			23	
Spline shaft dimensions		Cutter dimensions		
DIN 5464 Nom. dimens.*	Number of splines	**d_1**	**b_1**	**d_2**
16 x 20 x 2,5	10	56	5	22
18 x 23 x 3				
21 x 26 x 3			7	
23 x 29 x 4		63		
26 x 32 x 4			8	
28 x 35 x 4				
32 x 40 x 5		70	10	27
36 x 45 x 5			12	
42 x 52 x 6			13	
46 x 56 x 7				
52 x 60 x 5	16	80	9	32
56 x 65 x 5			10	
62 x 72 x 6			11	
72 x 82 x 7				
82 x 92 x 6	20	90		
92 x 102 x 7			12	
102 x 115 x 8			13	
112 x 125 x 9				

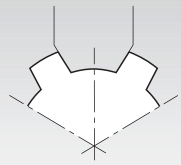
*Nominal dimension: inside dea. x outside dea. x spline width

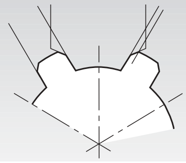
Unless otherwise specified, we supply form D in the relief turned version.

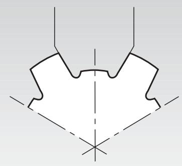
Cat.-No.	2730 relief turned or relief ground		
	Dimensions in mm		
Spline shaft dim.	Cutter dimensions		
DIN 5471 – 4 splines Nominal dimension*	d_1	b_1	d_2
11 x 15 x 3	56	11	22
13 x 17 x 4		12	
16 x 20 x 6			
18 x 22 x 6	63	14	
21 x 25 x 8			
24 x 28 x 8		16	
28 x 32 x 10		17	
32 x 38 x 10	70	22	27
36 x 42 x 10		23	
42 x 48 x 12		27	
46 x 52 x 14		28	
52 x 60 x 14	80	34	32
58 x 65 x 16		38	
62 x 70 x 16		40	
68 x 78 x 16		45	
Spline shaft dim.	Cutter dimensions		
DIN 5472 – 6 splines Nominal dimension*	d_1	b_1	d_2
21 x 25 x 5	63	9	22
23 x 28 x 6		10	
26 x 32 x 6		12	
28 x 34 x 7		13	
32 x 38 x 8	70	14	27
36 x 42 x 8		16	
42 x 48 x 10		17	
46 x 52 x 12	80	18	32
52 x 60 x 14		20	
58 x 65 x 14		22	
62 x 70 x 16		23	
68 x 78 x 16	90	27	
72 x 82 x 16		29	
78 x 90 x 16		33	
82 x 95 x 16		36	
88 x 100 x 16			
92 x 105 x 20		38	
98 x 110 x 20		40	
105 x 120 x 20	100	45	
115 x 130 x 20		45	
130 x 145 x 24		54	
P.t.o. shaft 1**	Cutter dimensions		
DIN 9611 – 6 splines	d_1	b_1	d_2
28,91 x 34,79 x 8,69	70	11	27

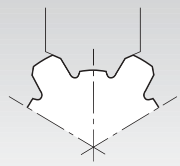
* Nominal dimension: inside dia. x outside dia. x spline width
** P.t.o. shafts 2 and 3 on request

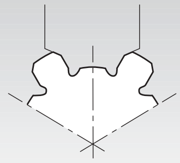
Unless otherwise specified, we supply form D in the relief turned version.

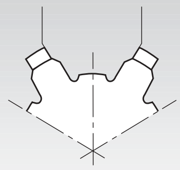

Form A
without clearance lugs
without chamfer


Form B
without clearance lugs
with chamfer


Form C
with clearance lugs
without chamfer


Form D (standard)
with clearance lugs
with chamfer


Form E
grinding size cutter


Forms A-E
for through-cutting
a shoulder

Form milling cutters for spline shaft profiles are supplied relief turned or for increased accuracy also relief ground. Gang cutters for the simultaneous machining of several workpieces on automatic spline shaft milling machines are also available. The cutters are designed as roughing- or finishing cutters, depending on the type of application.

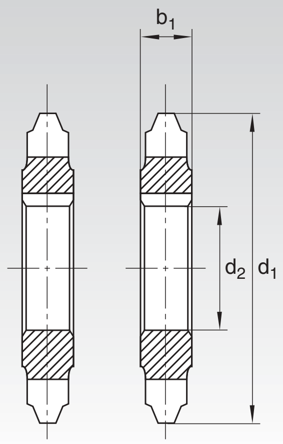
Standardized spline shafts comprise, among others:

DIN ISO 14 – light series
DIN ISO 14 – medium series
DIN 5464 – heavy series
DIN 5471 – 4 splines, internally centred
DIN 5472 – 6 splines, internally centred
DIN 9611 – p.t.o. shafts

Form milling cutter designs provided with clearance lugs (forms C and D) guarantee in the case of internally centred spline shafts perfect bearing down to the spline shaft root. Chamfering (forms B and C) is used to achieve the required clearance in the flute corners of the hubs. Flank-centred spline shafts which have a clearance for the inside and outside diameters in the spline hub, can be produced with cutter type A. The cutters of form E – for clearance at the root and the spline flanks – are intended as roughing cutters for grinding allowance. The cutters with extended flanks are suitable for through-cutting of a shoulder. This type can be combined with all forms from A to E.
Form cutters for involute gear shafts to DIN 5480 and DIN 5481 as well as for serrated shafts to DIN 5481 are also manufactured on request.

Form milling cutters

for straight sided and involute spline shafts designed as gang cutters
6° positive rake angle
staggered keyways
1 set (gang) equals 2 units
cutter no. 2 with 2 keyways



KHSS-E-PM

Cat.-No.	**2731** relief ground	
	Dimensions in mm	
d_1	**b_1**	**d_2**
75 to 85	10	40
	12	
	14	
	16	
	18	
	20	

This cutter design is mainly used for the batch production of slip gears on automatic spline shaft milling machines (e.g. Hurth type). Within the set, the cutters are precision ground for exact width, profile symmetry and equal outside diameters to close tolerances. Cutter no. 2 of a set is given a second keyway, which is offset by 1/2 tooth pitch.

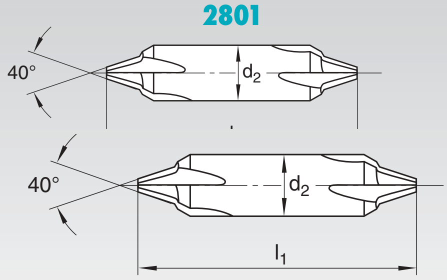
The main fields of application are spline shafts with parallel flanks as well as shafts with involute flanks.

When ordering, please quote dimensional and tolerance data or provide drawings of the workpiece profiles to be machined.

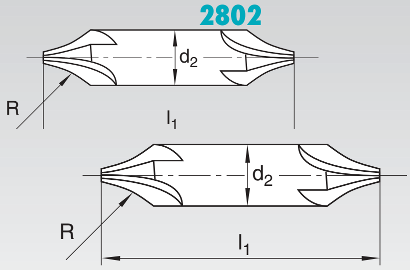
Gear chamfering cutters

for chamfering tooth edges

2801



2802



2803

Fig. 1

2804

Fig. 2

HSS

Cat.-No.

2801 **relief ground ■ with straight flanks**
2802 **relief ground ■ with curved flanks**
2803
2804

Dimensions in mm			2801	2802	2803	2804
m	d_2	l_1	Ident no.	Ident no.	Ident no.	Ident no.
1	13	80	1259311	1259918	–	–
1,25			1259320	1259927	–	–
1,5			1259339	1259936	–	–
1,75			1259348	1259945	–	–
2			1259357	1259954	–	–
2,25			1259366	1259963	–	–
2,5			1259375	1259971	–	–
2,75			1259384	1259981	–	–
3			1259393	1259990	–	–
3,25			1259400	1260005	–	–
3,5			1259419	1260014	–	–
3,75			1259428	1260023	–	–
4			1259437	1260032	–	–
4,5			1259446	1260041	–	–
5	18		1259455	1260050	–	–
5,5			1259464	1260069	–	–
6			1259473	1260078	–	–
6,5			1259482	1260087	–	–
7	25	110	1259491	1260096	–	–
8			1259507	1260103	–	–

For any number of teeth of one module size and for pressure angles of 15° or 20° only one cutter is required.

FETTE gear chamfering cutters
It is imperative in gear production to machine flanks and tip face edges of gears after they have been hobbed or produced by the single indexing method. Partly, this means deburring the tooth edges, but very often function-governed forms must be provided on the flanks and the tip face edges. This form is generally determined by the task which the gear has to perform. The best known forms are simple chamfers, semi-circular roundings, crowned roundings and crowned V-profiles, which must be present both on the external and on the internal gears.

For machining gear face edges, machines have been developed which allow the economical milling of the edge forms. A distinction must here be made between two machining processes, the correct process being determined by the type of the edge form.

Semi-circular or V-shaped roundings are produced with end-mill type cutters which are designed with outside profiled cutting edges (fig.1). The profile of the cutting edges is designed in accordance with the gear to be machined. The rotary and the axial motion of the gear are controlled by the machine, leaving the tooth edge roundings to be done by the copying or tracer process.

V-shaped meshing facilitations, deburring of gears as well as the cutting of special edge forms are generally performed with bell-type cutters (fig. 2), using the shaping method. With this process, a left-hand and a right-hand tooth flank are machined at the same time. The cutting edges of a bell type cutter are internally profiled and the cutter cuts mainly with the inner contours.

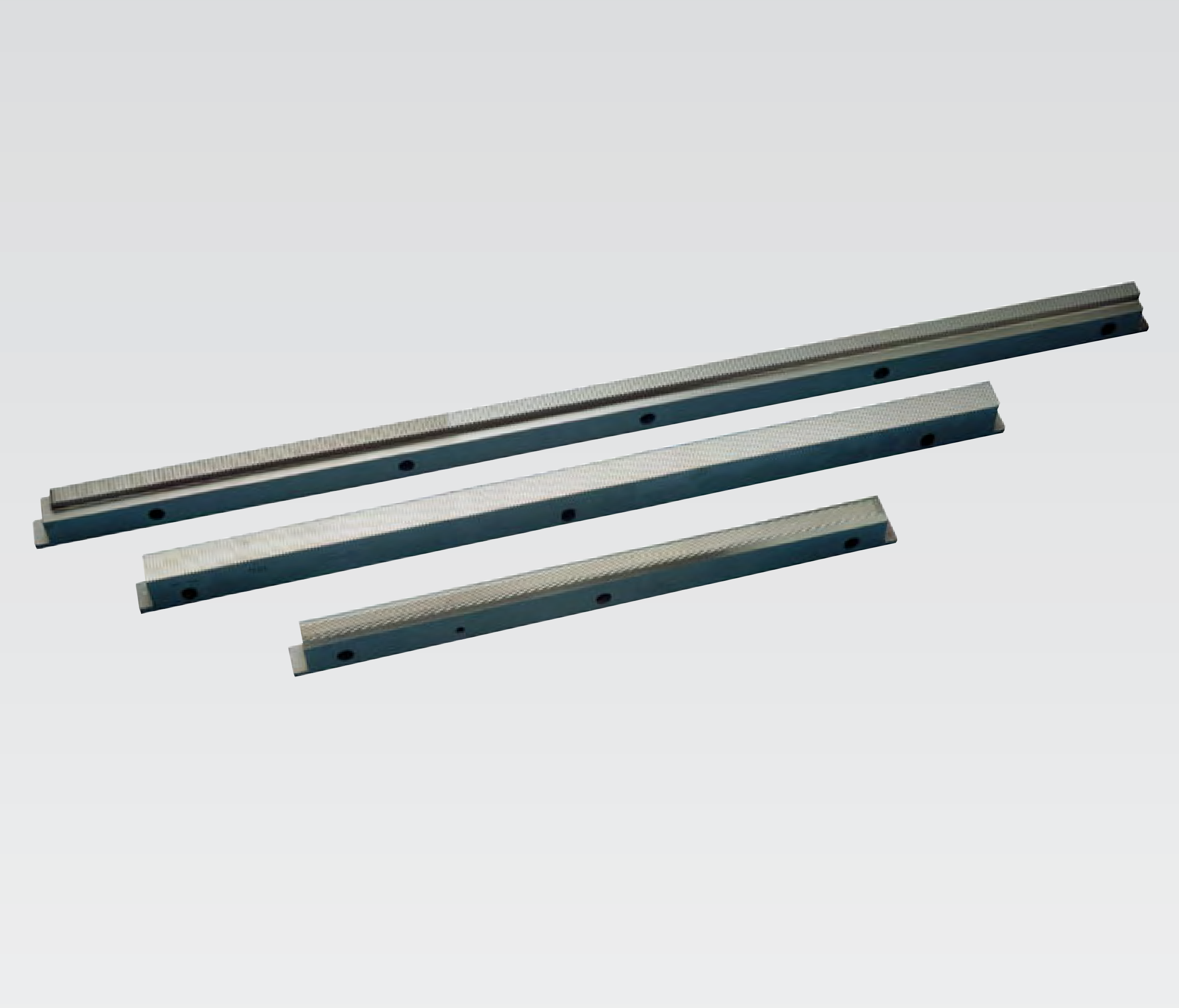
The cutting diameters of the gear tooth rounding-, V-type and deburring cutters depend on the gear size to be machined – i.e. on the module and the number of teeth of the gear. In addition, different tooth edge forms are decisive for the construction of the gear chamfering cutters. These factors result in a multitude of design possibilities, so that gear chamfering cutters must be regarded as purely special cutters which have to be adapted to each type of gear form.

Rolling racks

FETTE manufacture rolling bars for the production of gears on all popular rolling machines. Extreme accuracy and maximum service life are the quality characteristic here, too. FETTE provide an exceptionally comprehensive service in this sector. The tools can be made for spline shaft joints to DIN 5480 (up to module 1.25), for spline shaft joints to ANSI B92.1-1970 (up to DP 20/40) or for knurled work to DIN 82 RAA.

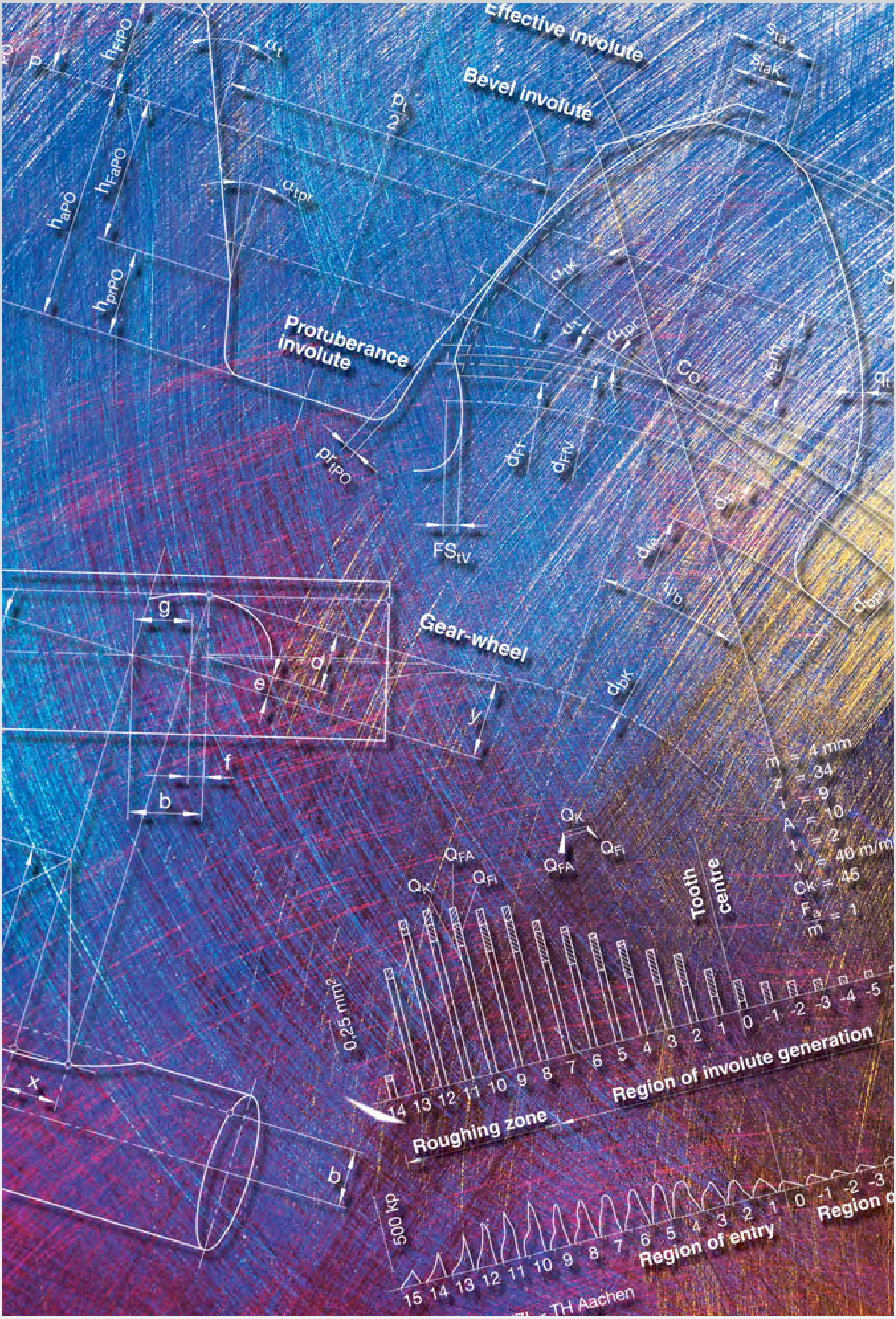
When enquiring, please state the machine on which the tool is to be used.

Rolling racks for helical teeth



Rolling racks for teeth


FETTE
Tlg.9.525 Rϕ6 Nr.3 Z.14-20 Frt.5,4 Spanw.6° HSS U 1258134

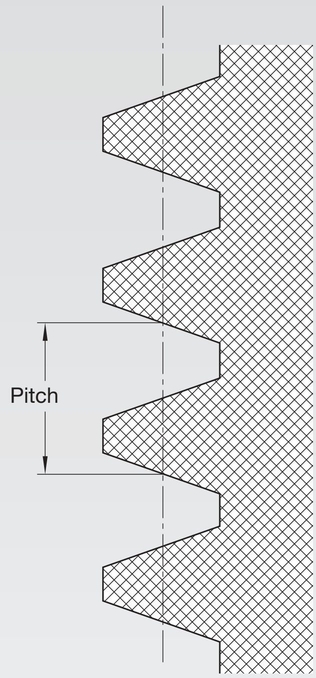

Effective involute
Bevel involute
Protuberance involute
Gear-wheel
Tooth centre
Region of involute generation
Roughing zone
Region of entry
0,25 mm²
500 kp
TH Aachen

Technical notes and tables

Comparison: module pitch - diametral pitch - circular pitch

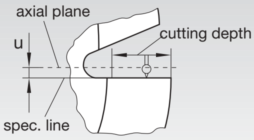
Module	Diametral Pitch	Circular Pitch
$m = \frac{25,4}{DP}$ $m = 8,08507111 \times CP$	$DP = \frac{3,14159265}{CP}$ $DP = \frac{25,4}{m}$	$CP = \frac{3,14159265}{DP}$ $CP = \frac{m}{8,08507111}$

Pitch mm	Module	DP	CP	Pitch mm	Module	DP	CP	Pitch mm	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	

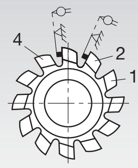


Tolerances for single-start hobs
for spur gears with involute teeth to DIN 3968 in µm.

No. 7



No. 8



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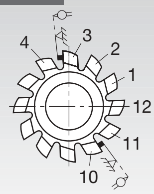
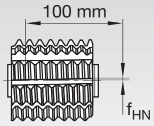


No. 11



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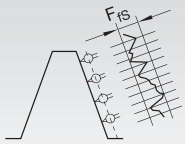

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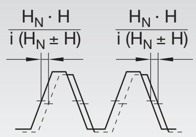

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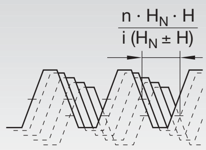
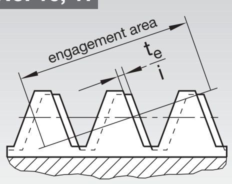


No. 16, 17



Item no.*	Measurement	Symbol		Quality grade	above 0,63–1	above 1–1,6	above 1,6–2,5	above 2,5–4	above 4–6,3	above 6,3–10	above 10–16	above 16–25	above 25–40
					For module range								
1	Diameter of the bore			AA	H 5								
				A	H 5								
				B	H 6**								
				C	H 6								
				D	H 7								
4	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	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	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	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	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	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	Gash lead over 100 mm hob length	f_{HN}	+ −	AA	50								
				A	70								
				B	100								
				C	140								
				D	200								
12	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	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	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	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	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	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

* Item no. of the measurement points to DIN 3968

** In accordance with the works standard, FETTE Hobs of quality grade B are made with bore tolerance H 5.

Tolerances for multiple start hobs

					For module range								
Item no.	Measurement	Symbol		Quality grade	above 0,63–1	above 1–1,6	above 1,6–2,5	above 2,5–4	above 4–6,3	above 6,3–10	above 10–16	above 16–25	above 25–40
1	Diameter of the bore			AA					H 5				
				A					H 5				
				B					H 6				
					Tolerances in µm								
4	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	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	Radial runout at the tooth tips	f_{rk}	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 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	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	Individual pitch of the gashes	f_{tN} $\pm$		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	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	Gash lead over 100 mm hob length	f_{HN} $\pm$		AA					50				
				A					70				
				B					100				
12	Form deviation of the cutting edge	F_{fS}	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 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 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

					For module range								
Item no.	Measurement	Symbol		Quality grade	above 0,63–1	above 1–1,6	above 1,6–2,5	above 2,5–4	above 4–6,3	above 6,3–10	above 10–16	above 16–25	above 25–40
					Tolerances in µm								
13	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	Hob lead from cutting edge to cutting edge in the direction of spiral	f_{HF} ±	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 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 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	Hob lead in the direction of spiral between any cutting edges in one axial pitch	F_{HF}	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 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 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	Pitch deviation between adjacent threads of a tooth segment	f_{px} ±	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 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	Pitch deviation between any two spirals of a tooth land within the hob lead	F_{px}	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 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

Hob inspection records

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.
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.
The deviations of the measured values can be written or marked down by hand, they can be mechanically recorded or stored in a computer.
In the case of quality grades AA or

Ident No.:	2352101	Tip circle diameter:	58.979	Lead angle:	02° 43'33"
Hob No.:	E1305	Cutting edge width:	150	Lead:	7.8314
Module:	2.49	Bore diameter:	–	Basic profile:	–
Pressure angle:	20° 00'00"	Handing/nbr. of starts:	R1	Profile modification:	–
Tooth addendum:	3.82	Number of gashes:	14	Cutting depth:	–
Axial tooth thickness:	3.9154	Cutting face offset:	0	Material:	–
Tooth height:	6.6	Gash lead:	1.E + 100	Hardness:	HRc –

(4) Right-hand radial runout:

	Intended value		Actual value	
f_{rp}	5	AA	2	AAA

(5) Right-hand axial runout:

	Intended value		Actual value	
f_{ps}	3	AA	2	AAA

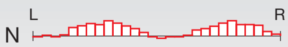
(5) Left-hand axial runout:

	Intended value		Actual value	
f_{ps}	3	AA	2	AAA

(4) Left-hand radial runout:

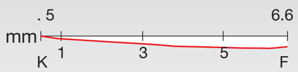
	Intended value		Actual value	
f_{rp}	5	AA	2	AAA

(6) Radial runout at the tooth tip



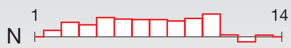
	Intended value		Actual value	
f_{rk}	12	AA	7	AAA

(7) Form and location of the cutting face



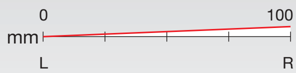
	Intended value		Actual value	
F_{fn}	12	AA	5	AAA

(8,10) Pitch of the gashes



	Intended value		Actual value	
F_{tN}	25	AA	11	AAA
f_{tN}	12	AA	8	AAA

(11) Gash lead



	Intended value		Actual value	
f_{HN}	50	AA	5	AAA

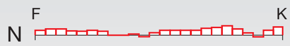
(14, 15) Right-hand lead

	Intended value		Actual value	
F_{HF}	6	AA	3	AAA
f_{HF}	4	AA	1	AAA

(14, 15) Left-hand lead

	Intended value		Actual value	
F_{HF}	6	AA	2	AAA
f_{HF}	4	AA	1	AAA

(16, 17) Right-hand base pitch



	Intended value		Actual value	
F_e	8	AA	4	AAA
f_e	4	AA	2	AAA

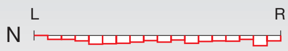
(16, 17) Left-hand base pitch

	Intended value		Actual value	
F_e	8	AA	3	AAA
f_e	4	AA	2	AAA

Right-hand axial pitch

	Intended value			
F_{px}	2			
f_{px}	1			

Left-hand axial pitch



	Intended value			
F_{px}	4			
f_{px}	2			

Tolerances to:
DIN 3968 AAA

FETTE
HOB MEASUREMENT

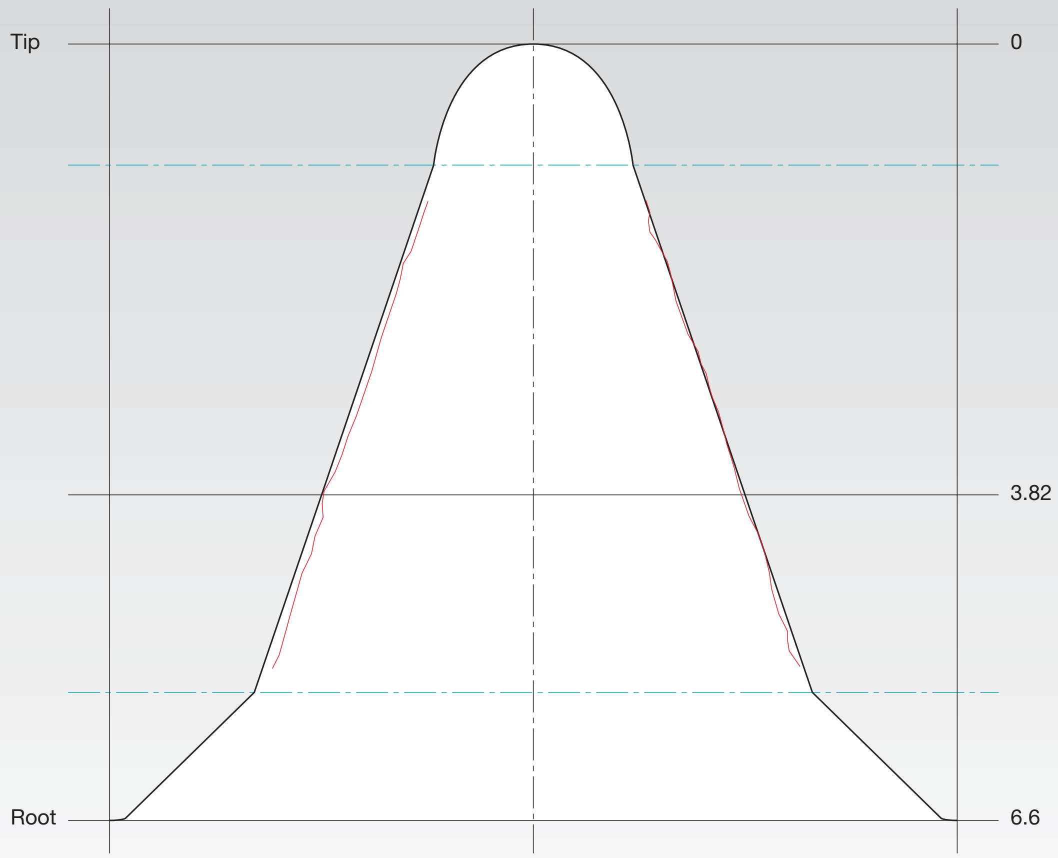
20 my

Date: 15 Jan 1998
Checked: Mumsen
Drwg. no.: 61574
Measur. file: E1305 05M

R
W
F

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 here in a reduced size; the original size is DIN A3.

(12) Form deviation of the cutting edge



(LF)	Intended value		Actual value		(13) Tooth thickness f_s	Intended value		Actual value		(RF)	Intended value		Actual value	
F_{fS}	6	AA	3	AAA		–16	AA	–3	AAA	F_{fS}	6	AA	2	AAA

Remarks:

FETTE
HOB MEASUREMENT

20 my

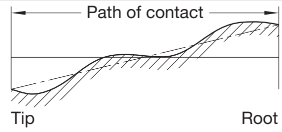
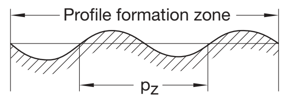
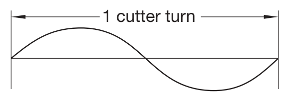
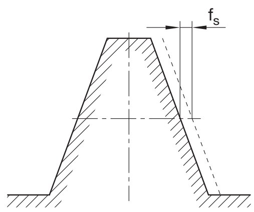
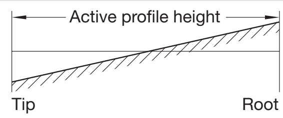
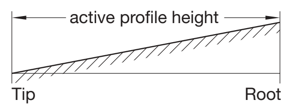
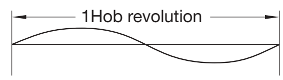
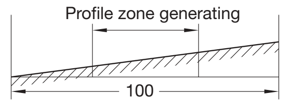
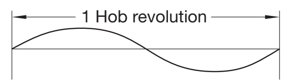
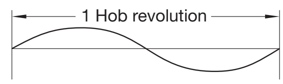
Date: 15 Jan 1998
Checked: Mumsen
Drwg. no.: 61574
Measur. file: E1305 05M

R
W
F

The effect of cutter deviations and cutter clamping errors on the gear

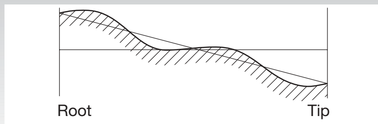
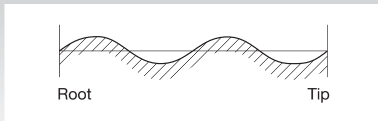
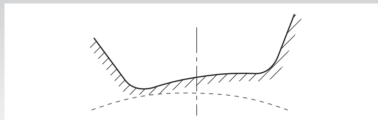
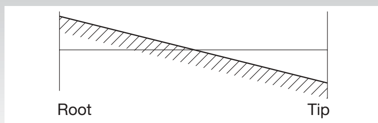
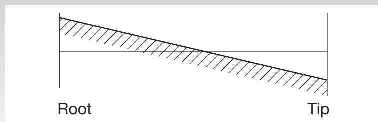
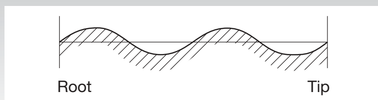
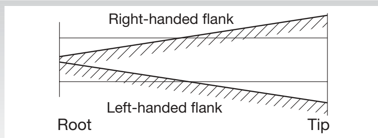
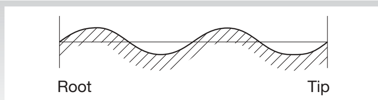
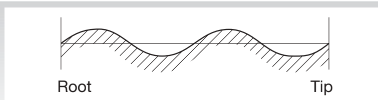
(for single-start hobs with 20° pressure angle and relief rake angle of approx. 10°)

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 deviations on the hob and clamping errors of the cutter affect gear quality.

Hobs			
Nature of the deviation	Designation and symbols of the deviation acc. to VDI 2606	Item no. & symbol of the deviation acc. to DIN 3968 (- Sept. 1960)	Representation of the deviation
Deviations on the enveloping helix of the hob	Total base pitch deviation F_{pe} within an engagement area	No. 17 F_e	
	Cutter lead height deviation in the direction of start F_{HF} between any cutting edges in one convolution	No. 15 F_{HF}	
	Radial runout f_{ra} on the tooth tip	No. 6 f_{rk}	
	Tooth thickness deviation f_s on the basic reference cylinder	No. 13 f_s	
	Form deviation F_{fS} of the cutting edge	No. 12 F_{fS}	
Deviations on the cutting faces of the hob	Form- and position-deviation F_{fN} of the cutting faces	No. 7 F_{fN}	
	Cumulative pitch deviation F_{pN} of the gashes (cutting faces)	No. 10 F_{tN}	
	Gash lead deviation f_{HN} over 100 mm cutter length	No. 11 f_{HN}	
Clamping errors of the hob on the hobbing machine	Radial runout f_{rP} on the two indicator hubs	No. 4 f_{rP}	
	Axial runout f_{rx} on the clamping faces	No. 5 f_{ps}	

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.

Gear		
Effect of the deviation	Order of magnitude of the effect	Typical course of the deviation Remarks
Profile deviation	≈ 100 %	
Profile deviation (only the deviation of the profile formation zone in question is effective)	≈ 100 %	
Form deviation in the bottom of the tooth space (only the deviation of the tip cutting edges forming the root cylinder is effective)	≈ 20 %	
(Tooth thickness deviation)	(≈ 100 %)	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.
Diameter deviations	> 100 %	
Profile deviation	≈ 100 %	
Profile deviation	≈ 10 %	
Profile deviation	≈ 10 %	
Profile deviation (only the deviation of the profile forming zone is effective)	≈ 10 %	
Profile deviation	≈ 30 %	
Profile deviation	≈ 100 %	

Effect of the quality grades of the hob on gear quality

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 to12. Gear quality 1 is the most accurate.

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.

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.

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.

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.

Attainable gear qualities to DIN 3962 part 1 – 8.78 (F_1)

Quality grade to DIN 3968 for single-start hobs		Module ranges										
		from 1 to 1,6	from 1,6 to 2	from 2 to 2,5	from 2,5 to 3,55	from 3,55 to 4	from 4 to 6	from 6 to 6,3	from 6,3 to 10	from 10 to 16	from 16 to 25	from 25 to 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	*	12	12	12	12	12	12	12	12	12

* Inferior to gear quality 12

Notes concerning DIN 3968 tolerances, page 127

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 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.

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).

Tool holding of hobs in the hobbing machine

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.

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**.

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

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.

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.

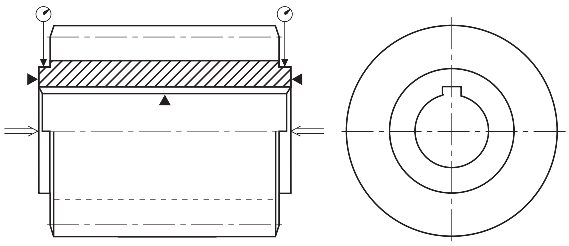
The most widely used hob type is the bore-type hob with keyway. The reasons for this are partly historical. Shank-type hobs are employed only where necessitated by geometric constraints or higher quality requirements. Bore-type hobs are a good choice for small production runs and where requirements on 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 (1/2 drive slot depth according to DIN 138). Bore-type hobs may also be manufactured without keyway or drive slot.

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. Pre-alignment 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.

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.

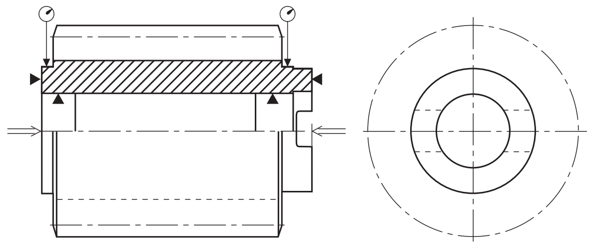
Where necessary, worm gear hobs are manufactured with an interface geometry adapted to the hobbing machine (refer to the worm gear hob chapter).

Hob clamping
Keyway



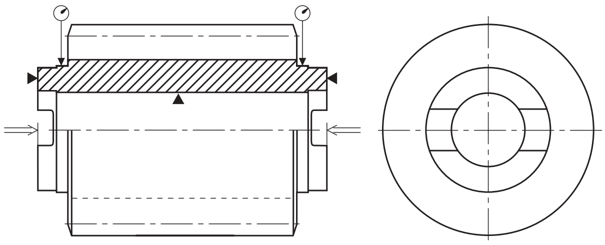
◷ ≙ Runout indicator surface
▼ ≙ Mounting surface
⟹ ≙ Clamping force

Hob clamping
Drive slot at one end



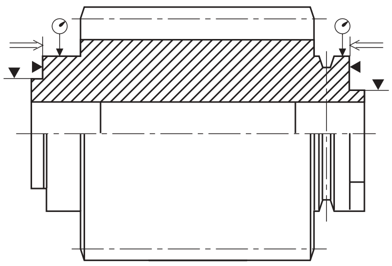
◷ ≙ Runout indicator surface
▼ ≙ Mounting surface
⟹ ≙ Clamping force

Hob clamping
Drive slots at both ends



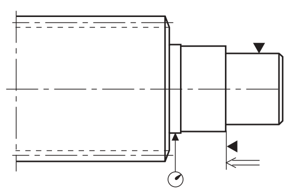
◷ ≙ Runout indicator surface
▼ ≙ Mounting surface
⟹ ≙ Clamping force

Hob clamping
Frictional torque transmission



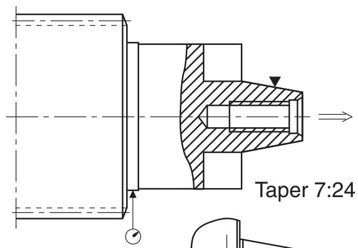
◷ ≙ Runout indicator surface
▼ ≙ Mounting surface
⟹ ≙ Clamping force

Hob clamping
Cylindrical shank

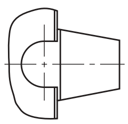


◷ ≙ Runout indicator surface
▼ ≙ Mounting surface
⟹ ≙ Clamping force

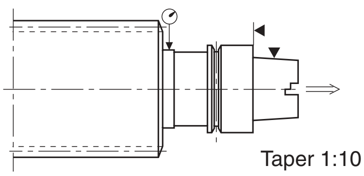
Hob clamping
Tapered shank



◷ ≙ Runout indicator surface
▼ ≙ Mounting surface
⟹ ≙ Clamping force

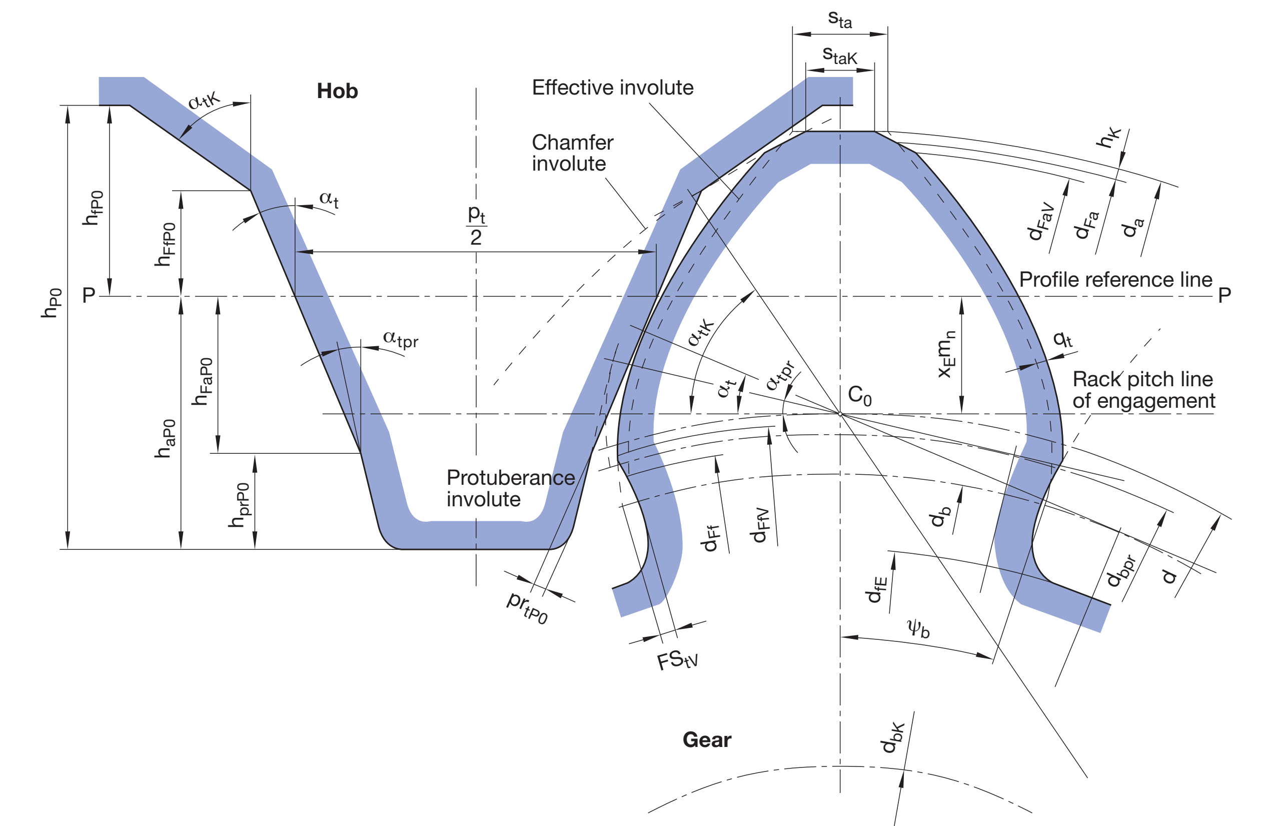


Hob clamping
HSK hollow taper shank



◷ ≙ Runout indicator surface
▼ ≙ Mounting surface
⟹ ≙ Clamping force

Basic tool profile and gear profile in hobbing



Pre-formed helical spur gear face profile with chamfer and root clearance cut, with corresponding basic profile of the pre-forming tool.

Basic profiles for spur gears with involute teeth

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.

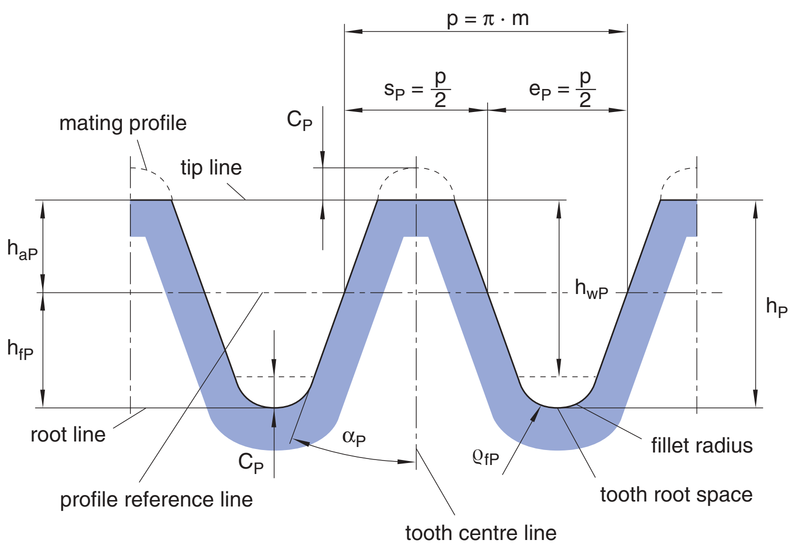
Details of standardized basic profile for spur gears are found in:

DIN 867
DIN 58400
ISO 53

Basic profile of a spur gear

- $p = m \cdot \pi$ = Pitch
- e_P = Tooth space width on the profile reference line
- s_P = Tooth thickness on the profile reference line
- h_P = Profile height
- h_{aP} = Addendum
- h_{fP} = Dedendum
- α_P = Profile angle
- ϱ_{fP} = Root fillet radius
- h_{wP} = Common tooth heigt of basic profile and mating profile
- c_P = Tip clearance between basic profile and mating profile

The basic profiles of spur gears are denoted by the index p.



Basic profile for spur gears

Standardized basic profiles for spur gears with involute flanks

Basic profiles for involute teeth

Symbols:

p = Pitch
e_P = Tooth space width on the profile reference line
s_P = Tooth thickness on the profile reference line
h_P = Profile height
h_{aP} = Addendum
h_{fP} = Dedendum
α_P = Profile angle
ϱ_{fP} = Root fillet radius
h_{wP} = Common tooth heigt of basic profile and mating profile
c = Tip clearance between basic profile and mating profile
m = Module
C_a = Addendum tip relief
h_{Ca} = Height of the addendum tip relief

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 0,3 · m
= 0,4 · m in special cases
h_{wP} = 2 · m
$\varrho_{fPmax.}$ = 0,25 · m at c_P = 0,17 · m
= 0,38 · m at c_P = 0,25 · m
= 0,45 · m at c_P = 0,3 · m

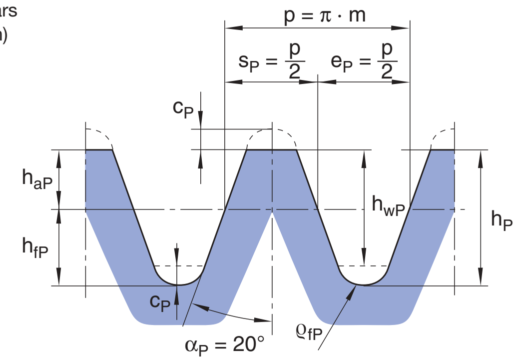


Fig. 1.00

ISO 53 – Basic profile for spur gears with involute flanks

p = $m \cdot \pi$
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

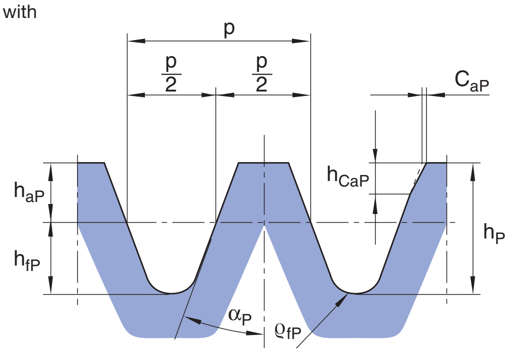


Fig. 1.01

Basic hob profiles

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:

1. The basic profile line of the rack rolls on a defined pitch circle diameter of the workpiece.

2. The pitch of the rack is equal to the pitch on the pitch circle diameter.

3. Meshing with the workpiece takes place:
   a) 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
   b) 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_{po} 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

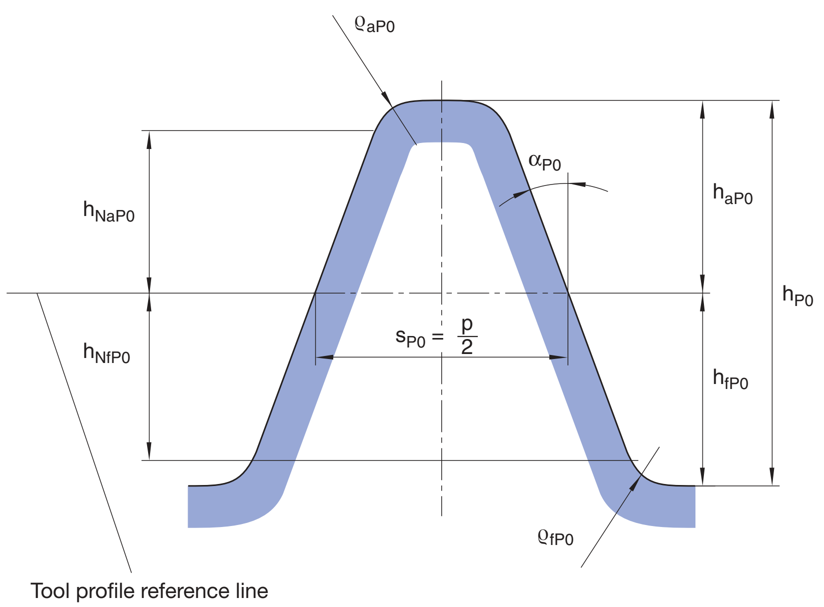
Basic hob profile and hob profile

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.

Basic hob profile

$p = m \cdot \pi$ = Pitch
s_{P0} = Tooth thickness
h_{P0} = Profile height
h_{aP0} = Addendum
h_{fP0} = Dedendum
d_{P0} = Flank angle (pressure angle)
ϱ_{aP0} = tip radius
ϱ_{fP0} = root fillet radius
h_{NaP0} = effective addendum height
h_{NfP0} = effective dedendum height

Values of the basic tool profile are identified by the addition of PO indexes.



Basic cutter profile

Basic hob profiles to DIN 3972

Symbols:

h_{aP0} = addendum of the basic profile

h_P = profile height of the gear = cutting depth

h_{P0} = profile height of the basic profile

s_{P0} = tooth thickness

ϱ_{aP0} = tip radius

ϱ_{fP0} = root fillet radius

DIN 3972 – basic profile I – 20° pressure angle

$h_{aP0} = 1{,}167 \cdot m$

$h_P = 2{,}167 \cdot m$

$h_{P0} = 2{,}367 \cdot m$

$\varrho_{aP0} \approx 0{,}2 \cdot m$

$\varrho_{fP0} \approx 0{,}2 \cdot m$

$s_{P0} = \frac{\pi}{2} \cdot m$

for finishing

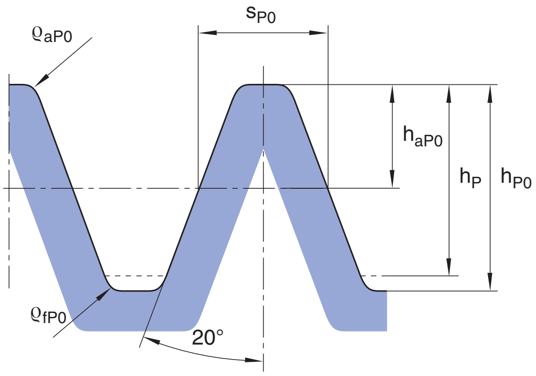


Fig. 2.00

DIN 3972 – basic profile II – 20° pressure angle

$h_{aP0} = 1{,}250 \cdot m$

$h_P = 2{,}250 \cdot m$

$h_{P0} = 2{,}450 \cdot m$

$\varrho_{aP0} \approx 0{,}2 \cdot m$

$\varrho_{fP0} \approx 0{,}2 \cdot m$

$s_{P0} = \frac{\pi}{2} \cdot m$

for finishing

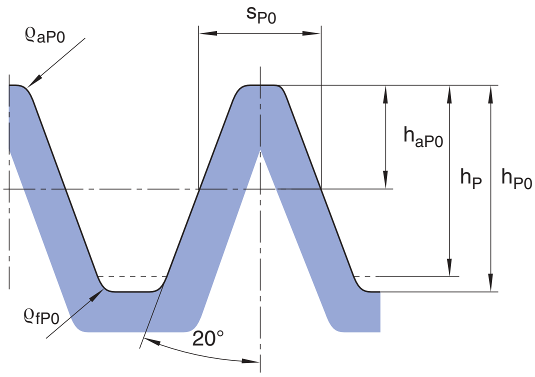


Fig. 2.01

DIN 3972 – basic profile III – 20° pressure angle

$h_{aP0} = 1{,}25 \cdot m + 0{,}25 \sqrt[3]{m}$

$h_P = 2{,}250 \cdot m$

$h_{P0} = 2{,}450 \cdot m$

$\varrho_{aP0} \approx 0{,}2 \cdot m$

$\varrho_{fP0} \approx 0{,}2 \cdot m$

$s_{P0} = \frac{\pi}{2} \cdot m$

$q = 0{,}25 \sqrt[3]{m} \cdot \sin 20°$

for machining prior to grinding or shaving

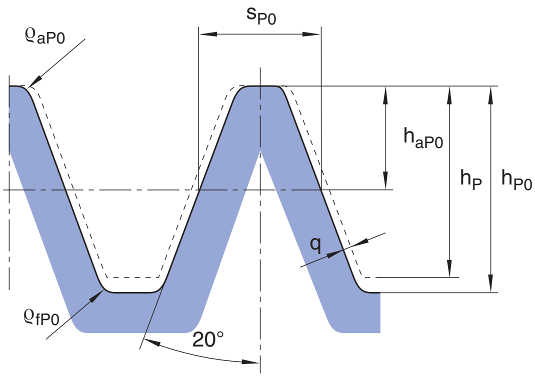


Fig. 2.02

DIN 3972 – basic profile IV – 20° pressure angle

$h_{aP0} = 1{,}25 \cdot m + 0{,}60 \sqrt[3]{m}$

$h_P = 2{,}250 \cdot m$

$h_{P0} = 2{,}450 \cdot m$

$\varrho_{aP0} \approx 0{,}2 \cdot m$

$\varrho_{fP0} \approx 0{,}2 \cdot m$

$s_{P0} = \frac{\pi}{2} \cdot m$

$q = 0{,}6 \sqrt[3]{m} \cdot \sin 20°$

for machining prior to finishing

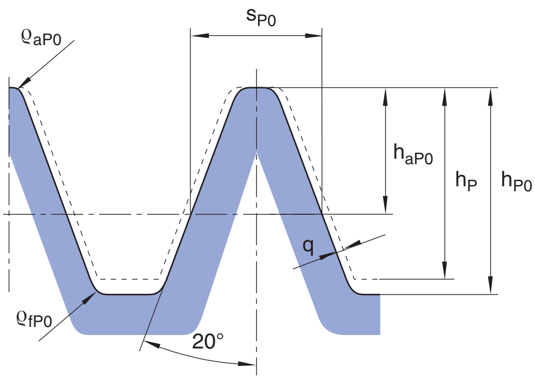


Fig. 2.03

Basic hob profiles to DIN 58412

Symbols:

h_{fP0} = dedendum of the basic profile

h_{Pw} = distance beween the tooth root and the end of the straight flank of the basic profile

h_{P0} = profile height of the basic profile

h_P = profile height of the gear = cutting depth

s_{P0} = $\frac{\pi}{2} \cdot m$ = tooth thickness

ϱ_{aP0} = tip radius

ϱ_{fP0} = root fillet radius

U1, N1, V1 } For gears with basic cutter profile to DIN 58400

U2, N2, V2 } For gears with basic cutter profile to DIN 867

DIN 58412 – 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 from module 0,1 ÷ 0,6
h_P = h_{P0} = 2,45 · m over module 0,6 ÷ 1
ϱ_{aP0} ≈ 0,2 · m
ϱ_{fP0} ≈ 0,2 · m max. size
for finishing

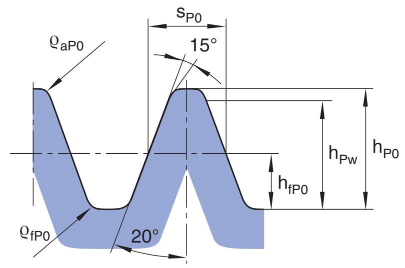


Fig. 3.00

DIN 58412 – basic profile N 1 – non-topping – 20° pressure angle

h_{fP0} = 1,3 · m
h_{Pw} = 2,4 · m
h_P = 2,6 · m from module 0,1 ÷ 0,6
h_P = 2,45 · m over module 0,6 ÷ 1
h_{P0} = 2,8 · m from module 0,1 ÷ 0,6
h_{P0} = 2,65 · m over module 0,6 ÷ 1
ϱ_{aP0} ≈ 0,2 · m
ϱ_{fP0} ≈ 0,2 · m max. size
for finishing

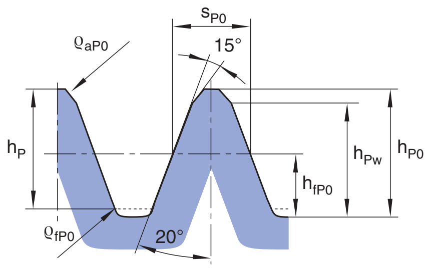


Fig. 3.01

DIN 58412 – basic profile U 2 – topping – 20° pressure angle

h_{fP0} = 1 · m
h_{Pw} = 2 · m
h_P = h_{P0} = 2,25 · m
ϱ_{aP0} = 0,2 · m
ϱ_{fP0} = 0,2 · m max. size
for finishing

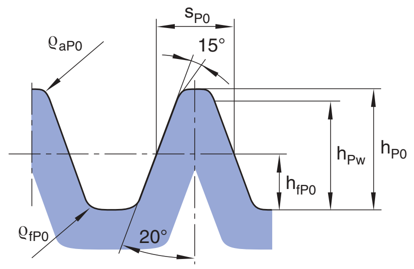


Fig. 3.02

DIN 58412 – basic profile N 2 – non-topping – 20° pressure angle

h_{fP0} = 1,2 · m
h_{Pw} = 2,2 · m
h_P = 2,25 · m
h_{P0} = 2,45 · m
ϱ_{aP0} = 0,2 · m
ϱ_{fP0} = 0,2 · m max. size
for finishing

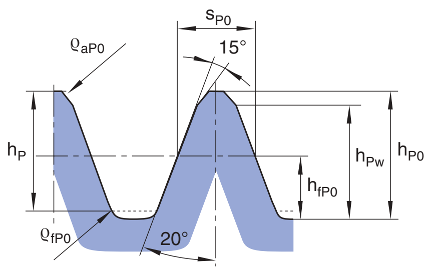


Fig. 3.03

DIN 58412 – basic profile V 1 – non-topping – 20° pressure angle

h_{fP0} = 1,3 · m
h_P = 2,6 · m from module 0,3 ÷ 0,6
h_P = 2,45 · m over module 0,6 ÷ 1
h_{P0} = 2,8 · m from module 0,3 ÷ 0,6
h_{P0} = 2,65 · m over module 0,6 ÷ 1
s_{P0} = $\frac{\pi}{2} \cdot m - \frac{2q}{\cos \alpha}$
ϱ_{aP0} = 0,1 · m
ϱ_{fP0} = 0,2 · m max. size
q = 0,05 · m + 0,03
for pre-machining

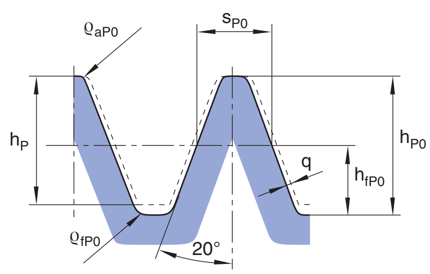


Fig. 3.04

DIN 58412 – basic profile V 2 – non-topping – 20° pressure angle

h_{fP0} = 1,2 · m
h_P = 2,25 · m
h_{P0} = 2,45 · m
s_{P0} = $\frac{\pi}{2} \cdot m - \frac{2q}{\cos \alpha}$
ϱ_{aP0} = 0,1 · m
ϱ_{fP0} = 0,2 · m max. size
q = 0,05 · m + 0,03
for pre-machining

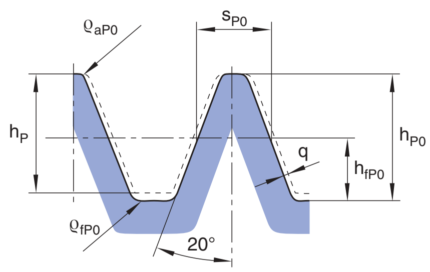


Fig. 3.05

Basic hob profiles for diametral pitch teeth

Symbols:

h_{fP0} = addendum of the basic profile

h_P = profile height of the gear = cutting depth

h_{P0} = profile height of the basic profile

s_{P0} = tooth thickness

h_{CP0} = height of the correction

C_{P0} = width of the correction

R_{CP0} = radius of the correction

ϱ_{aP0} = tip radius

ϱ_{fP0} = root fillet radius

For teeth to BS 2062, Part 1, 1959,
for DP 1 ÷ DP 20
20° pressure angle

$h_{aP0} = \frac{1,25}{DP}\,25,4$

$h_P = \frac{2,25}{DP}\,25,4$

$h_{P0} = \frac{2,45}{DP}\,25,4$

$s_{P0} = \frac{1,5708}{DP}\,25,4$

$h_{CP0} = \frac{0,63}{DP}\,25,4$

$C_{P0} = \frac{0,019}{DP}\,25,4$

$R_{CP0} = \frac{12,9}{DP}\,25,4$

$\varrho_{aP0} = \frac{0,39}{DP}\,25,4$

$\varrho_{fP0} = \frac{0,2}{DP}\,25,4$

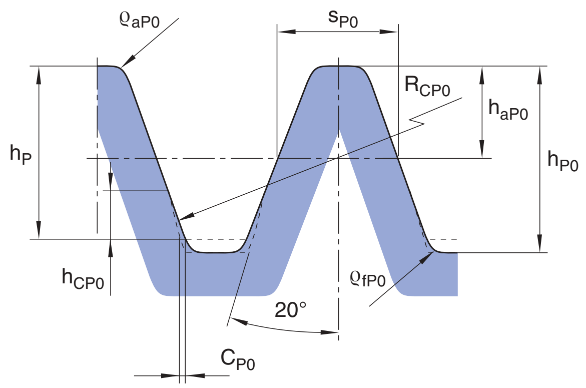


Fig. 4.00

For teeth to AGMA 201.02 - 1968
for DP 1 ÷ DP 19.99
14°30' pressure angle

$h_{aP0} = \frac{1,157}{DP}\,25,4$

$h_P = \frac{2,157}{DP}\,25,4$

$h_{P0} = \frac{2,357}{DP}\,25,4$

$s_{P0} = \frac{1,5708}{DP}\,25,4$

$\varrho_{aP0} = \frac{0,209}{DP}\,25,4$

$\varrho_{fP0} = \frac{0,2}{DP}\,25,4$

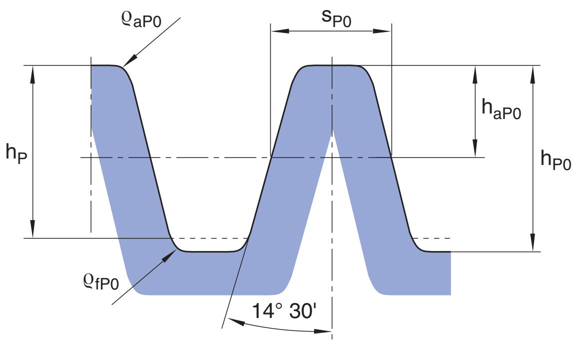


Fig. 4.01

For teeth to AGMA 201.02 - 1968
for DP 1 ÷ DP 19.99
20° pressure angle

$h_{aP0} = \frac{1,25}{DP}\,25,4$

$h_P = \frac{2,25}{DP}\,25,4$

$h_{P0} = \frac{2,45}{DP}\,25,4$

$s_{P0} = \frac{1,5708}{DP}\,25,4$

$\varrho_{aP0} = \frac{0,3}{DP}\,25,4$

$\varrho_{fP0} = \frac{0,2}{DP}\,25,4$

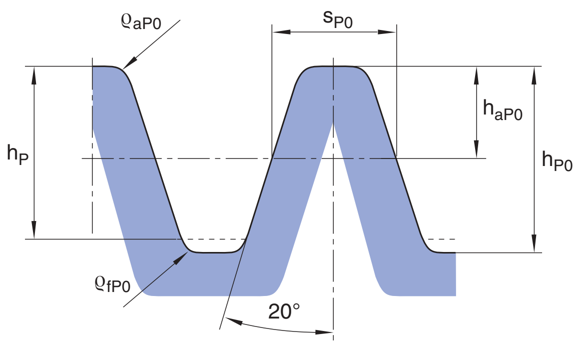


Fig. 4.02

For teeth to AGMA 201.02 - 1968
for DP 1 ÷ DP 19.99
20° pressure angle
stub-tooth

$h_{aP0} = \frac{1}{DP}\,25,4$

$h_P = \frac{1,8}{DP}\,25,4$

$h_{P0} = \frac{2}{DP}\,25,4$

$s_{P0} = \frac{1,5708}{DP}\,25,4$

$\varrho_{aP0} = \varrho_{fP0} = \frac{0,2}{DP}\,25,4$

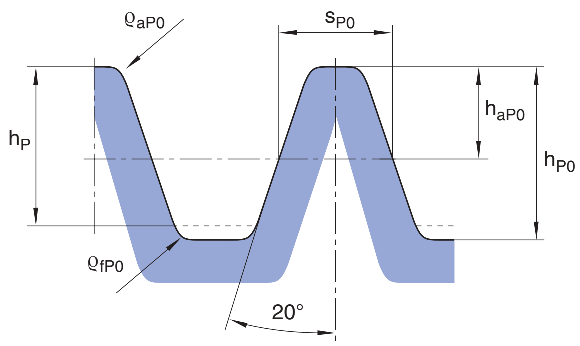
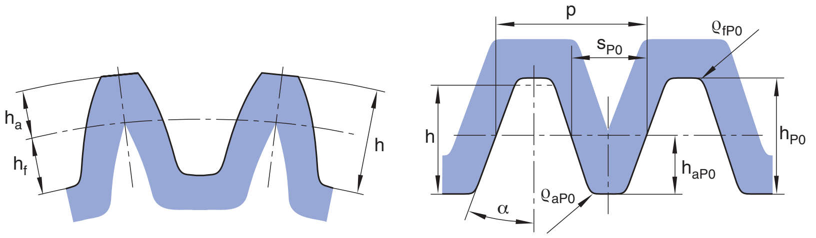


Fig. 4.03

Profiles of current tooth systems and corresponding basic hob profiles

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 (fig.1.00) or basic hob profile (fig. 2.02).



Workpiece
h = profile height = cutting depth
h_a = addendum
h_f = dedendum

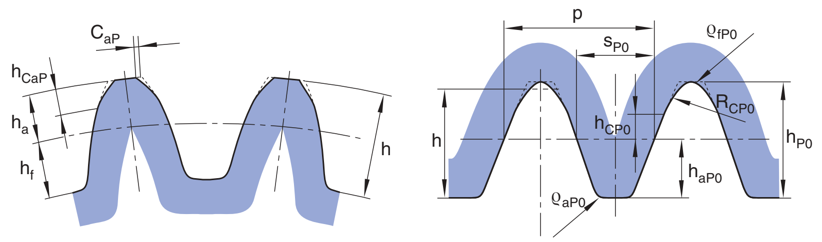
Basic cutter profile
h_{P0} = profile height
h_{aP0} = addendum
α = pressure angle
$\frac{p}{\pi}$ = m = module

Fig. 5.00

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.



Workpiece
h_{CaP} = height of the tip relief
C_{aP} = tip relief

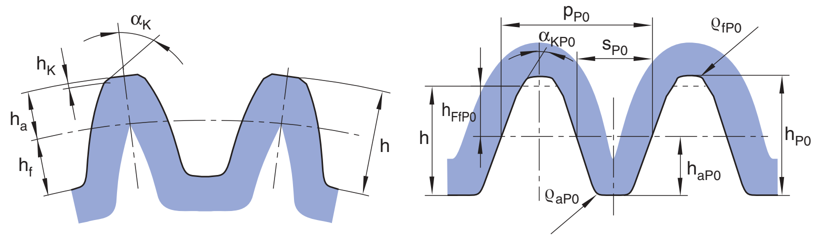
Basic cutter profile
h_{CP0} = height of the correction over the reference line
R_{CP0} = radius of the correction

Fig. 5.01

Involute teeth for spur- and helical gears with tip chamfer.

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.

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.



Workpiece
h_K = radial amount of the tip chamfer
α_K = angle of the chamfer

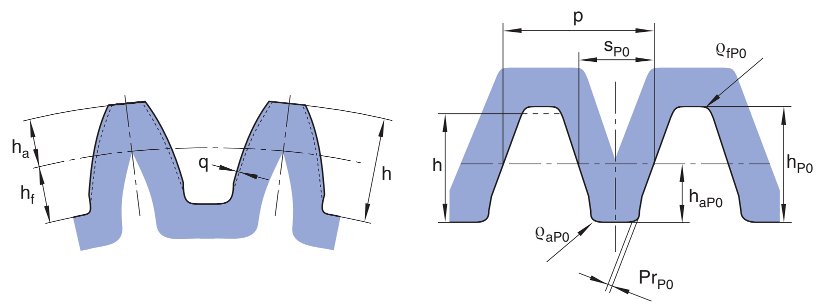
Basic cutter profile
h_{FfP0} = effective dedendum of the basic cutter profile
α_{KP0} = profile angle of the chamfer flank

Fig. 5.02

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.

When ordering please quote:
Module, pressure angle, basic profile of the tooth system, machining allowance and root clerance or basic hob profile.

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.



Workpiece
q = Machining allowance

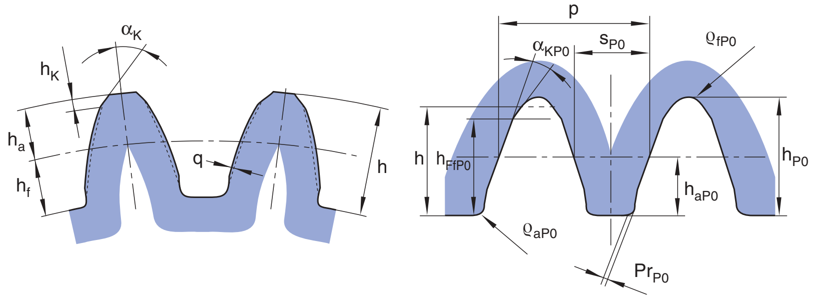
Basic cutter profile
Pr_{P0} = amount of protuberance

Fig. 5.03

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.



Workpiece

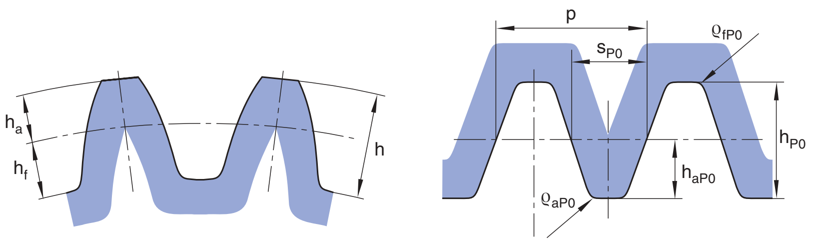
Basic cutter profile

Fig. 5.04

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 5.00 to 5.04.

When ordering please quote:
'Topping cutter' and the details according to the pofiles 5.00 to 5.04.

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 guaranted.



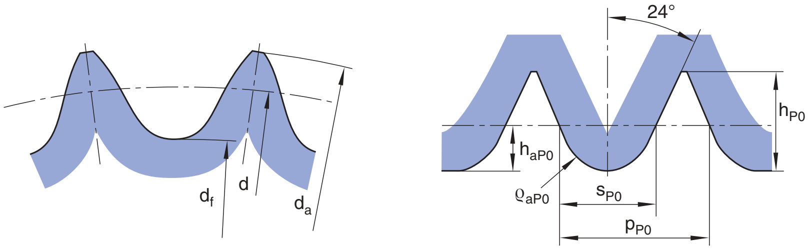
Workpiece

Basic cutter profile
h_{P0} = h

Fig. 5.05

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.



Workpiece

p = chain pitch
d_1 = roller diameter
d = pitch circle diameter
d_f = $d–d_1$ = root circle diameter
d_a = tip circle diameter

Basic cutter profile

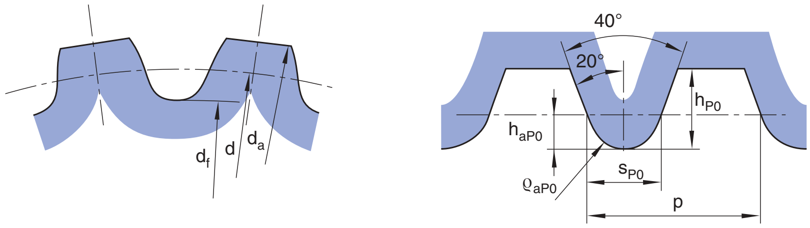
p_{P0} = $1{,}005 \cdot p$ = pitch of the basic profile
h_{aP0} = $0{,}5 \cdot d_1$

Fig. 5.06

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°.



Workpiece

d_f = $d – d_1$

Basic cutter profile

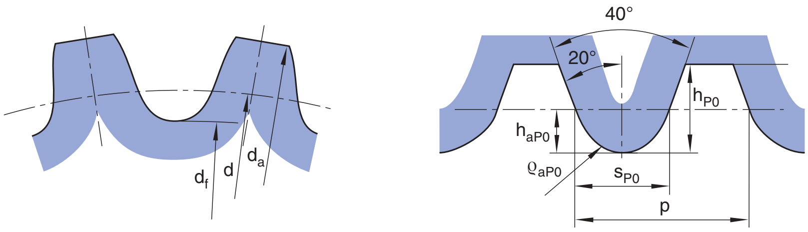
ϱ_{aP0} = $0{,}54 \cdot d_1$
h_{aP0} = $0{,}5 \cdot d_1$
h_{P0} = $d_1 + 2$ to $d_1 = 5$
h_{P0} = $d_1 + 2{,}5$ for $d_1 > 5$

Fig. 5.07

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°.



Workpiece

d_f = $d – d_1$

Basic cutter profile

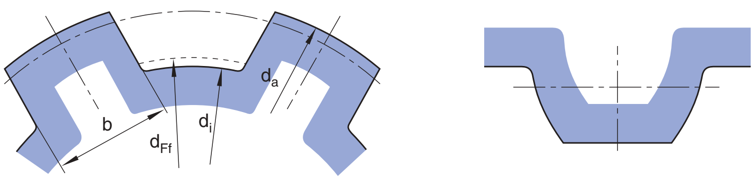
ϱ_{aP0} = $0{,}54 \cdot d_1$
h_{aP0} = $0{,}5 \cdot d_1$
h_{aP0} = $d_1 + 1{,}5$

Fig. 5.08

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.



Workpiece

d_i = inside diameter
d_a = outside diameter
b = spline width
d_{Ff} = form circle diameter
Above d_{Ff} the spline flanks are straight, below d_{Ff} the rounding curve starts

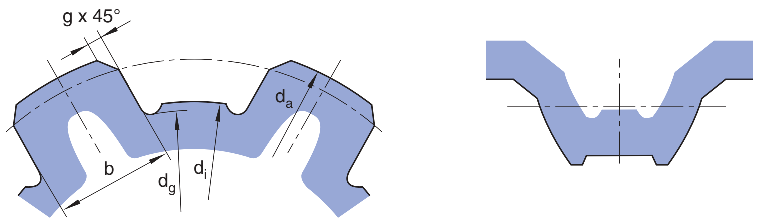
Basic cutter profile

Fig. 5.09

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.



Workpiece
d_i = inside diameter
d_a = outside diameter
d_g = base diameter
b = spline width
g = width of the tip relief

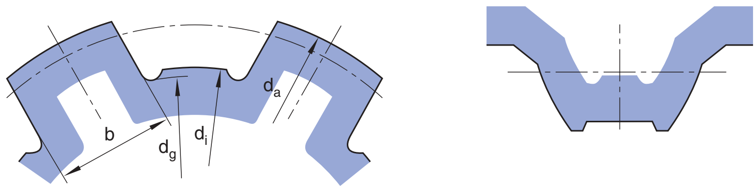
Basic cutter profile

Fig. 5.10

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. 5.10 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.



Workpiece
d_i = inside diameter
d_a = outside diameter
d_g = base diameter
b = spline width

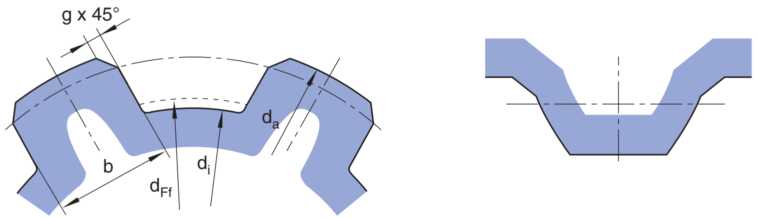
Basic cutter profile

Fig. 5.11

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.



Workpiece
d_i = inside diameter
d_a = outside diameter
b = spline width
g = width of the tip chamfer
d_{Ff} = form diameter

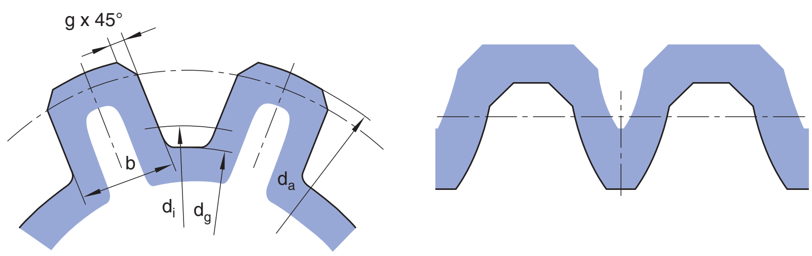
Basic cutter profile

Fig. 5.12

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).



Workpiece
d_i = inside diameter
d_a = outside diameter
d_g = base diameter
b = spline width
g = width of the tip chamfer

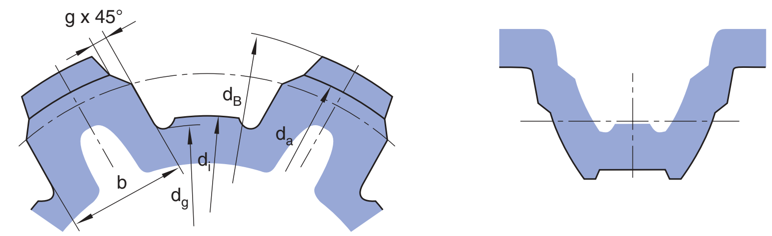
Basic cutter profile

Fig. 5.13

Spline shaft tooth system; basic cutter profile with raised tooth for through-cutting a shoulder.

When ordering please quote:
Collar dia. d_B and also the details as under profiles 5.09 to 5.13.

If in the case of spline shafts the spline-way 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.



Workpiece

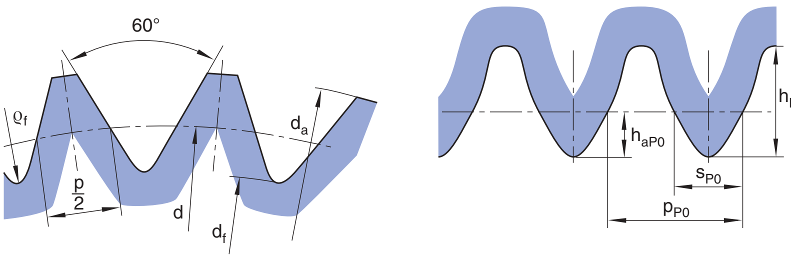
d_i = inside diameter
d_a = outside diameter
d_g = base diameter
b = spline width
d_B = shoulder diameter
g = width of the tip chamfer

Basic cutter profile

Fig. 5.14

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.

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. 5.16.
Serrations are used for making form-fit plug-on connections.



Workpiece

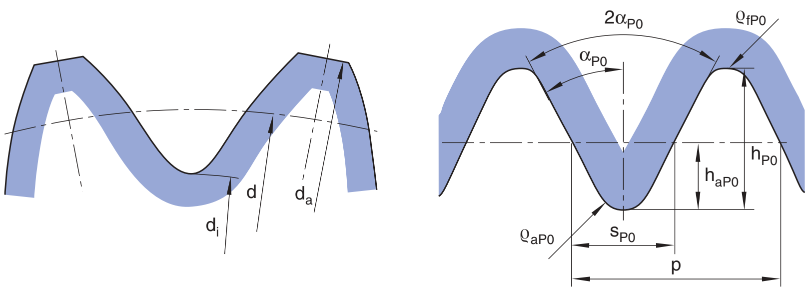
d_f = root circle diameter
d = pitch circle diameter
d_a = tip circle diameter

Basic cutter profile

Fig. 5.15

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 5.15 can also be used.

When ordering please quote:
DIN standard of the serrations and tolerances.



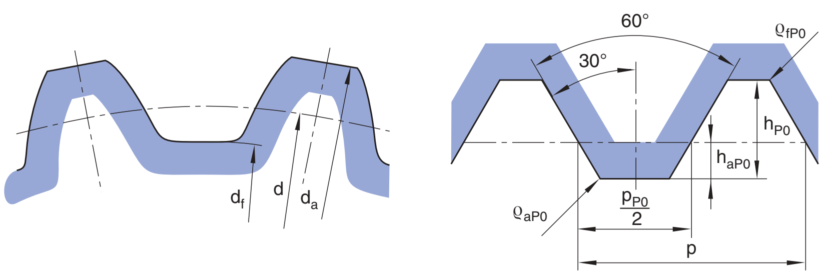
Workpiece

Basic cutter profile

Fig. 5.16

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.



Workpiece

Basic cutter profile

h_{aP0} = 0,60 · m
h_{P0} = 1,25 · m
ϱ_{aP0} = 0,16 · m
ϱ_{fP0} = 0,10 · m

Fig. 5.17

Cutting materials for hobs

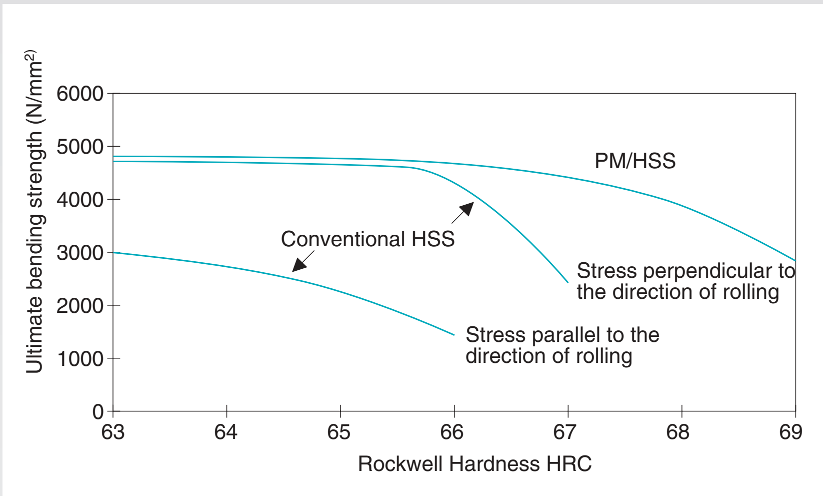
Hobs in particular are subject to clear technological limits with regard to the selection of an ideal cutting material. Owing to the high manufacturing precision required in gear manufacture, solid tools are preferred, for example. Not all materials are suitable for the manufacture of solid hobs, however. Certain high-speed steels (HSS) are therefore a popular choice; carbides have also been gaining in popularity recently.

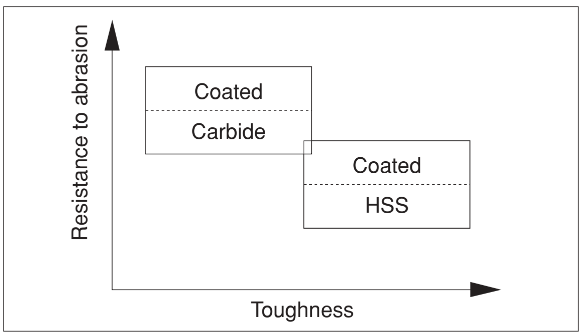
HSS is a generic term for a group of high-alloy steels whose alloy composition enables them to be subjected to extremely high precipitation heat treatment. Cobalt alloyed high speed steels are now employed for the manufacture of all but a very few high speed steel gear cutting tools. Cobalt (chemical symbol: Co) increases the red hardness and the heat resistance, thus permitting higher cutting speeds in tool use.

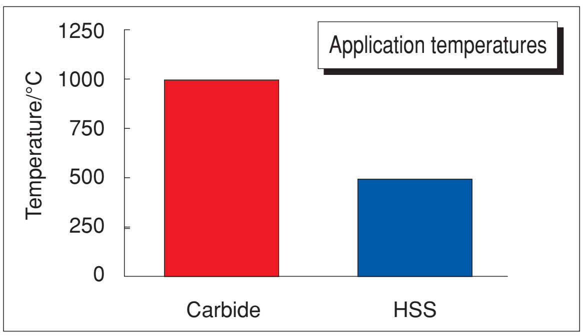
Material no.	Abbreviation	Trade designation	Chemical breakdown in % weight					
			C	Co	W	Mo	V	Cr
Conventionally melted steels								
1.3202	S 12-1-4-5 (EV4Co)	–	1,37	4,8	12	0,8	3,8	4,3
1.3207	S 10-4-3-10 (EW9Co10)	–	1,27	10	9,5	3,5	3,2	
1.3243	S 6-5-2-5 (EMo5Co5)	–	0,92	4,8	6,4	5	1,9	
Powder metallurgical high-speed steels (PM/HSS)								
1.3344	S 6-5-3	ASP 2023	1,28	–	6,4	5	3,1	4,1
	S 6-5-3-9	ASP 2030		8,5				4,2
	S 10-2-5-8	ASP 2052	1,60	8	10,5	2	5	4,8
1.3241	S 6-7-6-10	ASP 2060	2,30	10,5	6,5	7	6,5	4,2
	S 10-2-5-8	S390 PM	1,60	8	10,8	2	5	4,75
	S 12-0-5-5	CPM REX T15	1,55	5	12,25	–		4
	S 10-5-3-9	CPM REX 76	1,50	9	10	5,25	3,1	3,75

Chemical analysis of common HSS grades

Together with carbon (C), the alloying elements tungsten (W), molybdenum (Mo), vanadium (V) and chromium (Cr) form carbides, which are very hard and resistant to abrasion. High contents of these elements therefore improve the resistance to wear, but also tend to reduce the toughness to some degree. Powder metallurgical high-speed steels represent a solution to this problem, as they can be provided with higher toughness reserves than conventional HSS grades for a given hardness.







"Carbide" is a generic term for powder metallurgical high-speed steels, which consist essentially of the hard materials tungsten carbide (WC), titanium carbide (TiC) and tantalum carbide (TaC), and the auxiliary metal cobalt (Co). A comparison of the technological characteristics of high-speed steels and carbides can be found in the table on the right.

A classification system for the chemical composition similar to the HSS material numbers does not exist for carbides. Carbides are classified into "Main groups of chip removal" and "Groups of application" by the ISO 513 standard according to their applications.

Characteristic	Unit	HSS	Carbide
Hardness	HV10	800–900	1200–1900
Ultimate bending strength	N/mm^2	5000	1000–2500
Density	g/cm^3	8–8,3	11–15
Modulus of elasticity	10^3 N/mm^2	217	480–660
Coefficient of thermal expansion	µm/(m °C)	10–13	5–7
Thermal conductivity (up to 20°C)	W/(m °C)	19	30–100

The most suitable carbide is therefore selected according first to the material to be machined, and second to the anticipated stress upon the tool, which is also reflected in the grades table.

A comparison shows that HSS is significantly tougher, whilst carbide has the greater resistance to abrasion. For this reason, HSS is often easier to use in practice. It ceases to be practically viable as a tool material, however, when the cutting speed is increased drastically in order to achieve substantially higher metal removal capacities. The application temperature limit of HSS is approximately 500 °C, that of carbides approximately 1000 °C. This characteristic makes carbide predestined for machining at increased cutting speeds and for dry machining, provided the tools are used on suitable machines.

Main groups of chip removal	Constituents	For machining	Group of application	Operating conditions
P	WC TiC, (Ta, Nb) C Co	Long chipping steels and cast steel materials	P10 P20 P30 P40 P50	Finishing General tasks Light roughing Medium roughing Heavy roughing
M	WC TiC, (Ta, Nb) C Co	Stainless austenitic steels and elevated temperature metals	M 10 M 20 M 30 M 40	Finishing General tasks Roughing Heavy roughing
K	WC Co	Short chipping cast iron and non-ferrous metals	K05 K10 K20 K30 K40	Finishing General tasks Light roughing Medium roughing Heavy roughing

Classification of carbides according to ISO 513

Grade	ISO 513	Coating	Machining from the solid in Steel	Cast iron	Skive hobbing	Re-coating following regrinding
FC222N	HC-P25	Tin (PVD)	●			Not required
FC232N	HC-P30	TiN (PVD)	○	●		Required
FC612N	HC-K15F	TiN (PVD)		●	●	Required
FW606	HW-K10	–			●	–

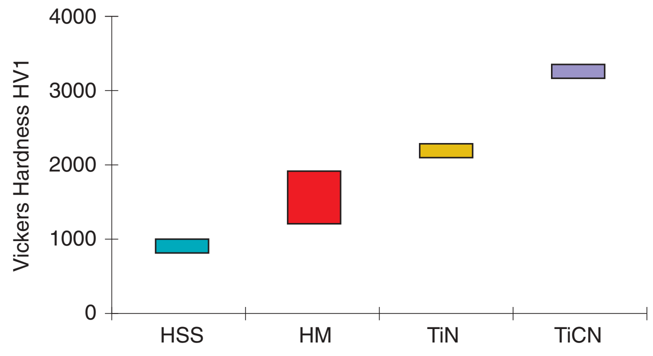
FETTE carbide grades for hobs

● Recommended application ○ Also suitable

Hard material coatings for gear cutting tools

The ion plating process, which permitted the decisive breakthrough in the manufacture of titanium nitride coatings (TiN) for carbides in the early nineteen-eighties, opened up considerable performance reserves in machine tool applications. 15 years on, coated tools now represent around 80% of the market, and considerably more when considered in terms of machined workpiece volume.

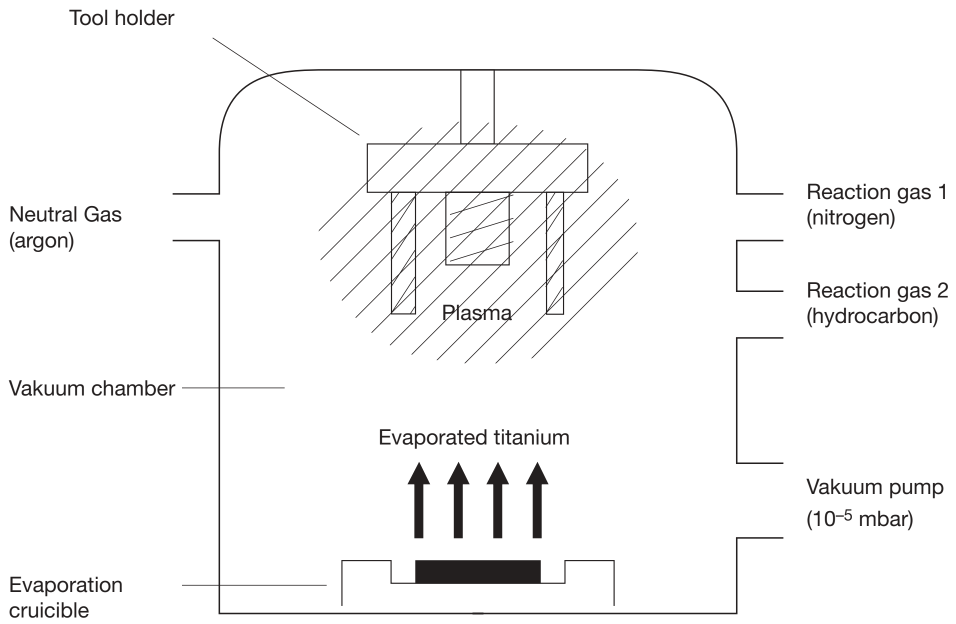
Ion plating is a physical vapour disposition process. Following meticulous cleaning and degreasing, the tools are placed in an annular arrangement on rotating mounts in a vessel, the recipient, which is evacuated to a high vacuum. Titanium is vaporized from a crucible located in the centre of the vessel. Nitrogen in gaseous form and the neutral gas argon are injected into the recipient through a number of valves. A carbon carrier gas is required in addition for the manufacture of titanium carbonitride (TiCN). Finally, an electrical glow discharge is ignited at a defined pressure of a few millionths of a bar. The gas is ionized, and a plasma is created which supplies the energy required for the chemical reaction



$$2\,Ti + N_2 \rightarrow 2\,TiN$$

Gold titanium nitride is deposited upon the tool surface. During the coating process, the high-energy ions in the plasma continually bombard the layer as it forms. Like little steam hammers they compact the TiN, which consequently becomes particularly firm and hard.

The temperature of the tools is maintained at 450 °C during the process. This low process temperature also enables high speed steels to be coated without risk of distortion or thermal damage to the microstructure. Carbides can also be coated. The integrity of the cutting edge is of great importance for hobs. Here too, the low process temperature of the ion plating process ensures that the embrittlement of the cutting edge, which presents such problems with carbides, is avoided. The coatings, which are only a few µm in thickness, enable very sharp cutting edges to be attained on the hobs.



Schematic diagram of a PVD process

The enormous increases in tool life over that of uncoated tools can be attributed to the physical friction and the chemical characteristics, in addition to the high hardness. The low chemical affinity of the TiN to the hot steel chip leads to lower friction and in turn to less frictional heat, thereby reducing the wear.

The coating acts as a barrier which protects the underlying substrate against wear.

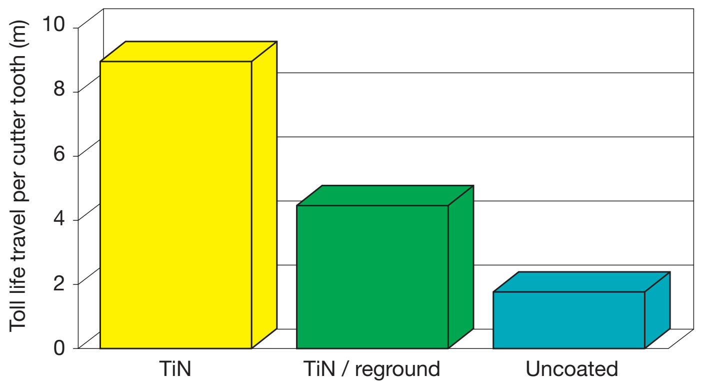
The higher cutting and feed speeds possible with coated tools are particularly advantageous for the user. A chief factor is not only the longer tool life, but also the reduction in production times. Coated hobs thus recoup their coating costs within a very short space of time.

The tool life of an HSS hob used for the manufacture of a sun wheel was increased five-fold from 100 to 502 finished wheels by the application of a TiN coating. Following regrinding, the tool was not recoated, and was therefore coated only on the flank, and not on the cutting face. It nevertheless attained an average tool life of 251 finished wheels in this condition. Over a total of 22 regrinding cycles, a total of 2300 wheels were manufactured with the uncoated hob and 6024 with the coated hob, i.e. 2.6 times the number. The relatively low additional cost of the TiN coating was therefore recouped with ease.

Re-coating following regrinding (of the cutting face) of a worn HSS tool is also economically viable. Use of the ion plating process for TiN coating presents no problems. The tool can be re-coated several times; alternatively, the coating can also be removed chemically in a bath.

The combination of TiN on carbide is somewhat more complicated, although repeated coating is still possible. Removal of the coating from carbide in the bath is however difficult, owing to the chemical affinity of the carbides and the TiN coating.

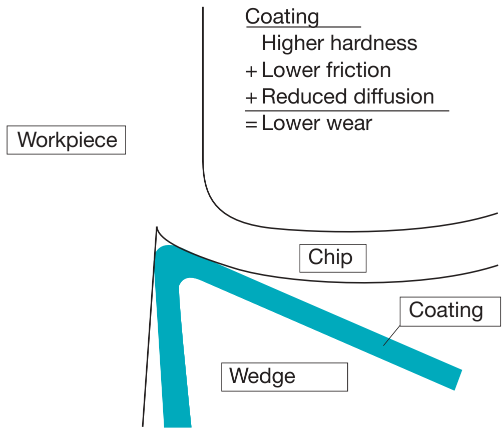
Re-coating of the grey-violet TiCN presents greater problems, since



Workpiece:	Sun wheel
Material:	17CrNiMo6
Tool:	HSS hob
Dimensions:	d 90 x 80 mm
Module:	3 mm
Number of starts:	1
Number of gashes:	12
Quality grade:	AA

Cutting data

Cutting depth:	6,808 mm
Cutting speed:	65 m / min
Axial feed:	3 mm / WU
Tip chip thickness:	0,224 mm
Shift length:	54,3 mm



TiCN has a multi-layer structure. Structures of this kind cannot simply be "stacked" one upon the other without difficulty. Removal of the coating from HSS by immersion in a bath is possible, but still more complex than with TiN. On carbide, the problems described above are also encountered.

The gold TiCN Plus is an interesting coating type. Essentially, this is a TiCN multi-layer coating with high resistance to abrasion. A pure TiN surface coat is however deposited at the end of the coating process. As a result, the friction behaviour of the chip on the tool is influenced chiefly by the TiN- surface layer, the abrasion resistance by the underlying TiCN. TiCN Plus is more conducive to re-coating than TiCN.

Development of wear

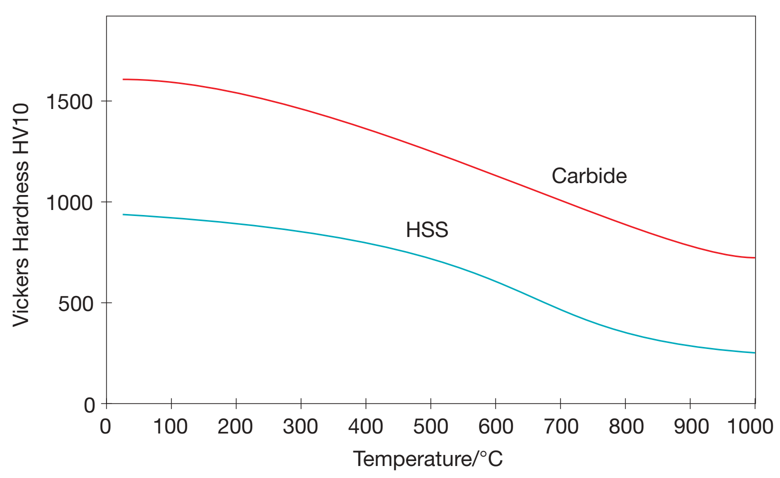
The cutting edge in use is subject to a range of external influences which combine to produce tool wear. The process temperature is particularly significant. The chief sources of process heat and their approximate contribution to the overall temperature are:

- Plastic deformation in the tool immediately ahead of the cutting edge: 60%
- Friction phenomena between the chip and the tool cutting surface: 20%
- Friction phenomena between the workpiece and the tool flank: 20%

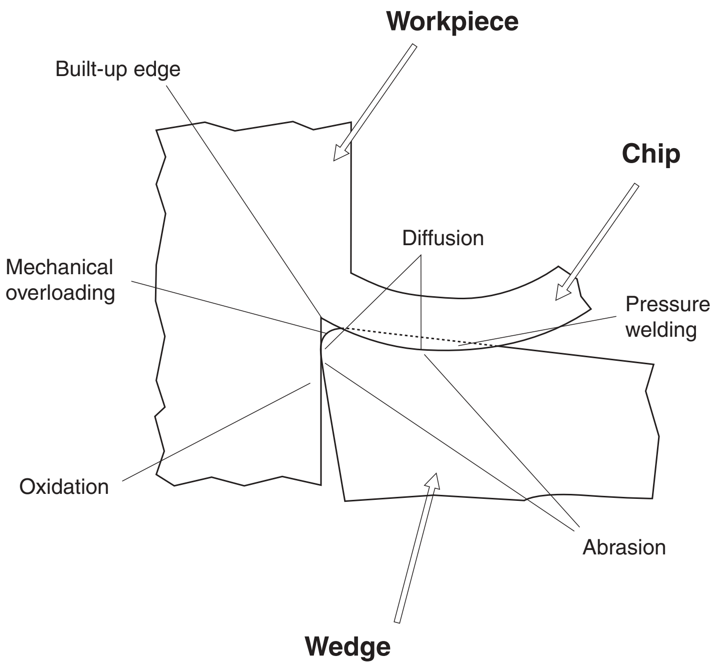
Part of this heat (approximately 5-10%) flows into the tool and leads to softening of the cutting material. The higher the working temperature, the softer the cutting material becomes, and the lower the resistance which it can present to the abrasive wear. Approximately 75-80% of the heat is dissipated through the chip.

The wear mechanisms of scaling (oxidation) and diffusion increase particularly strongly with rising temperature. Their dramatic increase with rising temperature defines a critical application temperature limit above which the tool life is reduced drastically, and ultimately beyond the limit of economic viability.

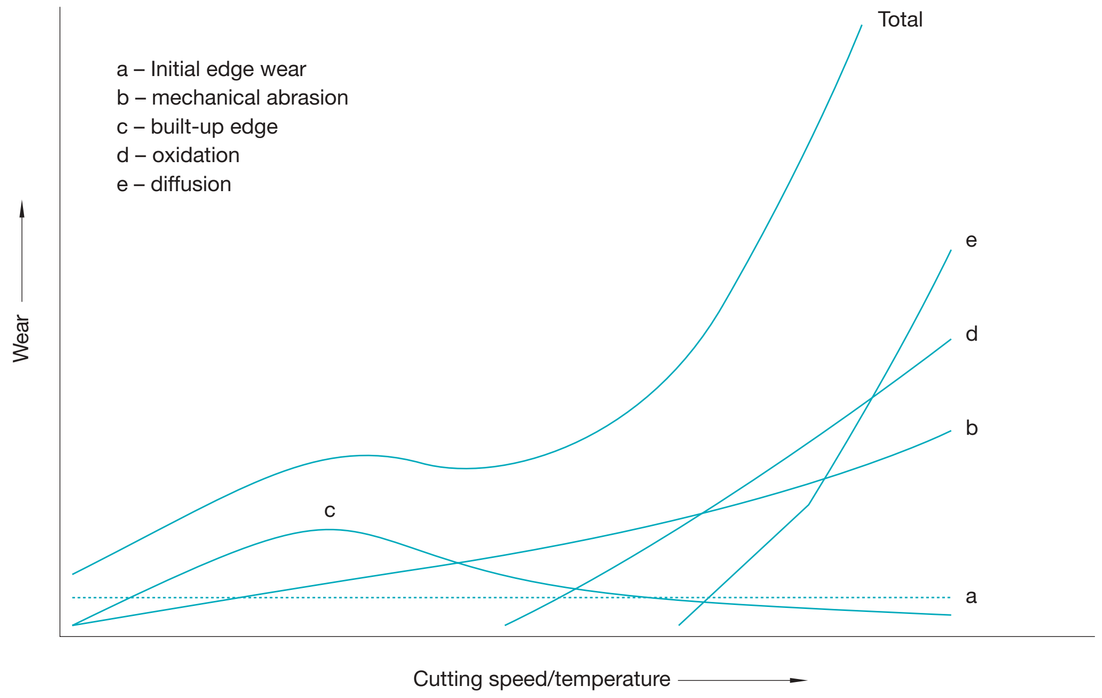
Each cutting material therefore has a range of optimum cutting speeds for each specific task. The material to be machined, the requisite manufacturing tolerances, the specified machining conditions such as the system rigidity and the efficacy of cooling, and the thermal stability of the cutting material have a major influence upon the cutting speed.



Red hardness of HSS and carbide



Causes of wear on the cutting edge



Causes of wear against temperature (according to Vieregge)

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.

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.

During coarse shifting, in particular, cutter regions temporarily uninvolved in the machining process have sufficient opportunity to cool down.

The cutting conditions applicable to hobbing are principally the cutting speeds and the feeds.

Cutting conditions in hobbing

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: HSS, 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.

Cutting materials for hobs

(See also Page 149)
KHSS (cobalt alloyed super high speed steels), and increasingly also carbides, are the chief materials from which hobs are manufactured.

The maximum economic cutting speed for (coated) KHSS hobs is 120 m/min for the machining of gears with small modules from metals which are easily machined. The KHSS most frequently employed is **EMo5Co5** (S 6-5-2-5, material no. 1.3243)

Higher-alloyed KHSS must be employed for gear materials with a tensile strength above 1200 N/mm². Powder metallurgical high-speed steels are a good choice for this application. They can be subjected to higher precipitation heat treatment but still have a higher toughness than comparable steels melted conventionally.

Powder metallurgical high-speed steels are of course also suitable for gear materials with a tensile strength below 1200 N/mm² if higher cutting parameters or higher tool life qualities must be achieved than those attained by EMo5Co5.

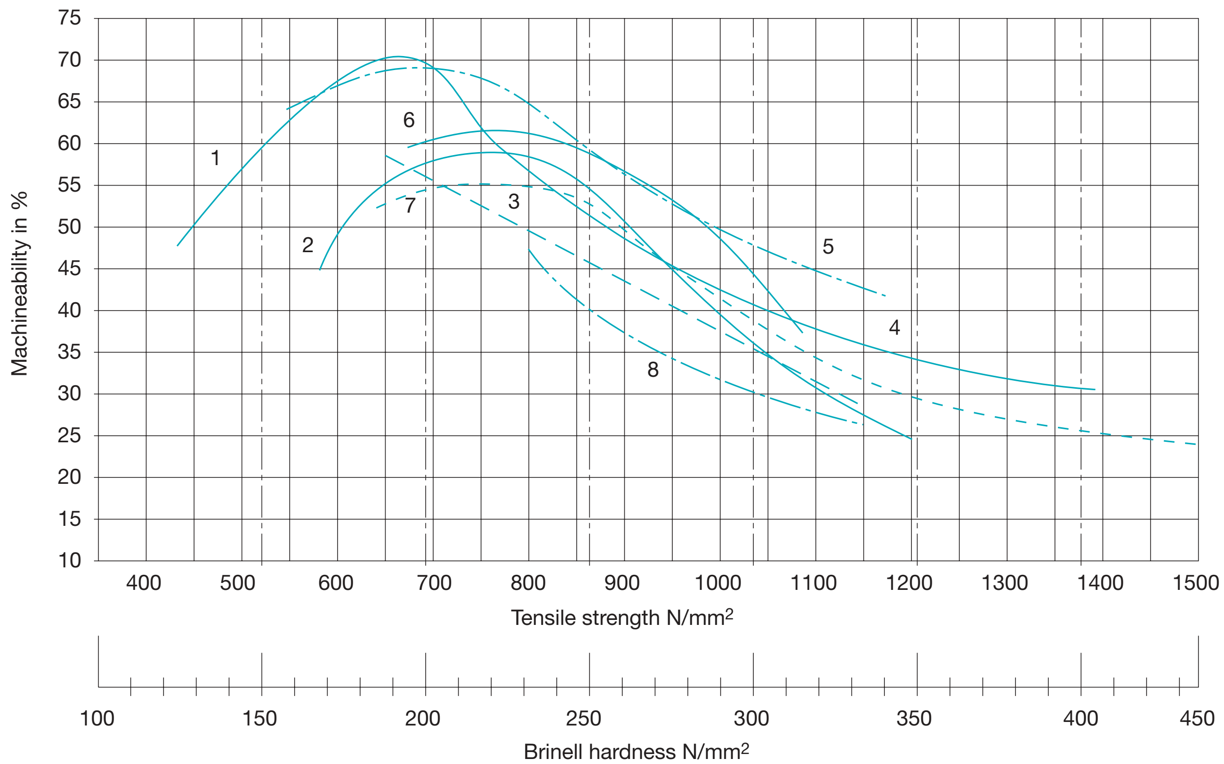
Hobs manufactured from KHSS are generally coated with TiN.
Hobs manufactured from carbide for machining of gears up to approximately module 3 from the solid can be employed at cutting speeds which are higher by a factor of three than those which can be achieved by KHSS hobs. These hobs are always coated, generally with TiCN Plus.

Machineability

The machineability of a gear material can be referenced to a range of characteristics. 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 168). 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 eco-



1 Plain carbon steels
2 Nickel steels and chrome/nickel steels (low alloy)
3 Chrome/nickel steels
4 Chrome/nickel/molybdenum steels
5 Nickel/molybdenum steels
6 Chrome/molybdenum steels
7 Chromium steels and chrome/vanadium steels
8 Silicon/manganese steels

Diagram 1: Machineability of the gear materials

nomic 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/mm² 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 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 hobs.

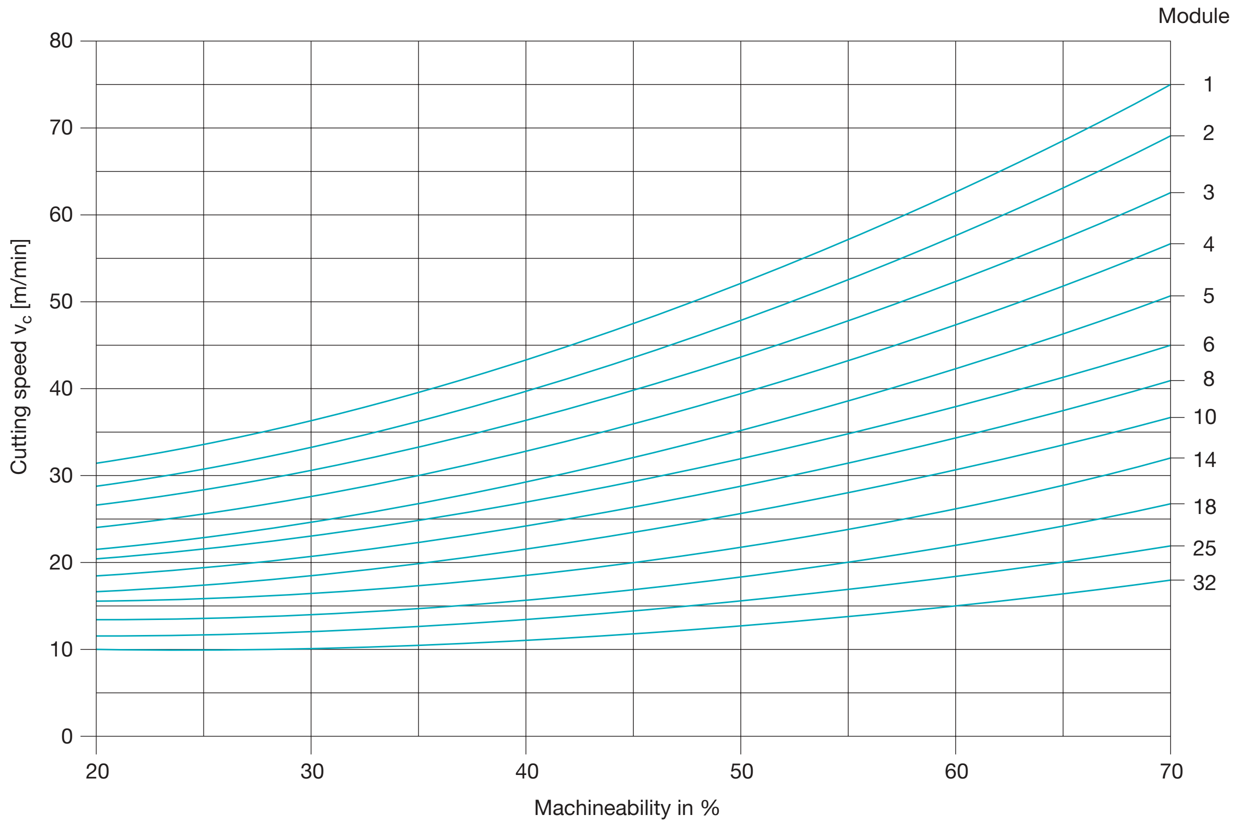


Diagram 2: Cutting speed when hobbing

A further a table of recommended values have been compiled, based upon practical experience, for the cutting speed for machining with hobs on which the cutting material is KHSS S-6-5-2-5 (1.3243, EMo5Co5). The common gear materials are assigned to the categories "good", "medium" and "difficult" on the basis of their machineability. The cutting speeds are shown for each module for the roughing cut and for the finishing cut. Table 1 is sub-divided into hobs with TiN coating and uncoated hobs.

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, generally with TiCN Plus.

Module	Machineability					
	Good Tensile strength up to 700 N/mm²		**Medium** Tensile strength up to 900 N/mm²		**Difficult** Tensile strength up to 1.200 N/mm²	
	16 Mn Cr 5, C 15, C 35, 20 Mn Cr 5, 15 Cr Ni 6		Ck 45, C 60, 18 Cr Ni 8, 42 Cr Mo 4, 37 Mn Si 5, 18 Cr Ni 8, 17 Cr Ni Mo 6		34 Cr Ni Mo 6 V, 30 Cr Mo V9 V, 40 Ni Cr Mo 7	
	m/min		m/min		m/min	
	Roughing	Finishing	Roughing	Finishing	Roughing	Finishing
	With TiN coating					
< 2	100	130	75	98	55	77
2	92	120	69	90	50	70
3	84	110	63	82	40	56
4	76	99	57	74	30	42
5	68	88	51	66	26	36
6	60	84	45	63	25	35
7	56	78	42	59	24	34
8	52	73	39	55	23	32
9	48	67	36	50	22	31
10	44	62	33	46	21	29
12	38	53	29	41	20	28
14	35	49	26	36	19	27
16	33	46	25	35	18	26
18	30	42	23	32	17	24
	Without TiN coating					
< 2	75	90	56	67	34	41
2	69	83	52	62	31	37
3	63	75	47	56	29	35
4	57	68	43	52	26	31
5	51	61	38	46	23	28
6	45	56	34	41	22	26
7	42	55	32	38	21	25
8	40	52	30	36	20	24
9	38	49	29	35	19	25
10	37	48	28	34	18	23
12	34	44	26	32	17	22
14	32	42	24	29	16	21
16	30	39	23	28	15	20
18	27	35	20	24	14	18
20	25	31	19	25	13	17
22	23	29	18	23	13	17
25	22	28	17	22	12	16
28	20	25	15	20	11	14
32	18	23	14	18	10	13

Table 1: Recommended cutting speed values for the machining of solid-type KHSS hobs

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.

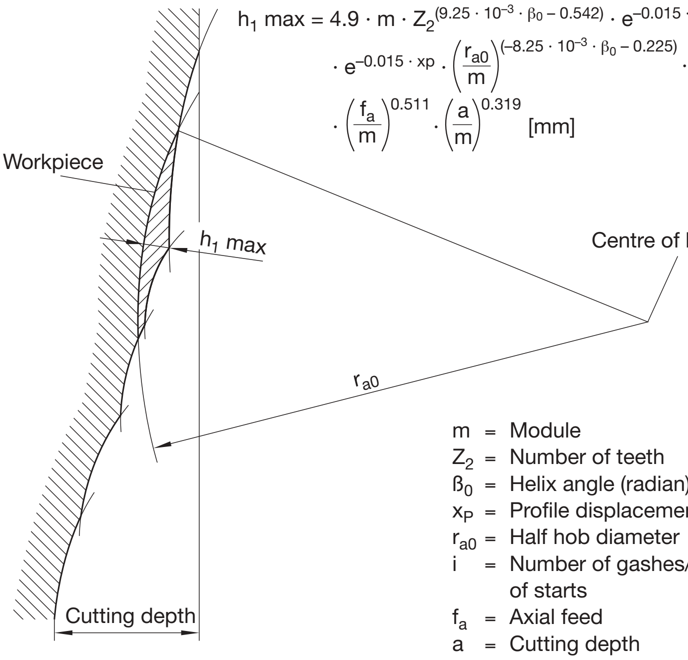
Hoffmeister [2] has devised a formula for the maximum tip chip thickness.

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.

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.

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.



$$h_1\,max = 4.9 \cdot m \cdot Z_2^{(9.25 \cdot 10^{-3} \cdot \beta_0 - 0.542)} \cdot e^{-0.015 \cdot \beta_0} \cdot e^{-0.015 \cdot x_P} \cdot \left(\frac{r_{a0}}{m}\right)^{(-8.25 \cdot 10^{-3} \cdot \beta_0 - 0.225)} \cdot i^{-0.877} \cdot \left(\frac{f_a}{m}\right)^{0.511} \cdot \left(\frac{a}{m}\right)^{0.319} \text{ [mm]}$$

m = Module
Z_2 = Number of teeth
β_0 = Helix angle (radian)
x_P = Profile displacement factor
r_{a0} = Half hob diameter
i = Number of gashes/number of starts
f_a = Axial feed
a = Cutting depth
e = 2,718282

Example:

m = 4	β_0 = 16	r_{a0} = 55	f_a = 4
Z_2 = 46	x_P = 0,2	i = 12/2	a = 9

h_1 = 0,3659

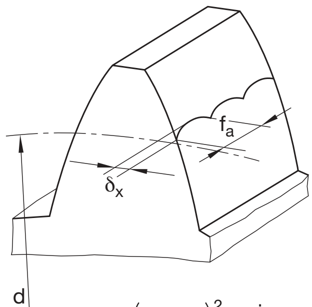
Dissertation by Bernd Hoffmeister 1970

Maximum tip chip thickness

$$t_h = \frac{Z_2 \cdot d_{a0} \cdot \pi \cdot (E+b+A)}{Z_0 \cdot f_a \cdot V_c \cdot 1000} \text{ [min]}$$

t_h [min] = Machining time
Z_2 = Number of teeth of the gear to be cut
d_{a0} [mm] = Tip circle diameter of the hob
E [mm] = Lead length of the hob
b [mm] = Tooth width of the gear to be cut
A [mm] = Idle travel distance of the hob
Z_0 = Number of starts of the hob
f_a [mm/WU] = Axial feed
V_c [m/min] = Cutting speed

Machining time (production time) for hobbing



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

δ_x [mm] = Depth of the feed marking
f_a [mm/wr] = Axial feed
β_0 = Helix angle
α_n = Profile angle
d_{a0} [mm] = Tip circle diameter of the hob

Depth on the feed markings

Number of starts of the hob

With the exception of worm gear hobs, multiple start hobs have the function of increasing hobbing performance.

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).

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).

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.

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.

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.

Specification of the number of starts on the basis of the tip chip thickness and the depth of the feed markings

Table 2 shows the optimization of the number of starts and the axial feed by way of an example gear.

Line/column	1	2	3	4	5	6
1	Module			2,5		
2	Pressure angle [°]			20		
3	Number of teeth			29		
4	Helix angle [°]			15		
5	Profile displacement factor			0,2		
6	Cutting depth			5,63		
7	Cutter diameter			110		
8	Number of gashes			24		
9	Number of starts z_0	1	2	3	4	5
10	Tip chip thickness	0,2	0,2	0,2	0,2	0,2
11	Axial feed f_a	15,71	4,78	2,38	1,46	0,99
12	$z_0 \times f_a$	15,71	9,56	7,14	5,84	4,95
13	Relative machining time	1	1,64	2,2	2,69	3,17
14	Depth of the feed markings	0,206	0,019	0,005	0,002	0,001

Table 2: Feeds and depth of the feed markings for multiple start hobs

The number of starts 1 to 5 and a constant tip chip thickness of 0.2 mm were entered in columns 2 to 6.

Line 11 contains the maximum feeds permissible at a tip chip thickness of 0.2 mm.

Line 12 shows the product of the number of starts and the axial feed.

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.

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.

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.

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.

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.

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.

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).

Enveloping cut deviations

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.

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.

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.

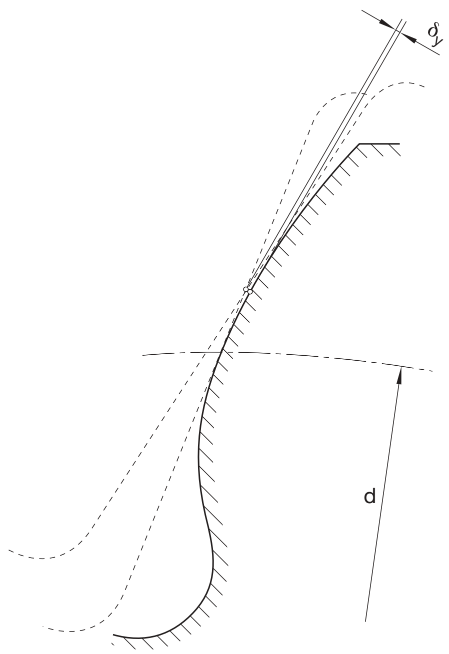
The enveloping cut deviations can be reduced considerably by increasing the number of gashes.

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.



δy [mm] = Magnitude of the enveloping cut deviation

z_0 = Number of cutter starts

m_n = Normal module

α_n = Profile angle

z_2 = Number of gear teeth

i = Number of gashes of the cutter

$$\delta y\,[\mathrm{mm}] = \frac{\pi^2 \cdot z_0^2 \cdot m_n \cdot \sin\alpha_n}{4 \cdot z_2 \cdot i^2}$$

Enveloping cut deviations

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.

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.

Referances

[1] Schmidthammer: Cutting conditions for hobbing: FETTE Cat.-No. 1137: Gear cutting tools

[2] B. Hoffmeister: Dissertation, Aachen 1979

Tool cutting edge length

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 tool cutting edge 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 (β - γ_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.

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.

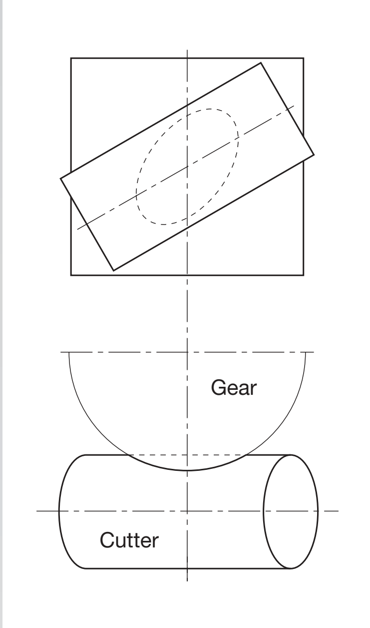


Fig. 1: Gear/cutter penetration

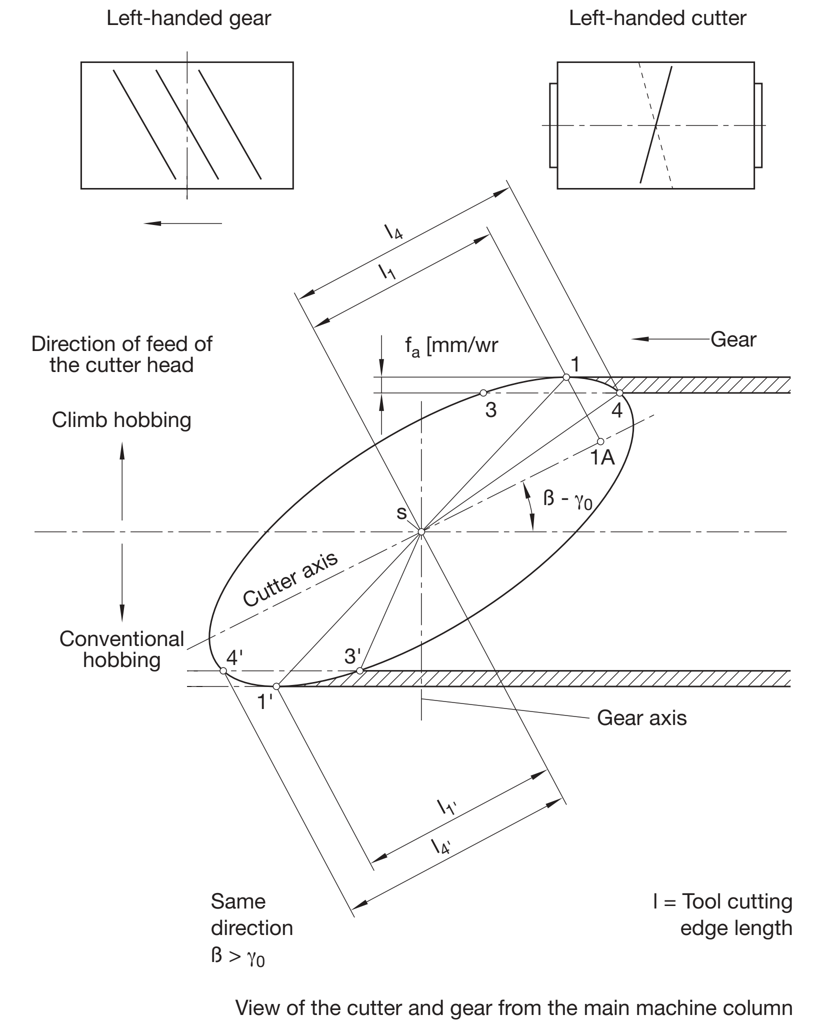


Fig. 2: Ascertainment of the tool cutting edge length from the penetration curve

Tool cutting edge length (continued)

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.

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.

The cutter length corresponding to Point 1 is then the tool cutting edge 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 $l_{1'}$.

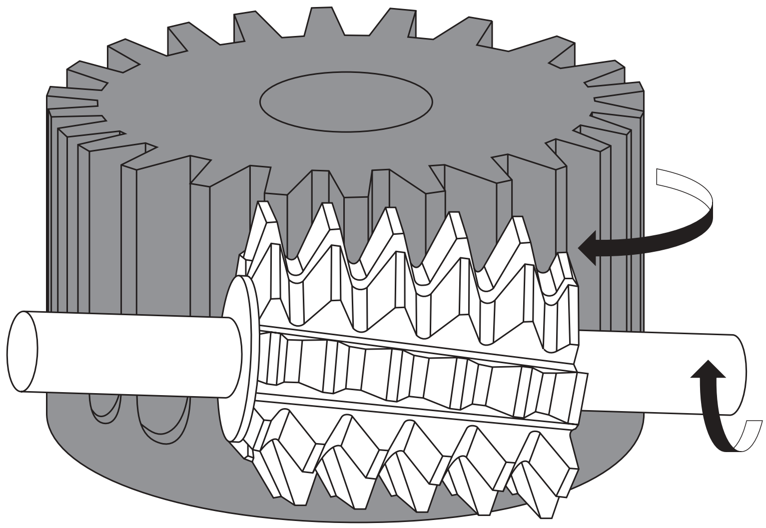
Since the two halves of the penetration curve to the left and right of the normals on the cutter axis through the point "S" are congruent and are inverted around the normal by "S" and around the cutter axis, $l_{1'} = l_1$ und $l_{4'} = l_4$.

Tool cutting edge length (continued)

Further combinations of hobbing method and direction of lead of gear and hob

Table 1 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 tool cutting edge 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.



View of the cutter and the gear from the main machine column

		Cutter: right-hand start			Cutter: left-hand start		
Gear		Right-hand lead	Left-hand lead	Straight teeth	Right-hand lead	Left-hand lead	Straight teeth
Climb hobbing	Leading end	Left	Left	Left	Right	Right	Right
	Pivoting angle	$\beta - \gamma_0$	$\beta + \gamma_0$	γ_0	$\beta + \gamma_0$	$\beta - \gamma_0$	γ_0
	Tool cutting edge length	l_4 Left, up	l_1 Right, up	l_1 Right, up	l_1 Left, up	l_4 Right, up	l_1 Left, up
Conventional hobbing	Leading end	Left	Left	Left	Right	Right	Right
	Pivoting angle	$\beta - \gamma_0$	$\beta + \gamma_0$	γ_0	$\beta + \gamma_0$	$\beta - \gamma_0$	γ_0
	Tool cutting edge length	l_1 Right, down	l_4 Left, down	l_4 Left, down	l_4 Right, down	l_1 Left, down	l_4 Right, down

Table 1

Profile generating length

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}".

$\tan \alpha_t = \tan \alpha / \cos \beta$

$l_{Pa} = 2 \cdot (h_{a0} - x \cdot m_n - \rho_{a0} \cdot (1 - \sin \alpha)) / \tan \alpha_t$

$d_b = z \cdot m_n \cdot \cos \alpha_{at} / \cos \beta$

$\cos \alpha_{at} = d_b / d_a$

$d = z \cdot m_n / \cos \beta$

$l_{Pf} = 2 \cdot (d_a / 2 \cdot \cos (\alpha_{at} - \alpha_t) - d/2) / \tan \alpha_t$

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

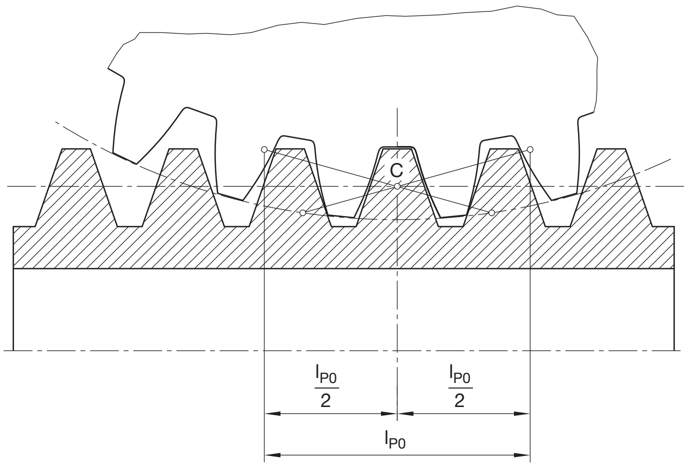


Fig. 3

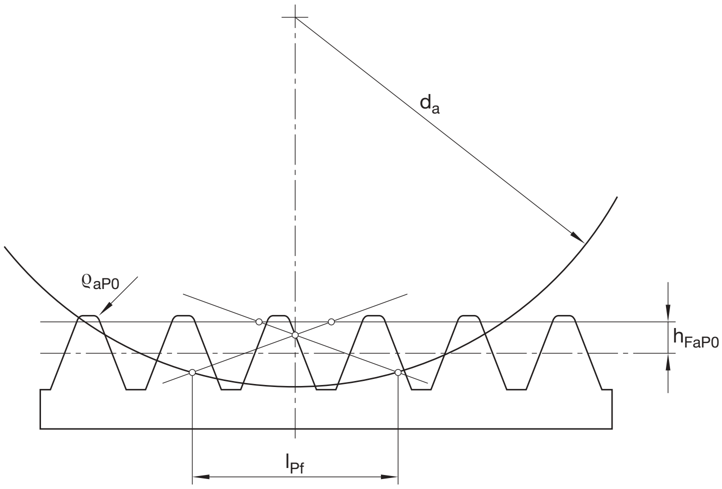


Fig. 4

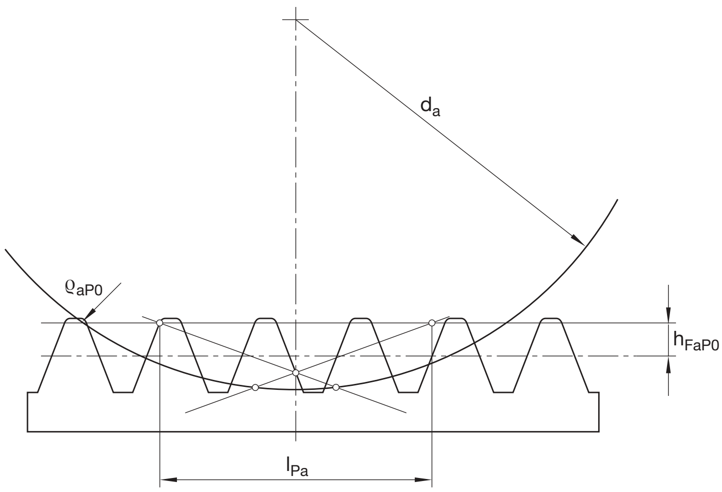


Fig. 5

Shift distance

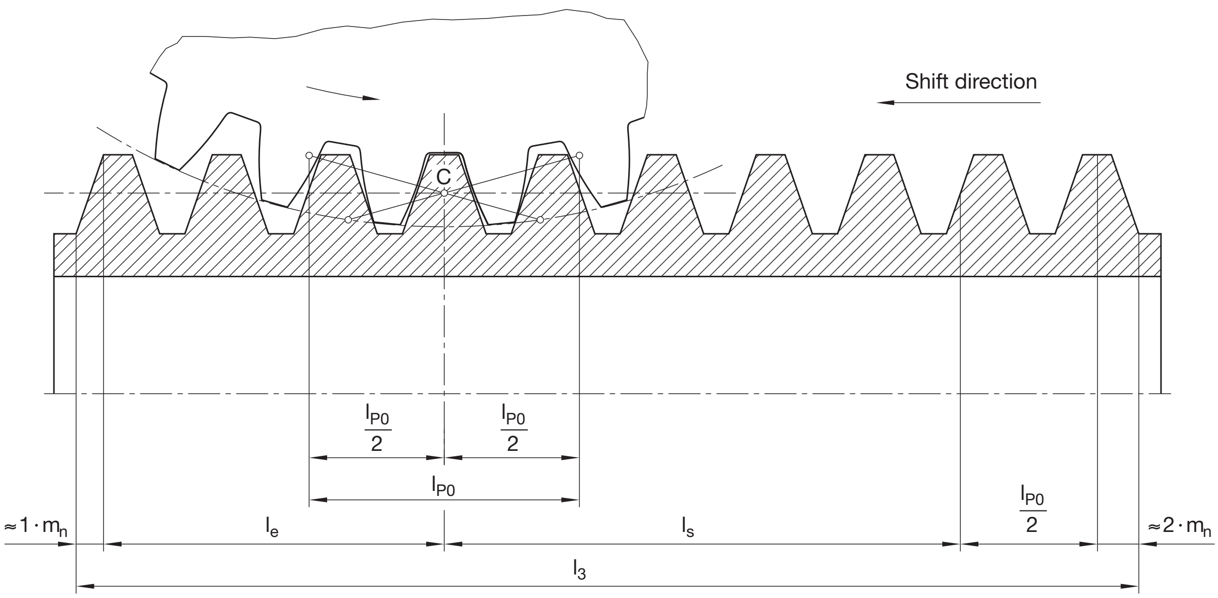
The chip cross-sections within the working area of a hob are known to be very different. In consequence, the individual cutter teeth are subject to different loads, and therefore exhibit non-uniform wear patterns. It is therefore logical for the hob to be moved tangentially in stages once one or more workpieces have been machined in one position. This tangential movement is termed "shifting".

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.

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.

$$l_s = l_3 - l_e - l_{P0} / 2 - 3 \times m_n$$

The quantity 3 x m_n makes allowance for the incomplete teeth at the ends of the hob.



l_3 = Useful length of cutter
l_e = Tool cutting edge length
l_s = Shift distance
l_{P0} = Length of the profile generating zone

Fig. 6: Ascertainment of the shift distance

Axial distance

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.

The approach distance can also be calculated with sufficient accuracy by means of the following formula:

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

No idle distance, except for a safety allowance, is required for straight teeth.

The idle distance for helical teeth is determined by the profile-generating zone in the face plane (fig. 8).

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:

If $l_{Pa} > l_{Pf}$, then $U = l_{Pa} \times \tan \beta$
If $l_{Pf} > l_{Pa}$, then $U = l_{Pf} \times \tan \beta$
U = idle distance
Axial distance = E + b + U

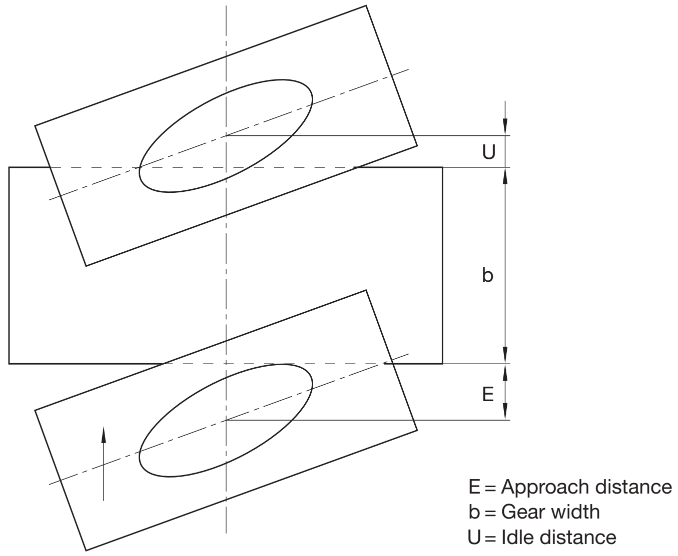


Fig. 7

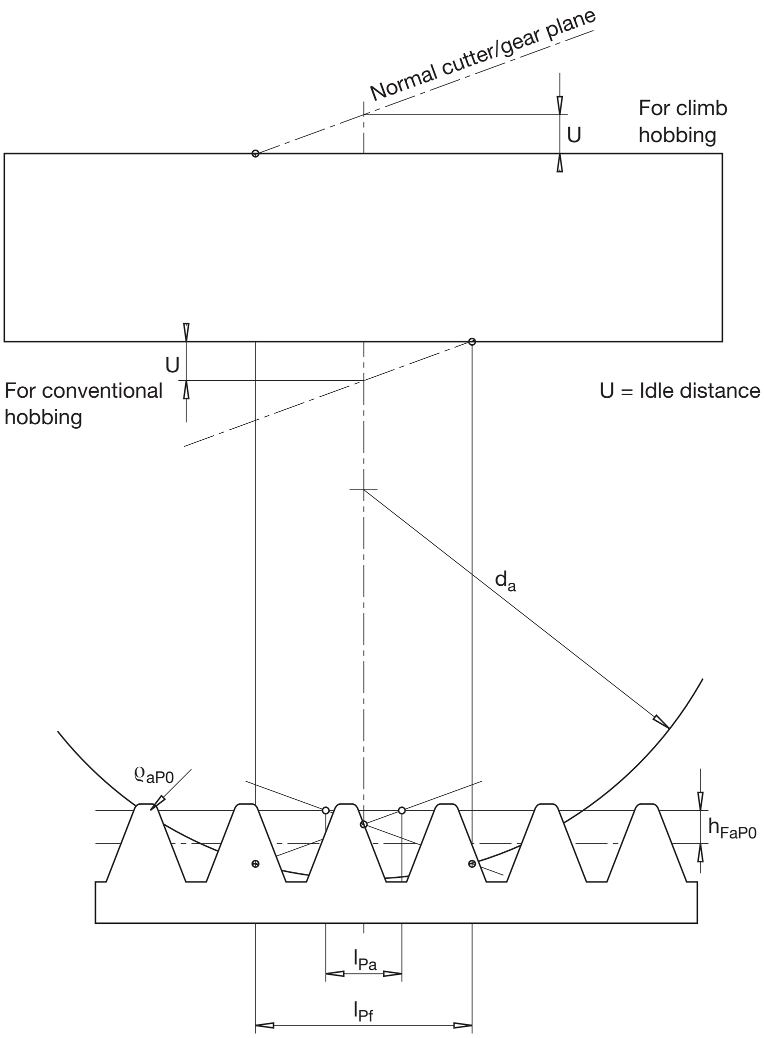


Fig. 8

Maintenance of hobs

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.
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

Carbide hobs assigned to the "ISO P" group:

Regrind cutting face
Re-coating is not required.

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 TiN-coated HSS hobs or 0.15 mm on carbide hobs if the lowest possible unit tool costs are an objective.

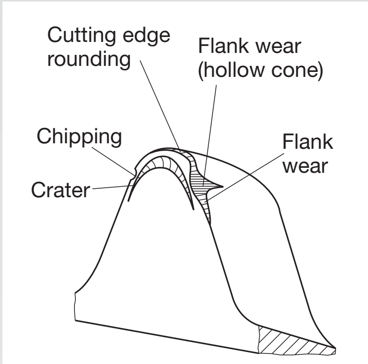


Fig. 1: Forms of wear on the hob tooth

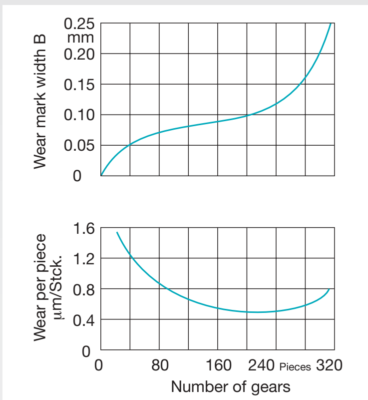


Fig. 2: Flank wear as a function of the number of workpieces cut

Since the wear curves cannot be determined in all cases in the form mentioned, some guide values are included 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.
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.

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 titanium nitride coated (TiN) 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.
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.

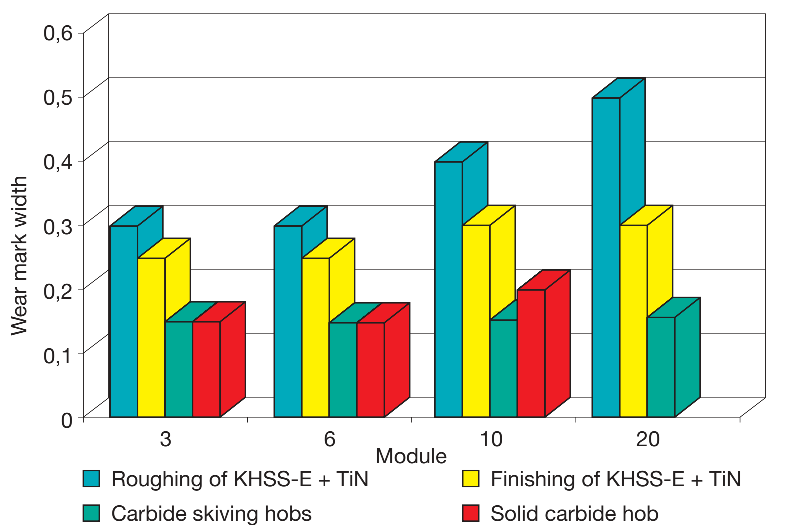


Fig. 3: Wear mark width for different hob materials

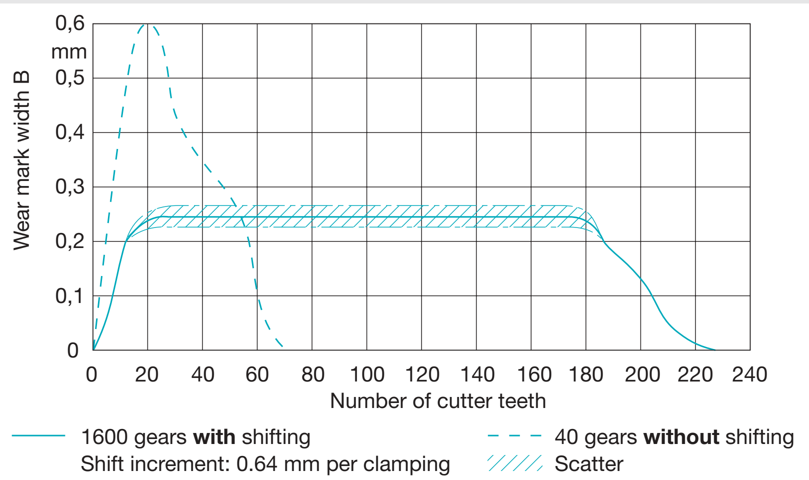


Fig. 4: Wear mark width when hobbing with and without shifting

Requirements placed upon the cutting surface grinder

Machine data:
Table speed 250-600 mm/min with HSS tools, 80-150 mm/min with carbide tools, according to module and quality
Feed 0.10-0.20 mm

General remarks:
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.

Incorrect grinding conditions may cause the grinding disk facing to disintegrate. The facing is cleaned, i.e. the reside adhering to the facing removed, by hand by means of a no. 2 stone (e.g. from Winter).

Grinding disks data:

	HSS-hobs	Carbide hobs
Geometry:	1K222-150-2-3,3-50,8	K222-150-2-3,3-50,8
Grain size:	CBN151	D126
Concentration:	C125	C100 = 4,4 carat/cm^3
Bond:	66	K-plus 888 RYA (synthe resin)
Cutting speed:	v = approx. 35 m/s	v = 23–25 m/s
Coolant:	Oil, e.g. Shell Garia TC	Emulsion e.g. Castrol S DC 83 (oil, e.g. Shell Garia TC)
Cooling oil pressure: 8–10 bar		
Cooling oil delivery: Approx. 100 l/min		

Dressers for diamond grinding disks
Dressing facility with centrifugal brake
Silicon carbide grinding disk e.g. 3" x 1" x 1/2" / 37C60-N5V
CBN diamond powder and dressing stone

Important:
Carbide hobs are very sensitive to impact. Protect the tooth tips during transport and storage.

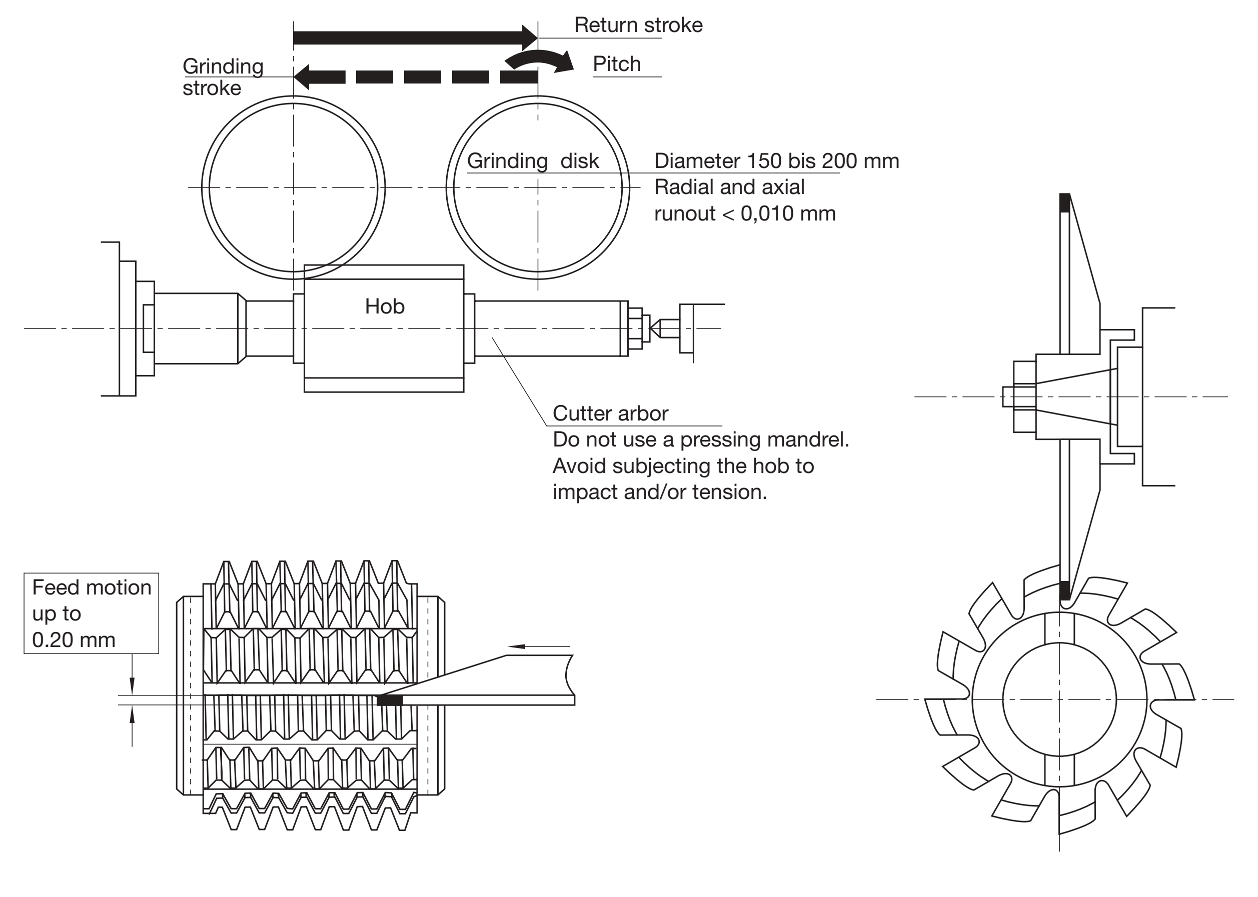


Fig. 5: Requirements placed upon the cutting face grinder

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.

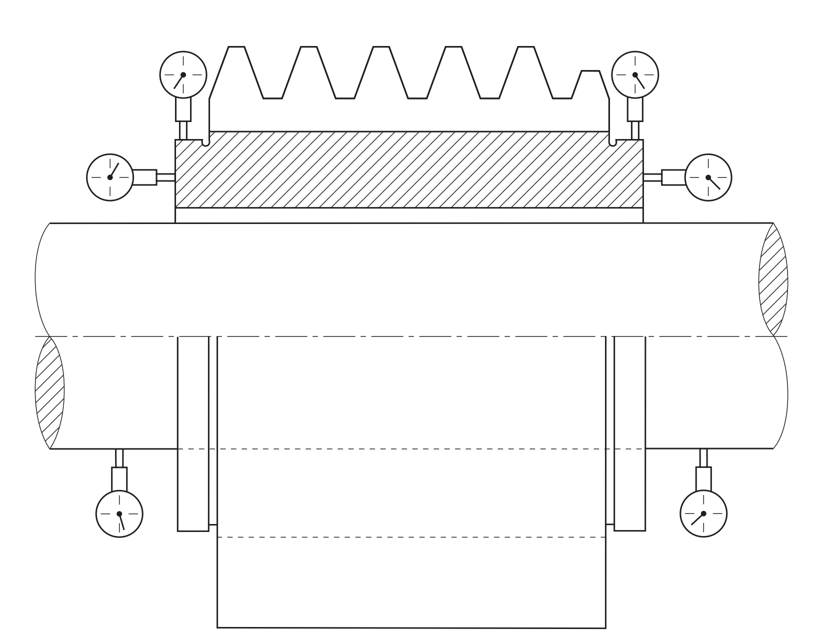


Fig. 6: Measurement of the radial runout on arbor and indicator hubs and of the axial runout on the clamping surfaces

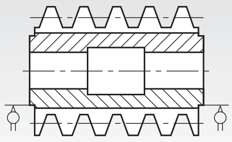
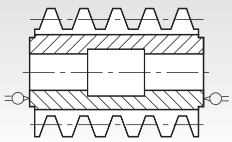
Value to be measured	Symbol of the deviation	Quality class	Tolerances in µm (1 µm = 0,001 mm) at module over 0,63 to 1	over 1 to 1,6	over 1,6 to 2,5	over 2,5 to 4	over 4 to 6,3	over 6,3 to 10	over 10 to 16	over 16 to 25	over 25 bis 40
Radial runout at the two indicator hubs based on the axis of the bore 	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	not determinded								
		The highest points measured at the two indicator hubs must not be offset by more than 90°.									
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

Fig. 7: Permissible radial and axial runouts to DIN 3868

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.

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.

Form- and positional deviation of the cutting faces
(item no. 7 DIN 3968)
The cutting faces are generated by the straight lines which normally pass through the cutter axis of the hob (fig. 8a). In the cases where these straight lines pass in front of or behind the cutter axis, they form negative or positive rake angles with the radials (fig. 8b, c). According to the rake angle, the grinding wheel and the dressing diamond must be set in front of or behind the cutter axis by the cutting face distance "u". The same does of course also apply to the height setting of the gauge stylus when checking the form- and positional deviation (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.

This regrinding diagram applies to the cutter diameter, the rake angle and the relief grinding operation and is supplied with the cutter (fig. 9).

Deviations from the specified value of the cutting face distance result in flank form and base pitch deviations on the hobbed workpieces.

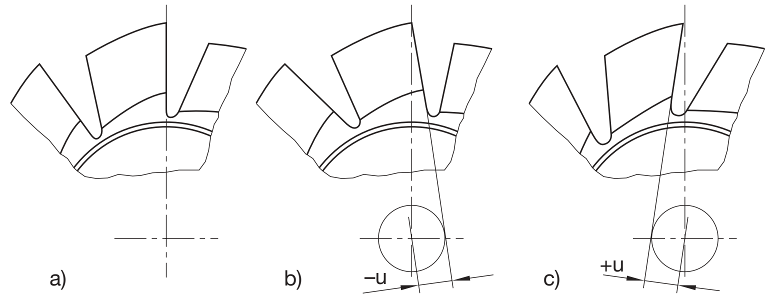


Fig. 8: Rake angle on the hob

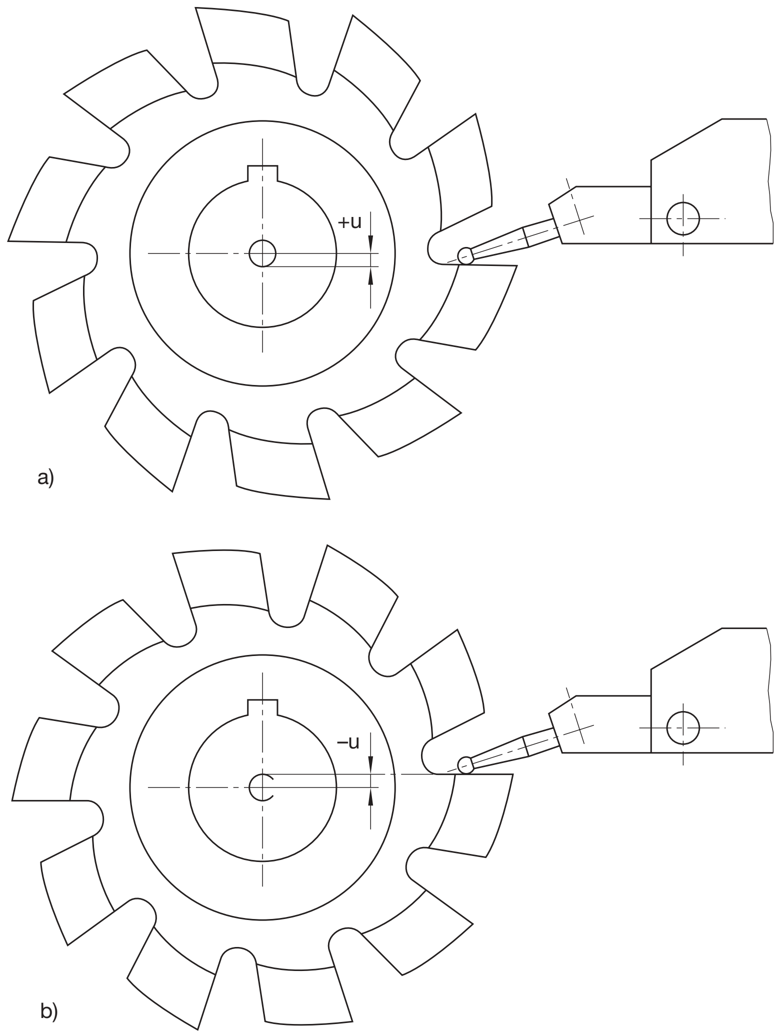


Fig. 9: Setting the gauge stylus for a) positive rake angle b) negative rake angle

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.

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.

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.

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. 15).

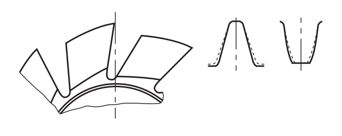


Fig. 11:
Positional deviation of the cutting face
a) Faulty, positive cutting face position
b) Elongated cutter tooth
c) The workpiece tooth becomes thicker at the head, tip contact
The broken-line contours indicate the theoretically correct profile of the cutter- or workpiece tooth.

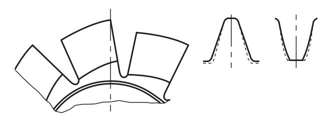


Fig. 12:
Positional deviation of the cutting face
a) Faulty, negative cutting face position
b) Shortened cutter tooth
c) The workpiece tooth becomes thinner towards the top

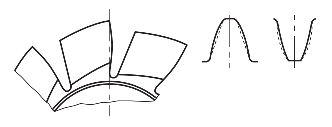
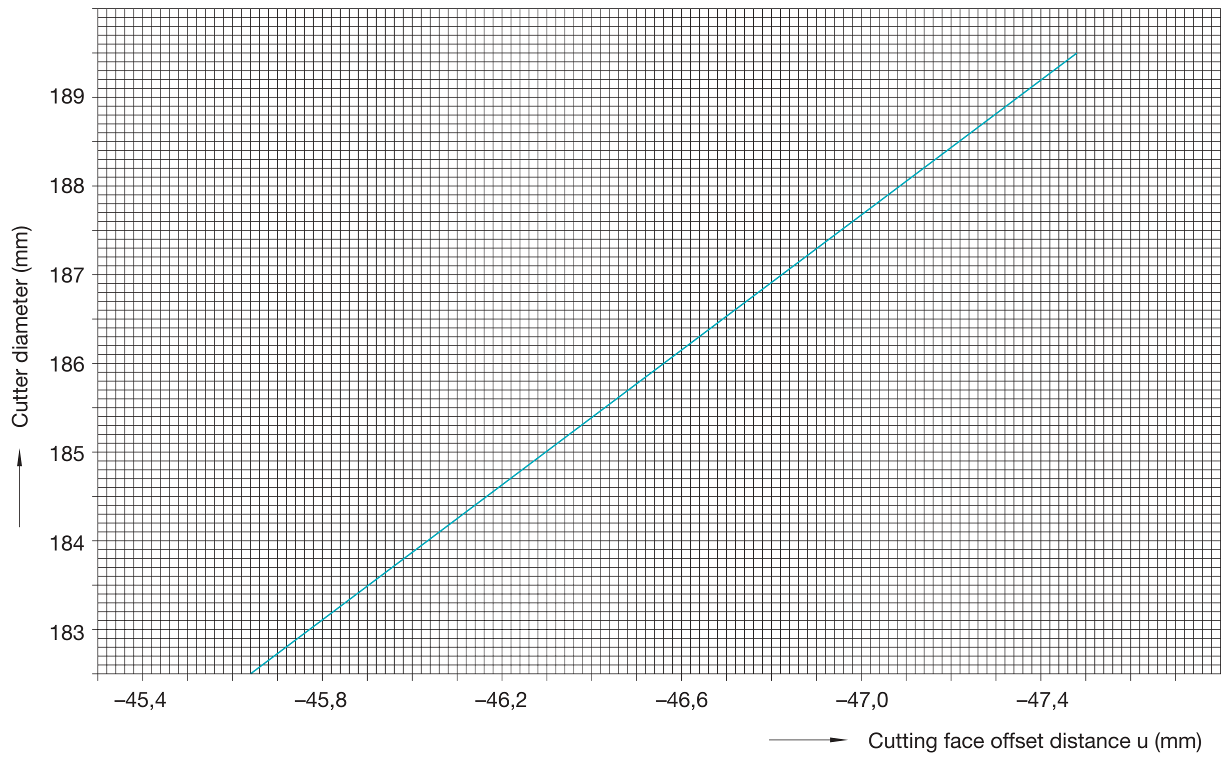


Fig. 13:
Form deviation of the cutting face
a) Faulty, crowned cutting face
b) Crowned cutter tooth
c) Concave flank form on the workpiece tooth, tip and root contact



Cutter no.: P250
Module: 10

Drawing no.: 1-46276-01 relief ground
Diameter = 189.52

u = –47,5

Fig. 10: Cutting face regrinding diagram for carbide skiving hobs

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.

Undulating form deviations on the cutting face are generally caused by badly dressed grinding wheels or worn or badly guided dressing diamonds (fig. 16).

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.

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.

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.

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.

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.

The difference between two adjacent individual pitch deviations is referred to as a tooth to tooth pitch error.

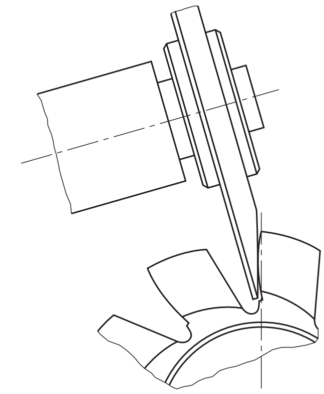


Fig. 15:
Cutting face form error on a hob with gash lead. Ground with straight-dressed grinding wheel.

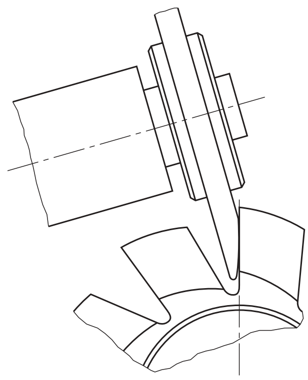
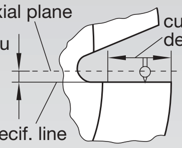


Fig. 14:
Cutting face on a hob with gash lead. Ground with convex-ground grinding wheel.

Value to be measured	Symbol of the deviation	Quality class	Tolerances in µm (1 µm = 0,001 mm) at module								
			over 0,63 to 1	over 1 to 1,6	over 1,6 to 2,5	over 2,5 to 4	over 4 to 6,3	over 6,3 to 10	over 10 to 16	over 16 to 25	over 25 bis 40
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



Distance µ of the specified line from the axial plane (at rake angle 0° = zero)

Inspection diagram

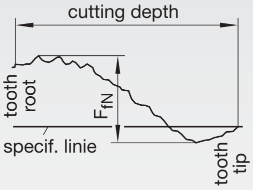


Fig. 16: Form- and positional deviation of the cutting faces to DIN 3968

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.

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 two-dial 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).

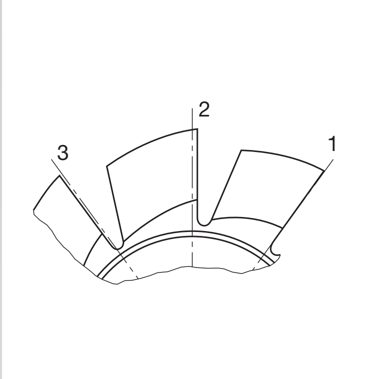
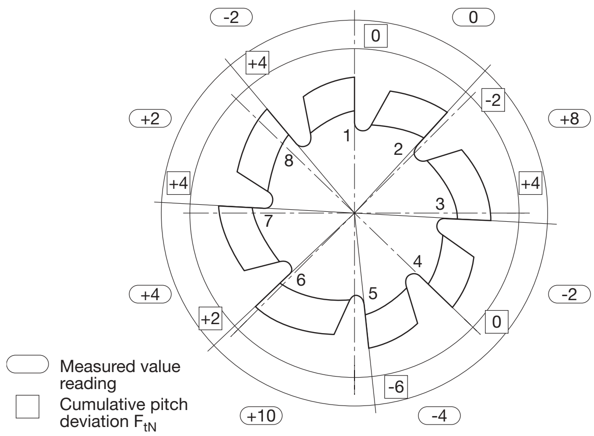


Fig. 17:
Pitch deviation of the gashes
Cutting face 1: theoretically correctly placed.
Cutting face 2: pitch too short, tooth profile projects relative to the profile on the cutting face.
Cutting face 3: pitch too great, tooth profile set back relative to the profile on cutting face 1.

Individual pitch deviation f_{tN}, tooth to tooth pitch error f_{uN}, cumulative pitch deviation F_{tN}

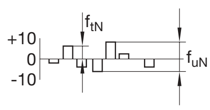


Individual pitch deviation f_{tN} is the difference between the reading of the 2-dial measurement and the correction value.
The correction value is determined from the algebraic sum of all read values, divided by the number of pitches

1. Calculation of the correction value
   0 + 8 – 2 – 4 + 10 + 4 +2 – 2 = + 16
   16/8 = **+ 2 correction value**

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



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.

Cutting-face	Measured value reading	Individual pitch deviation f_{tN}		Tooth to tooth pitch error deviation f_{uN}		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	

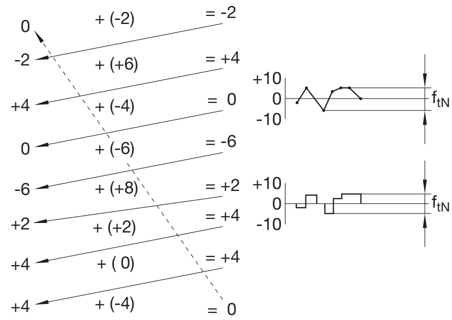


Fig. 18: Computation diagram for individual pitch deviation, tooth to tooth pitch error and cumulative deviation from the measured value readings of the two-dial measurement

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.

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 (fig. 19).

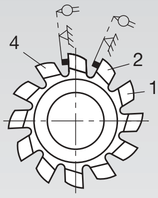
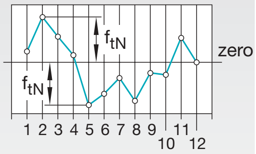
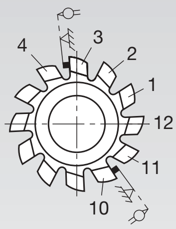
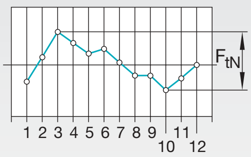
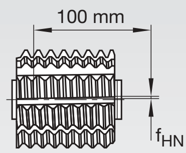
Value to be measured	Symbol of the deviation	Quality class	Tolerances in µm (1 µm = 0,001 mm) at module								
			over 0,63 to 1	over 1 to 1,6	over 1,6 to 2,5	over 2,5 to 4	over 4 to 6,3	over 6,3 to 10	over 10 to 15	over 16 to 25	over 25 bis 40
Individual pitch of the gashes measured at half tooth height  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
Cumulative pitch of the gashes measured at half tooth height  Inspection diagram 	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
Gash lead over 100 mm cutter length based on the reference cylinder 	f_{HN}	AA	± 50								
		A	± 70								
		B	±100								
		C	±140								
		D	±200								

Fig. 19: Permissible deviations for individual pitch and cumulative pitch of the gashes as well as the gash lead.

Regrinding of roughing hobs

FETTE roughing hobs can be reground on any hob regrinding machine.

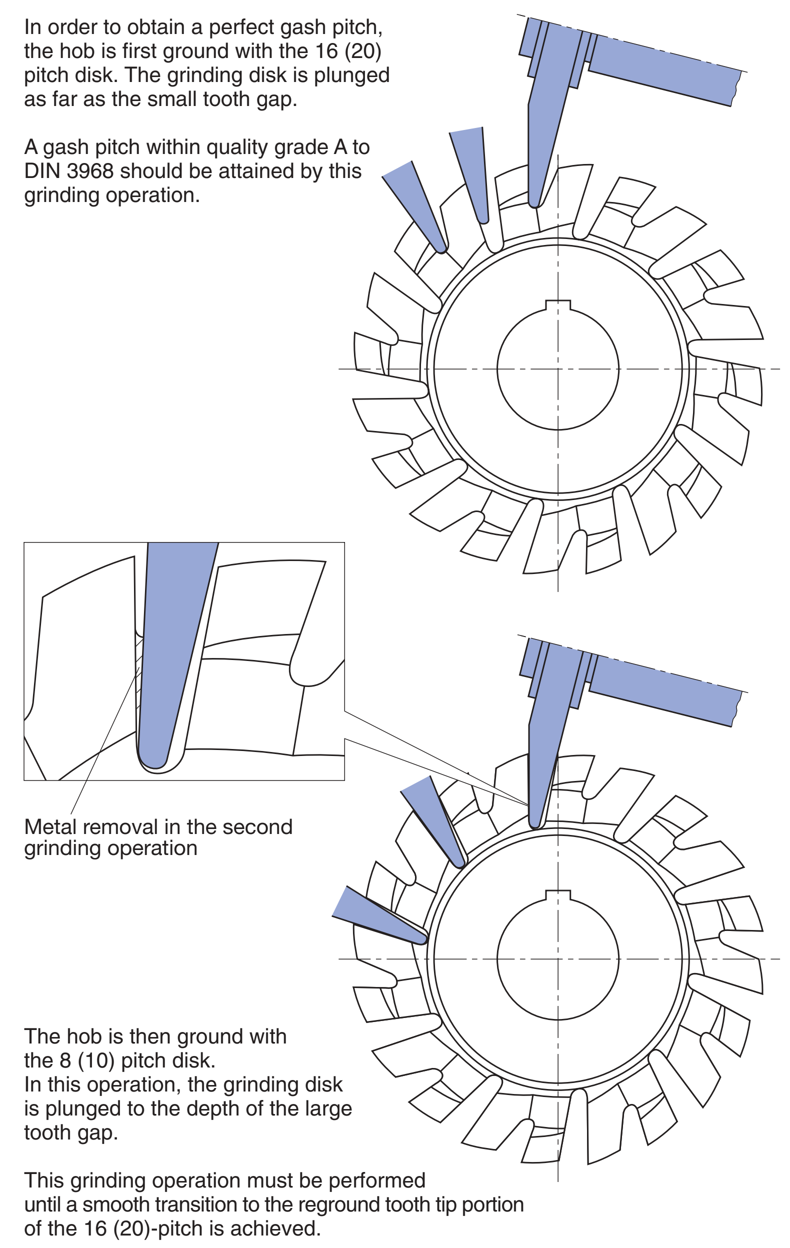
The hobs are manufactured with a positive rake angle. The cutting face is therefore off-centre. The deviation from the centre is indicated by the dimension "u", which is engraved on each hob.

Prior to beginning regrinding work, offset the grinding disk from the centre by the dimension "u".

On FETTE roughing hobs with a finite gash lead, ensure that the grinding disk is crowned, in order to ensure straight cutting faces.

All FETTE roughing hobs have 8 (10) teeth groups, each of which has 2 gashes, i.e. 16 (20) gashes in total.

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.



Regrinding of roughing hobs

When regrinding, ensure that the correct grinding disks are selected. Particular care must be taken when grinding the 8 (10) pitch owing to the greater gash depth. The feed rate should not therefore be selected too high, as local heat increases otherwise give rise to stresses. Grinding cracks may otherwise develop on the cutting face, or complete teeth may be chipped out.

On the basis of our experience, we therefore recommend the following grinding parameters for the regrinding of FETTE heavy-duty roughing hobs:

FETTE heavy-duty roughing hobs with **infinite** gash lead (table 1) are ground with CBN "B151 C125" grinding disks, with oil or emulsion.

The circumferential speed of the grinding disk should be approx. 35 m/sec.

FETTE heavy-duty roughing hobs with **finite** gash lead (table 2) are ground dry with ceramic bonded corundum grinding disks.

For hobs up to approximately 200 mm diameter: grain 36, hardness G-H

For hobs over approximately 200 mm diameter: grain 36, hardness F

The circumferential speed of the grinding disk should be approximately 30 to 35 m/sec.

After each final feed motion, grinding should be continued until the grinding disk ceases to spark, i.e. is no longer engaged, in order to ensure a well-ground cutting face.

In order to ensure an optimum lifespan for each hob, we recommend that the hob be reground as soon as a wear land of 0.3 and at the most 0.5 mm is reached.

Feed (table speed)**:**	**When roughing**	**When finishing**
Up to module 16 approx.	400 mm/min.	400 mm/min.
Up to module 16 approx.	350 mm/min.	350 mm/min.
over module 20	250 mm/min.	250 mm/min.
Feed motion in one pass:		
Up to module 16 approx.	0,20 mm	0,01 mm
Up to module 20 approx.	0,15 mm	0,01 mm
over module 20	0,10 mm	0,01 mm

Table 1: Roughing hob with infinite gash lead

Feed (table speed)**:**	**When roughing**	**When finishing**
Up to module 12 approx.	6 m/min.	5 m/min.
over module 12	5 m/min.	4 m/min.
Feed motion in one pass:		
Up to module 12 approx.	0,03 mm	0,02 mm
over module 12	0,02 mm	0,01 mm

Table 2: Roughing hob with finite gash lead

Protuberance hobs

General principles

Hobs with protuberance 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. 1.2). It is also intended to make it impossible for the grinding wheel or the shaving wheel to strike the tooth root of the gear, since this would have adverse effects – through the deflection of the grinding or shaving 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. 1.3 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. 1.4 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}).

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 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

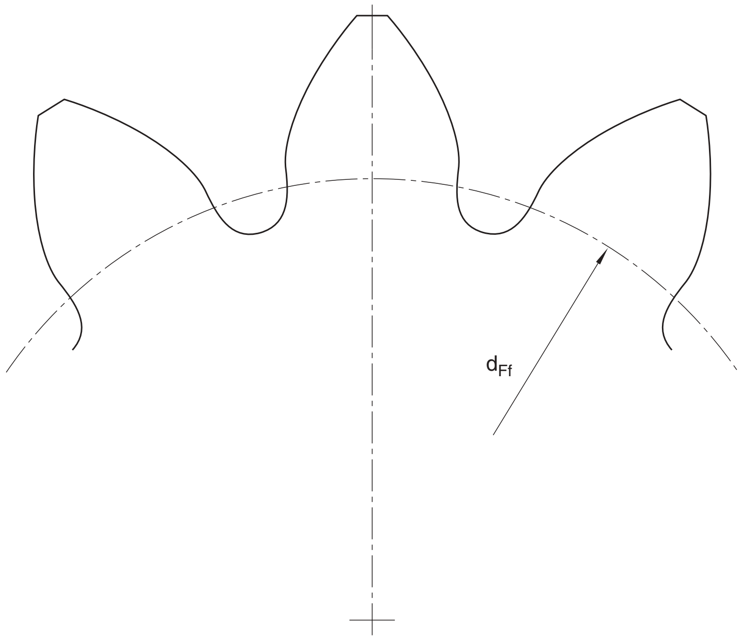


Fig. 1.5

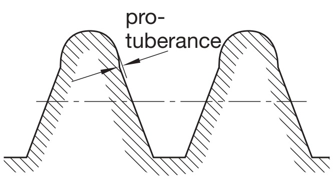


Fig. 1.1

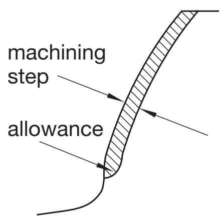


Fig. 1.2

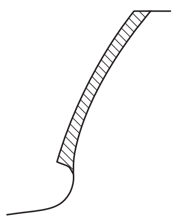


Fig. 1.3

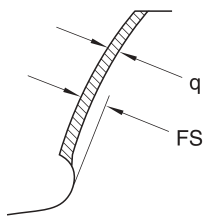


Fig. 1.4

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.

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.

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.

Terms used on the basic hob profile

Fig. 2.1 shows the basic hob profile. This is complemented by the definition of the terms used in conjunction with the basic profile.

An example showing the different dimensions of a basic hob profile is given below. This protuberance profile has been particularly successful in many cases.

$\varrho_{aP0} = 0{,}40 \cdot m$

$\varrho_{fP0} = 0{,}2 \cdot m$

$\alpha_{P0} = 20°$

$\alpha_{prP0} = 10°$

$q_{P0} = 0{,}09 + 0{,}0125 \cdot m$

$pr_{P0} = 0{,}129 + 0{,}0290 \cdot m$ $\leq$ module 7 $(u = 0{,}039 + 0{,}0165 \cdot m)$

$pr_{P0} = 0{,}181 + 0{,}0235 \cdot m$ $>$ module 7 $(u = 0{,}091 + 0{,}011 \cdot m)$

$h_{aP0} = 1{,}4 \cdot m$

$h_{P0} = 2{,}6 \cdot m$

$$s_{P0} = \frac{m \cdot \pi}{2} - \frac{2 \cdot q_{P0}}{\cos \alpha_{P0}}$$

ϱ_{aP0} = tooth tip radius
ϱ_{fP0} = root fillet radius
α_{P0} = profile ∢
α_{prP0} = protuberance angle
q_{P0} = machining allowance
pr_{P0} = amount of protuberance
h_{prP0} = height of protuberance
h_{aP0} = addendum
h_{P0} = profile height
s_{P0} = tooth thickness
u = root clearance cut on the finished gear
$u = pr_{P0} - q_{P0}$

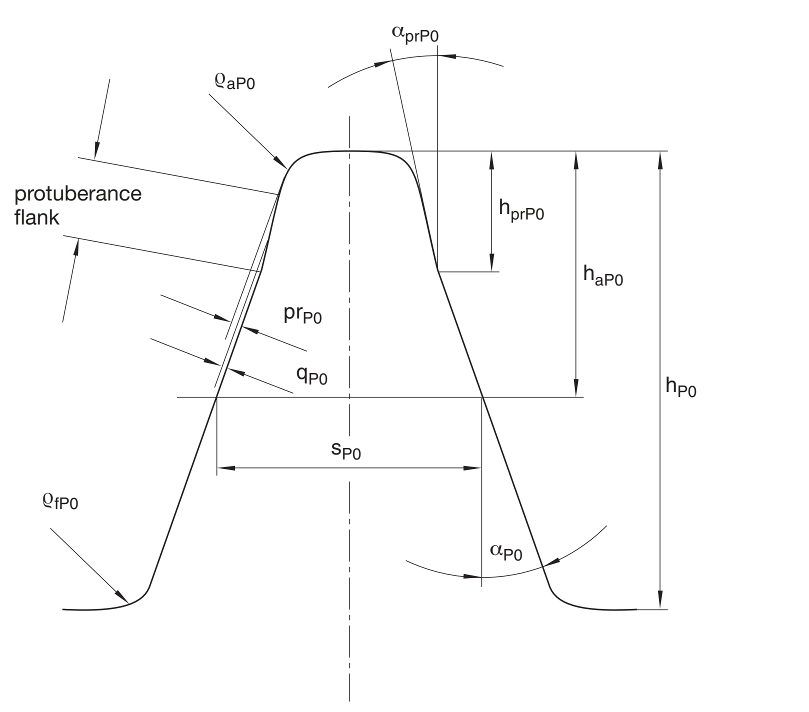


Fig. 2.1: Basic hob profile in the normal section

Calculation of the root form circle diameter

The root form circle diameter can be calculated using the software developed by 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 can be improved by a smaller protuberance quantity, a larger addendum, or a smaller tooth tip radius on the basic hob profile.

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:

$$(1)\quad d_{Nf1} = \sqrt{\left(2 \cdot a \cdot \sin\alpha_{wt} - \sqrt{d_{Na2}^2 - d_{b2}^2}\right)^2 + d_{b1}^2}$$

$$(2)\quad d_{Nf2} = \sqrt{\left(2 \cdot a \cdot \sin\alpha_{wt} - \sqrt{d_{Na1}^2 - d_{b1}^2}\right)^2 + d_{b2}^2}$$

$$(3)\quad \cos\alpha_{wt} = \frac{(z_1 + z_2) \cdot m_t}{2 \cdot a} \cdot \cos\alpha_t$$

$$(4)\quad m_t = \frac{m_n}{\cos\beta}$$

$$(5)\quad \tan\alpha_t = \frac{\tan\alpha_n}{\cos\beta}$$

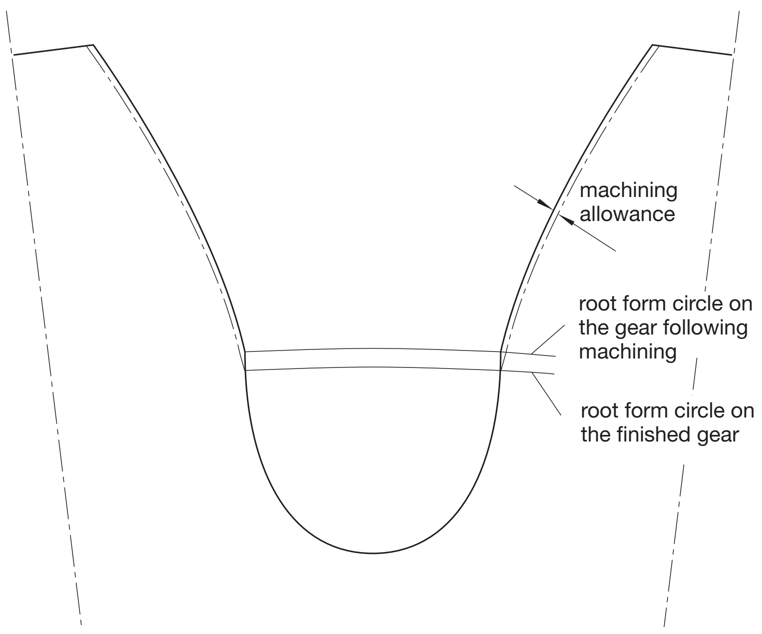
$$(6)\quad d_b = \frac{z \cdot m_n \cdot \cos\alpha_t}{\cos\beta}$$

Calculation of the effective root circle diameter

In formulae (1) and (2), 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.

Where:

d_{Nf1}, d_{Nf2}	= effective root circle diameter
d_{Na1}, d_{Na2}	= effective tip circle diameter
a	= centre distance
α_{wt}	= operating pressure angle
d_b	= base diameter
z_1, z_2	= number of teeth
m_t	= real module
α_t	= real pressure angle
β	= helix angle



Tooth gap profile in the face plane

Wear phenomena on the hob

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.
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.

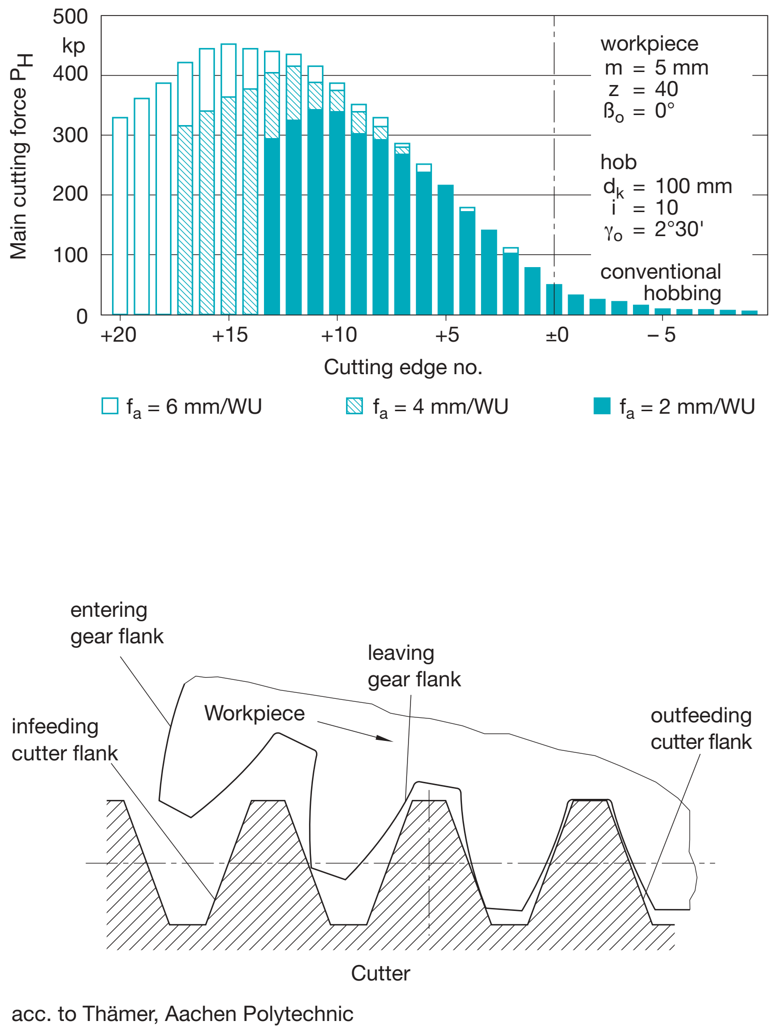
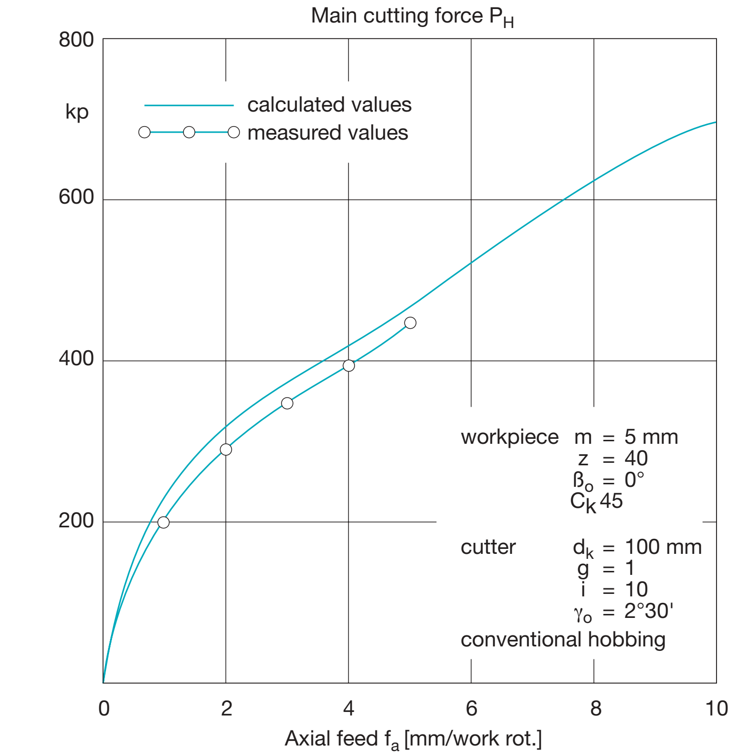


Fig. 1: Effect of the feed on the cutting force in hobbing

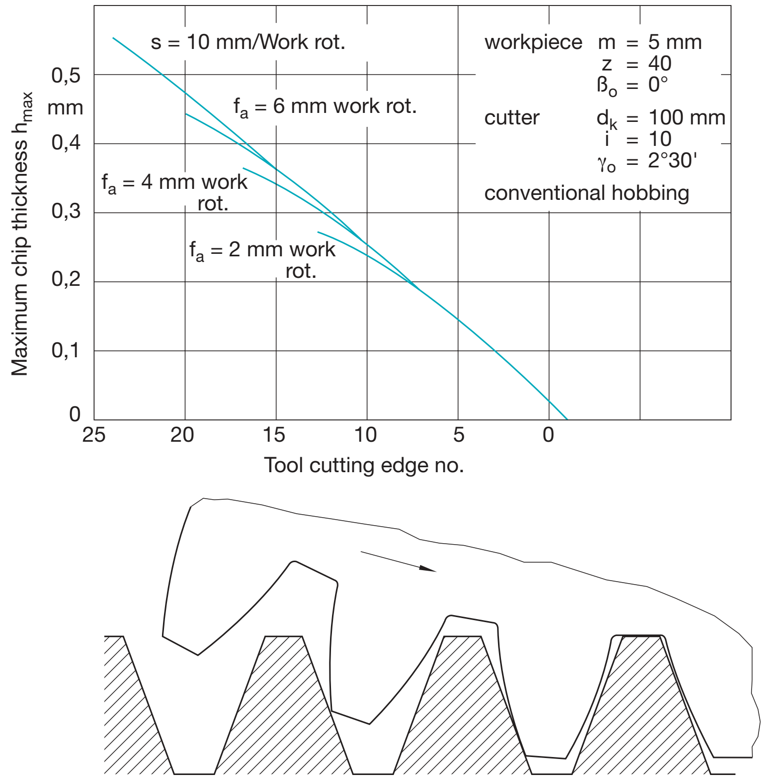
These cutting force diagrams also reveal that in hobbing the individual cutting edges carry different loads, which naturally results in a non-uniform wear pattern. The effect of the axial feed on the maximum main cutting force is shown in fig. 2. The cutting force increases in the present example degressively 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.



acc. to Thämer, Aachen polytechnic

Fig. 2: Effect of the axial feed on the maximum main cutting force



acc. to Thämer, Aachen polytechnic

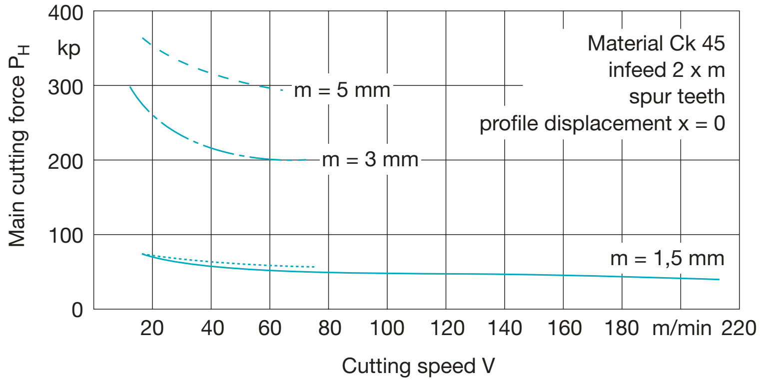
Fig. 3: Effect of the axial feed on the chip thicknesses

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.
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 component 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.



	Gear data		Hob data
- - -	m = 5 mm z = 31, f_a = 3 mm/U,	conventional hobbing,	HSS-hob, d_K = 100 mm, i = 10
—·—·	m = 3 mm, z = 53, f_a = 2 mm/U,	conventional hobbing,	SS-hob, d_K = 80 mm, i = 10
········	m = 1,5 mm, z = 26, f_a = 1 mm/U,	climb hobbing,	SS-hob, d_K = 63 mm, i = 12
——	m = 1,5 mm, z = 26, f_a = 1 mm/U,	climb hobbing,	carbide-hob, d_K = 40 mm, i = 15

acc. to Ziegler, Aachen polytechnic

Fig. 4: Effect of the cutting speed on the main cutting forces

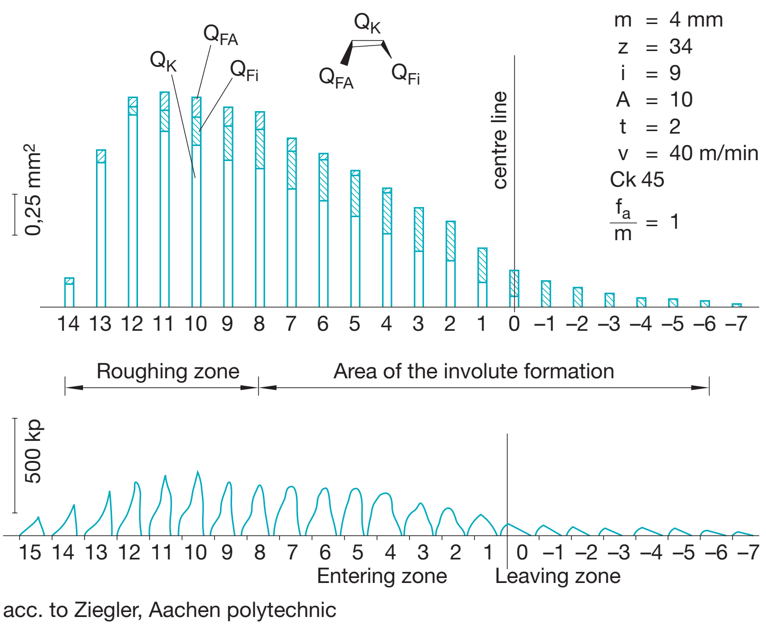


Fig. 5: Cross-sectional areas of cut and cutting forces in the case of a workpiece with only one tooth space

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, 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 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 during each work cycle, so that a large number of cutter teeth have a virtually identical wear mark width.

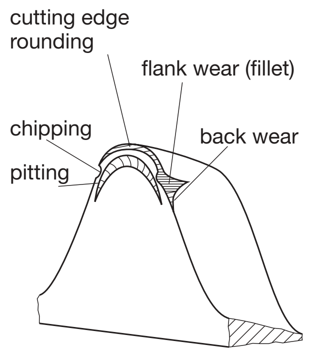
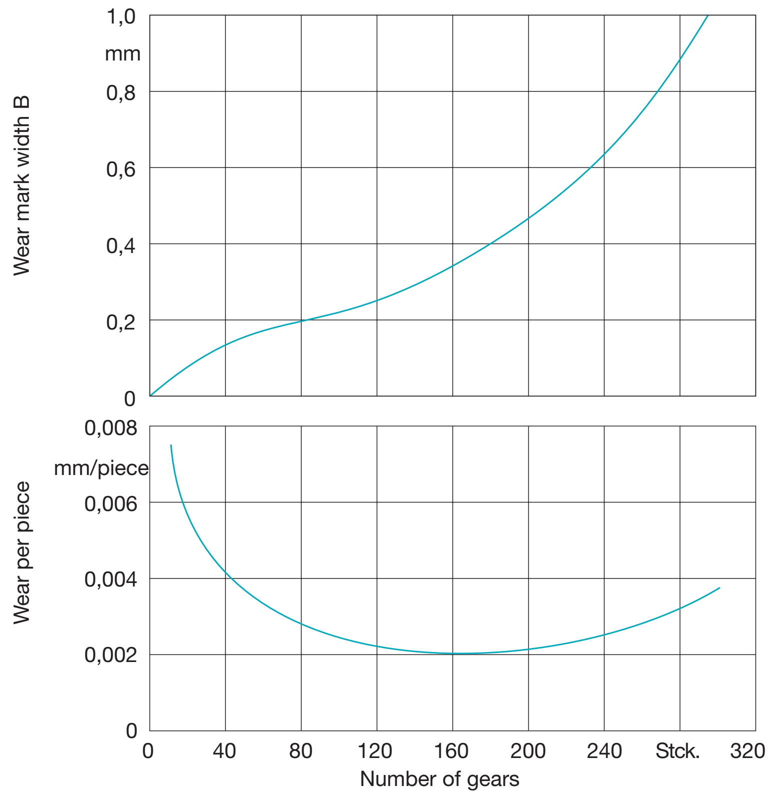


Fig. 6: Types of wear on the hob tooth



acc. to Ziegler, Aachen polytechnic

Fig. 7: Flank wear (back wear) as a function of the number of units

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.

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.

The wear is influenced strongly by the following machining conditions:

The feed "f_a", the shift "S_H", the infeed depth "a", the cutting speed "v". Other factors affecting wear are the hobbing process, the condition of the hobbing machine, the mounting and clamping of tool and workpiece and finally the coolant.

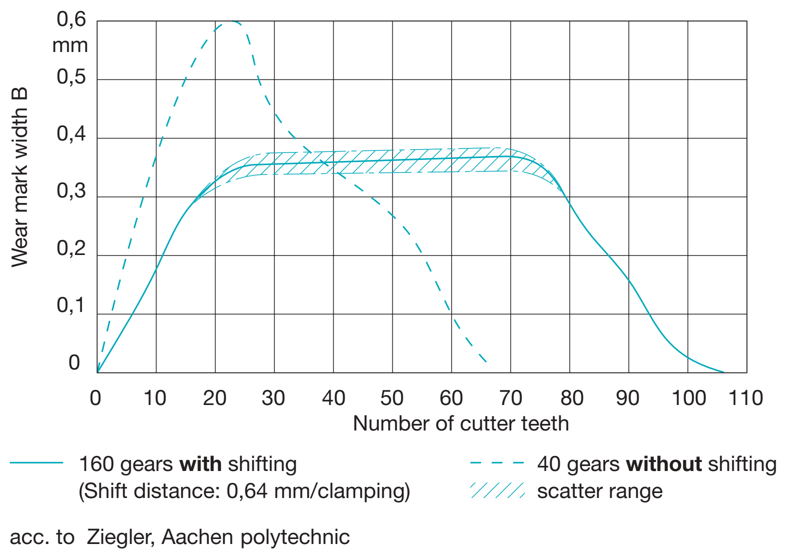


Fig 8: Wear mark width when hobbing with and without shifting

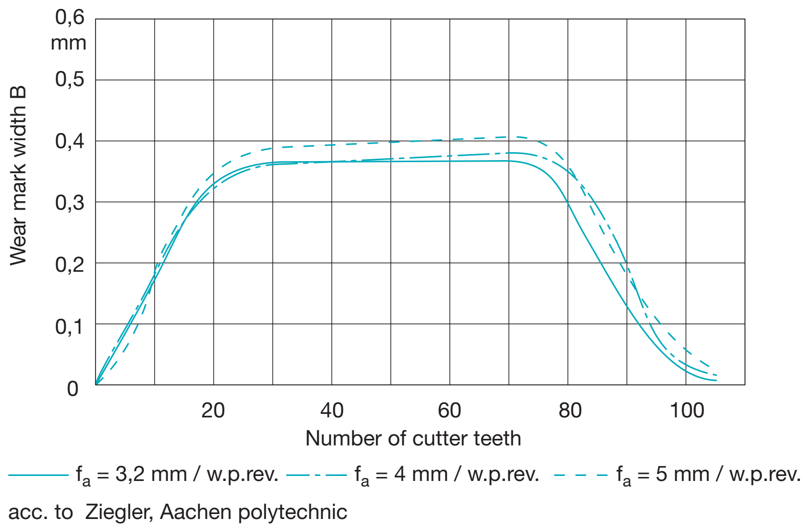


Fig. 9: Wear mark width as a function of the feed

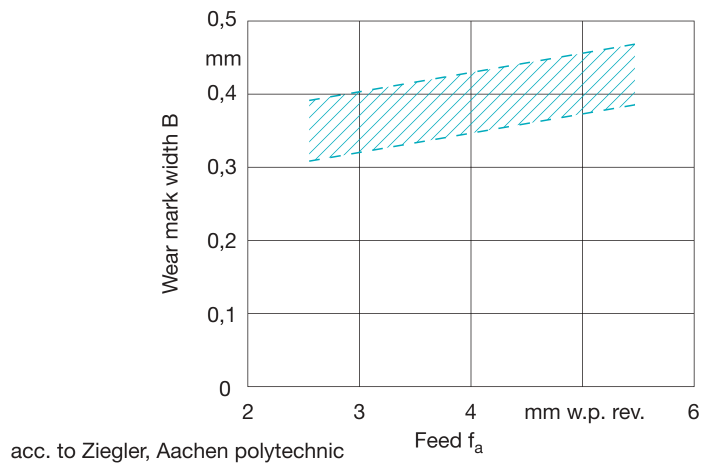


Fig. 10: Wear mark width as a function of the feed

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.

2. Technological effects, such as cutting speed, cutting material/tool pairing, cutting edge geometry, use of cutting oil etc.

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 pre-cutting 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.

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.

In the tool/workpiece penetration (7) 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 can be developed. 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

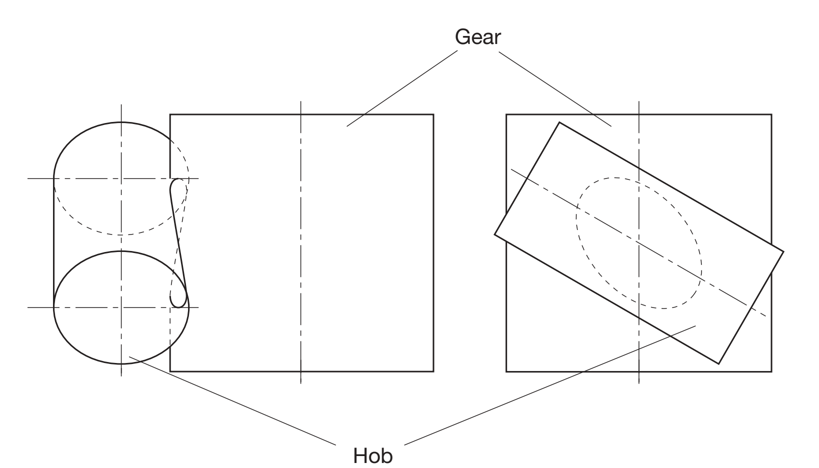


Fig. 11: Principle of the penetration curve

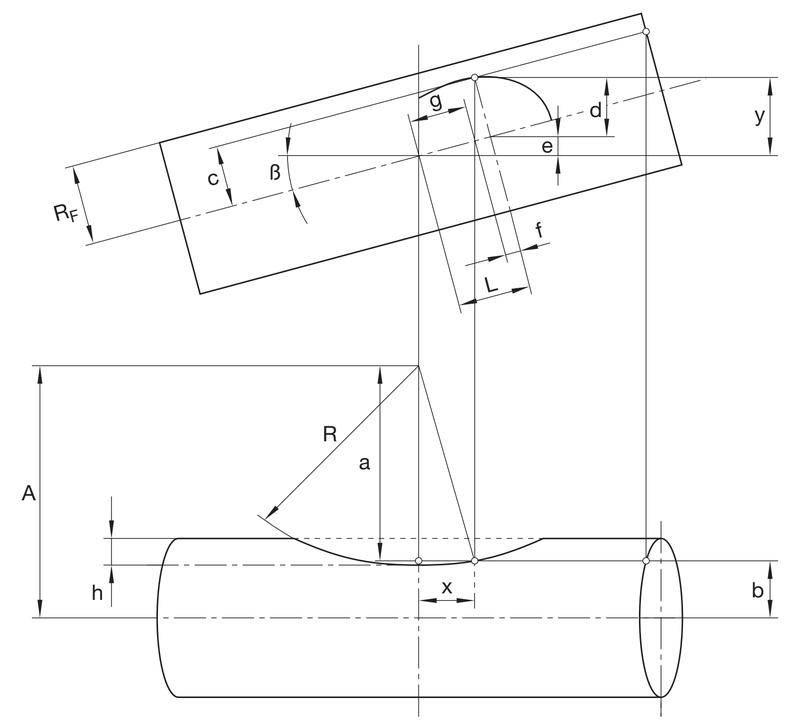


Fig. 12: Proportions of the penetration curve

the penetration line is important particularly with large gears.

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).

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

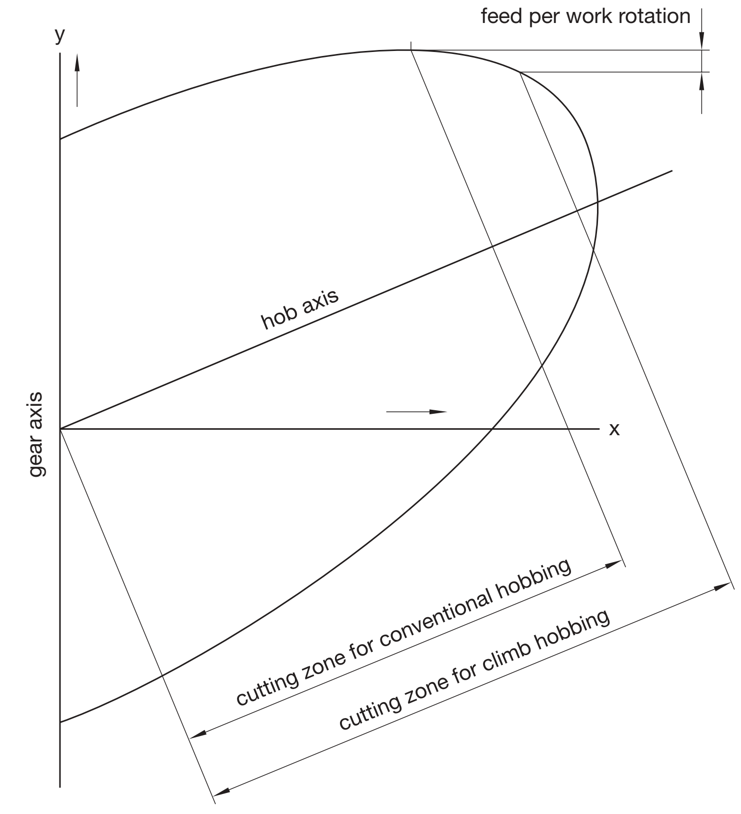


Fig. 14: Tool/gear penetration

R_F = Werkzeugradius
h = Zahnhöhe = Frästiefe
R = Werkstückaußenradius
β = $\beta_0 - \gamma_0$
β_0 = Schrägungswinkel der Verzahnung
γ_0 = Steigungswinkel des Wälzfräsers

$A = R_F - h + R$

$a = \sqrt[2]{R^2 - x^2}$

$b = A - a$

$c = \sqrt[2]{R_F^{\,2} - b^2}$

$d = \dfrac{c}{\cos \beta}$

$e = x \cdot \tan \beta$

$f = c \cdot \tan \beta$

$g = \dfrac{x}{\cos \beta}$

$y = d + e$

$L = f + g$

Fig. 13: Calculation of the penetration curve

Roghing hob
with taper lead angle 8°31'57''

conventional hobbing:
Ø 210 x 175 / 229 x Ø 100
lead length 40 mm
starting length 138 mm

Climb hobbing:
dia 210 x 225 / 279 x dia 100
lead length 90 mm
starting length 188 mm
feed f_a = 6 mm

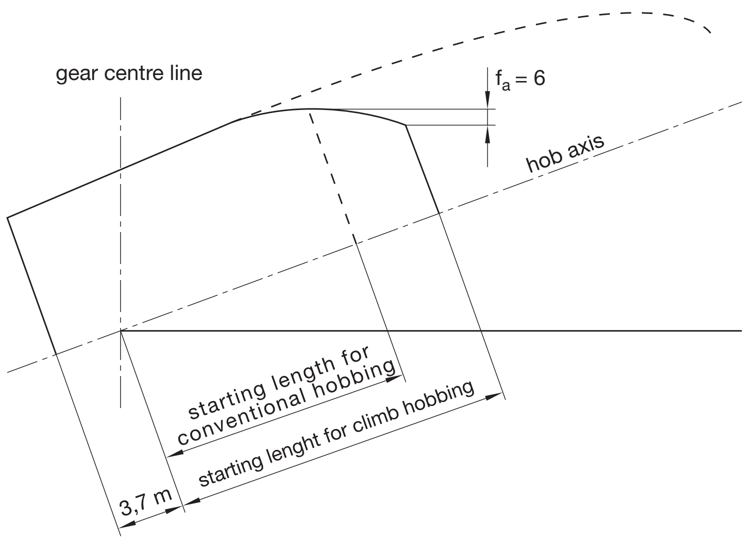


**Fig. 15: Penetration curve for a hob with lead.
Gear: module 10, 405 teeth, helix angle 29°**

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 conventional 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.

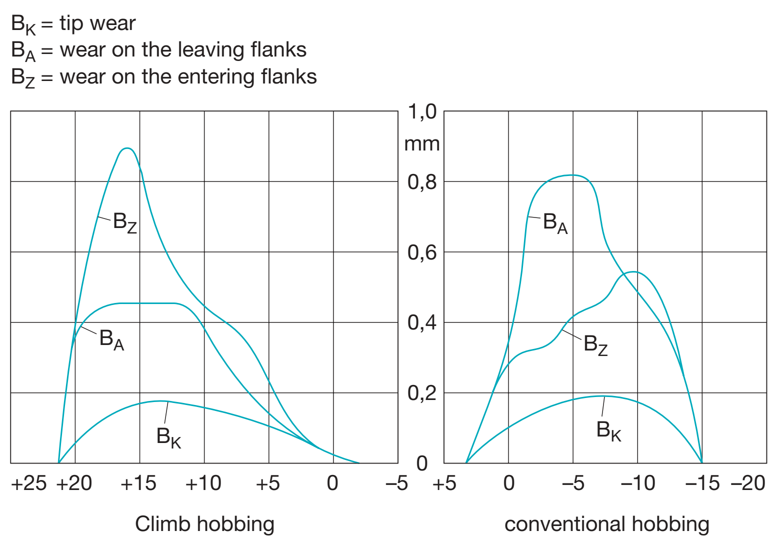
Chip geometry in hobbing

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 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). 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 machines 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



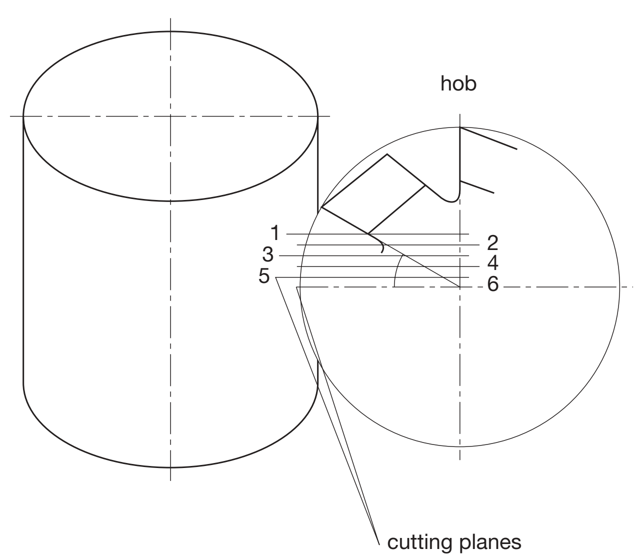
acc. to Hoffmeister, Aachen polytechnic

Fig. 16: Wear distribution on the hob

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."

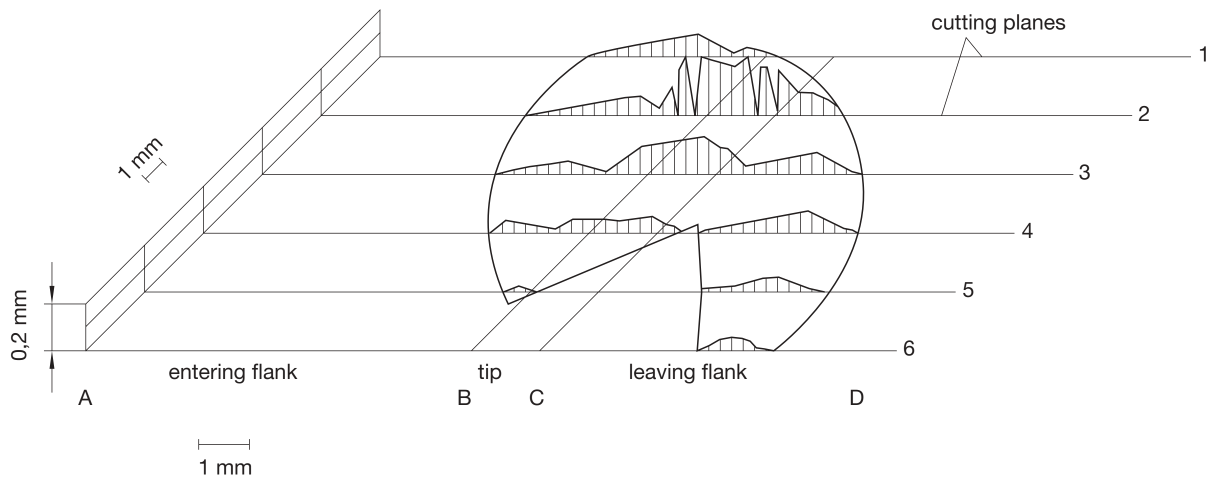
The plotter images produced by Sulzer's method (9 and 10) confirm this assumption. Sulzer's studies covered mainly the wear behaviour of carbide hobs. Instead of flank wear, he found micro-chipping in this area. Using the scanning electron microscope, he studied the leaving flanks for chip traces and found pressure welded deposits on the flanks. He states: (11 and 12) "The different dircection 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



acc. to Sulzer, Aachen polytechnic

Fig. 17: Determination of the chip forming cross-sections

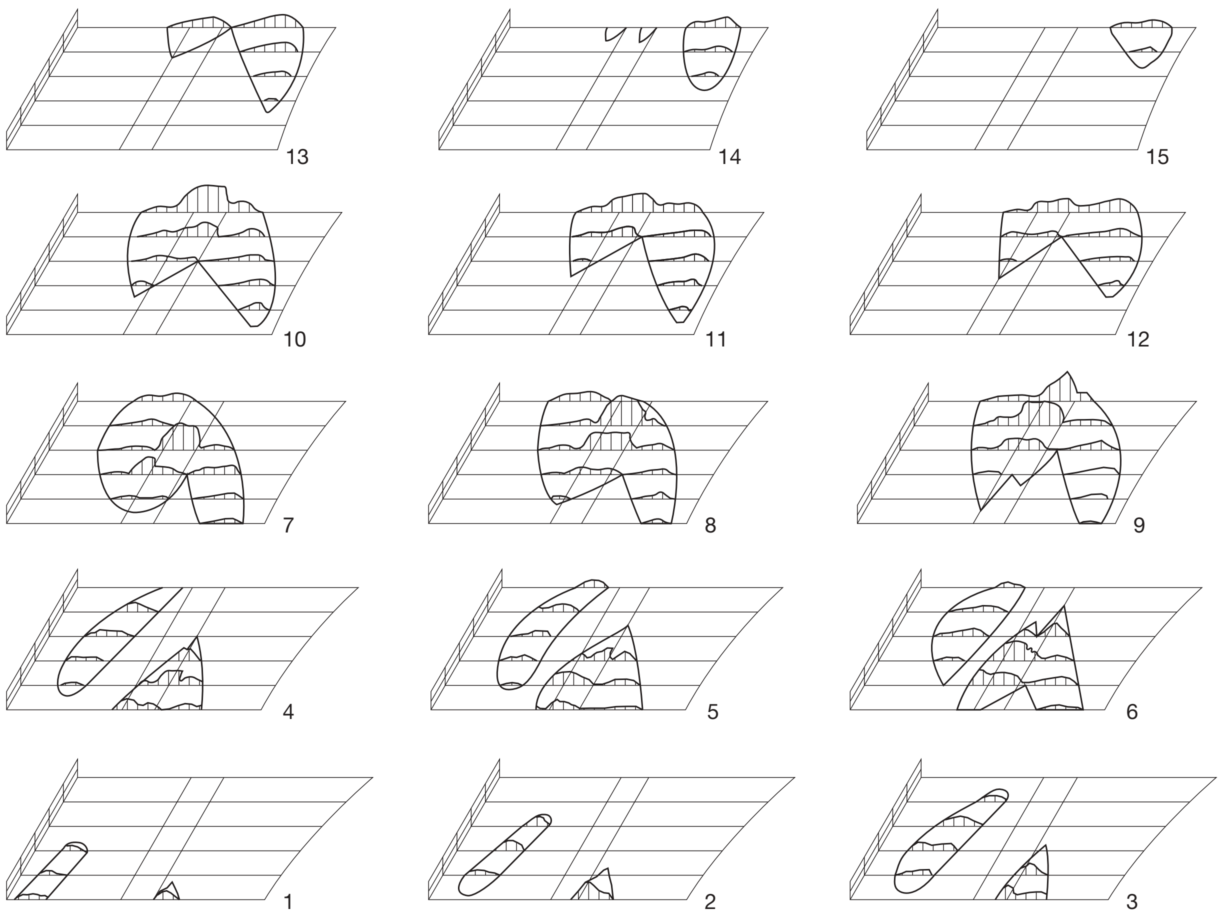


acc. to Sulzer, Aachen polytechnic

Fig. 18: Determination of the chip forming cross-sections

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.



acc. to Sulzer, Aachen polytechnic

Fig. 19: Different chip forming cross-sections on the meshing hob teeth

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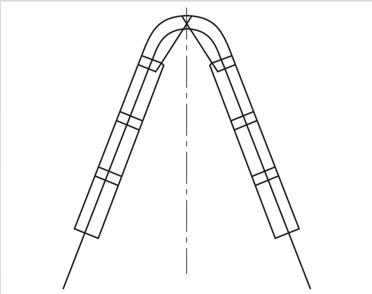
Involute gear cutter with indexable inserts

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

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 (Rm > 1000 N/mm²).

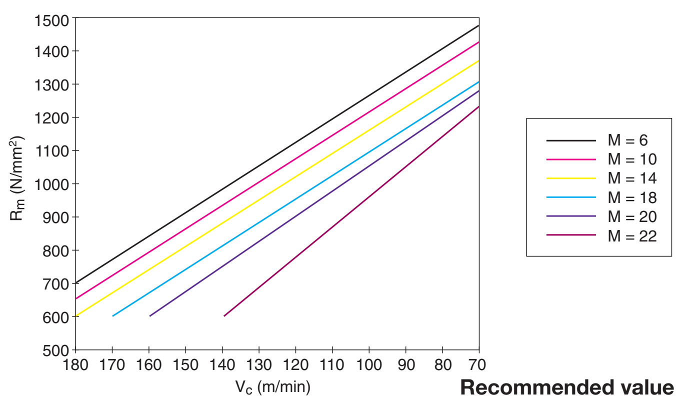
The tooth gaps are roughed trapezoidally with straight-sided flanks. The basic tool profile corresponds to BP IV according to DIN 3972. Other profiles can be supplied as non-standard versions upon request.

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.

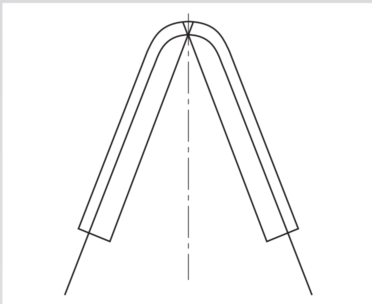
Involute finishing hob

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.

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.



Recommended value (v_c - m/min)



Design features
Continuous indexable insert cutting 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. A further regrind is possible on one side. 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.

Recommended values for the power requirement for involute roughing:

Where:

R_m = tensile strength (N/mm²)
V_c = cutting speed (m/min)
h_{m_1} = 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 (cm^3 min · kW) (Value taken from table)

Formula applicable for full profile depth:

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

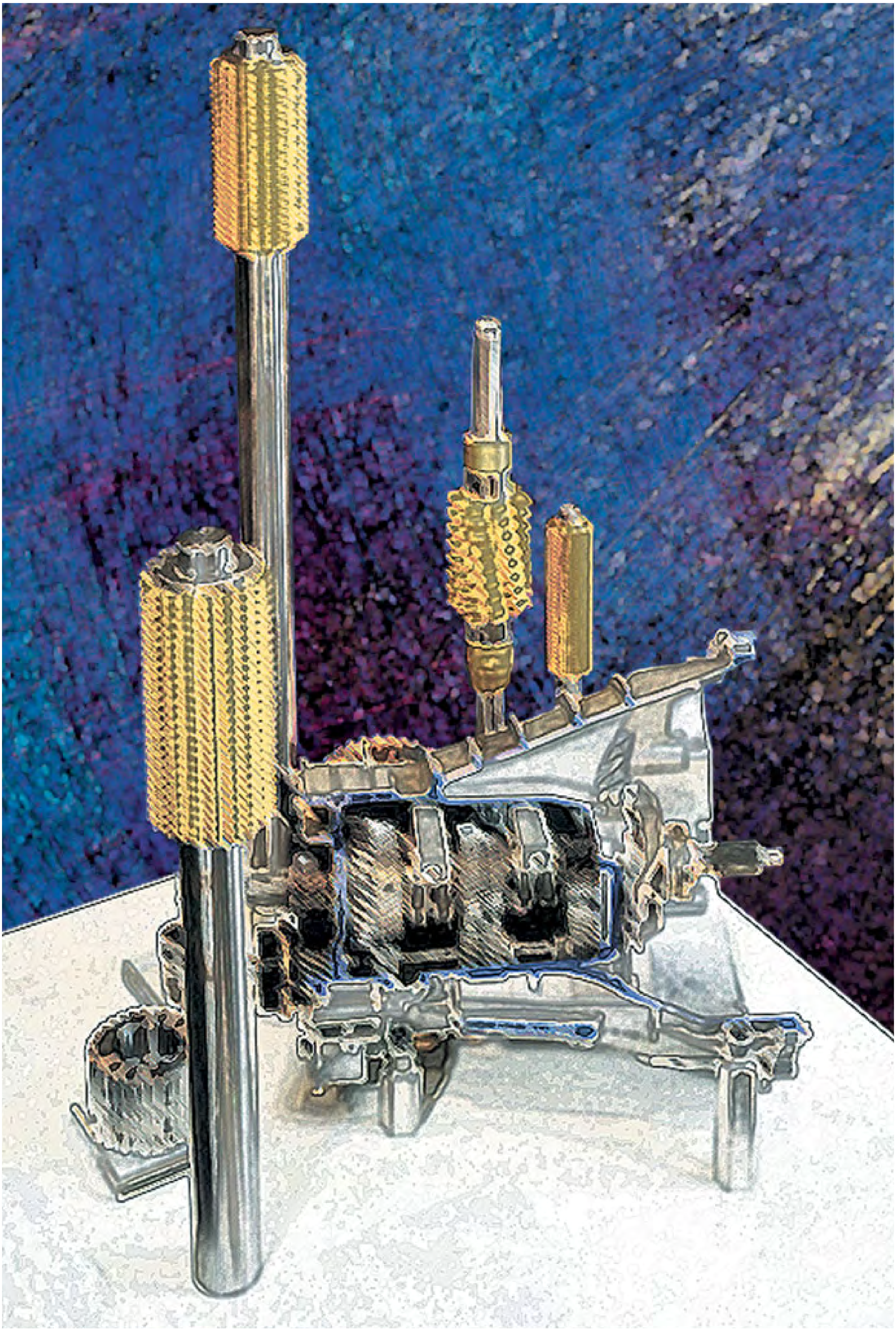
$$v_f = f_z \cdot n \cdot z$$

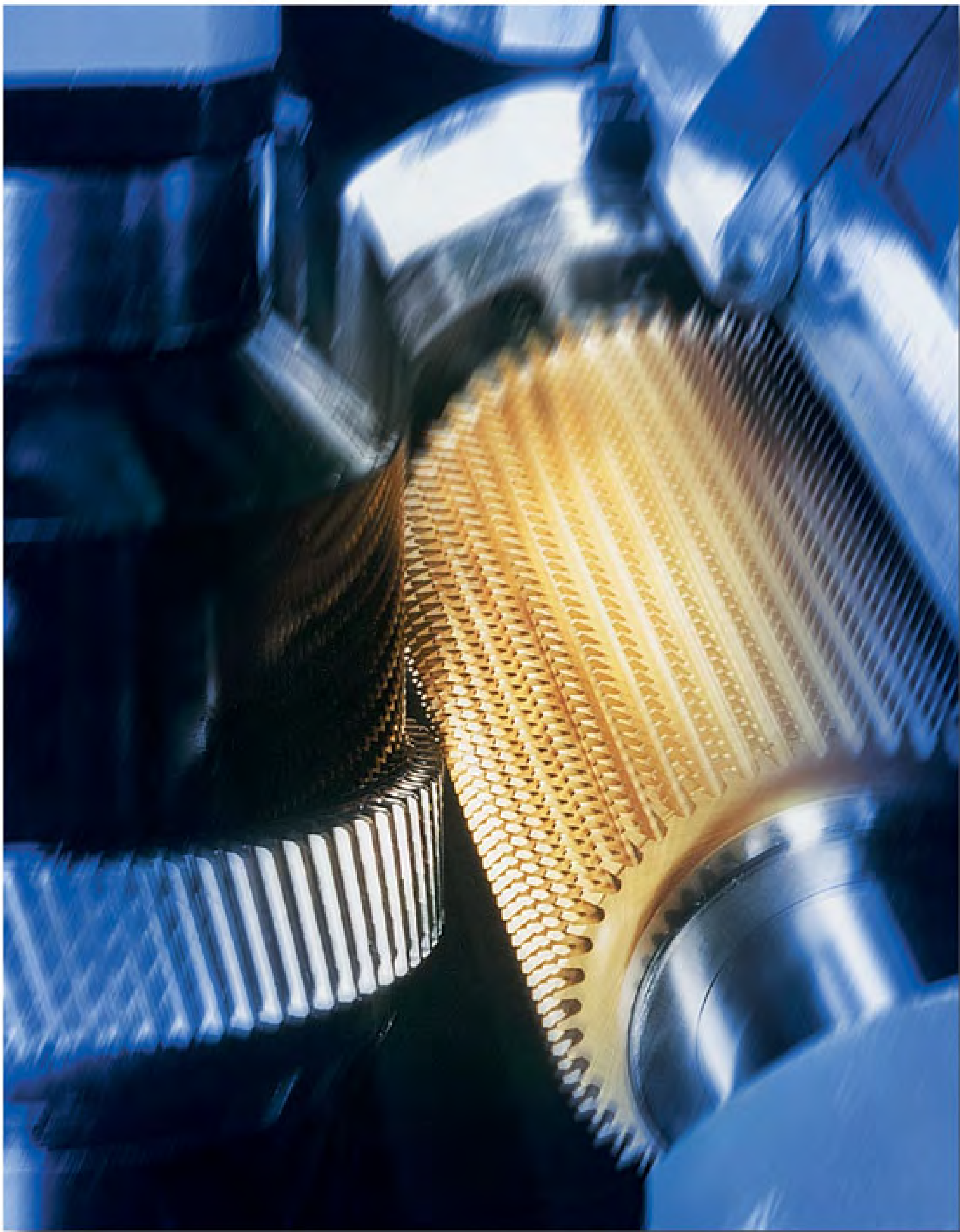
$$f_z = \frac{h_{m_1}}{\sqrt{\frac{a}{D}}}$$

Material	R_m/UTS (N/mm²)	Power factor $Q_{spez.}$ cm³/min x kW
Unalloyed structural steel	– 700	22 – 24
Free cutting steel	– 700	22
Structural steel	500 – 900	18 – 20
Heat-treatable steel, medium strength	500 – 950	18 – 20
Cast steel	– 950	18 – 20
Case hardening steel	– 950	18 – 20
Stainless steel, ferritic, martensitic	500 – 950	16 – 18
Heat-treatable steel, high-strength	950 – 1400	13 – 18
Nitriding steel, heat-treated	950 – 1400	13 – 18
Tool steel	950 – 1400	13 – 18
Stainless steel, austenitic	500 – 950	18 – 20
Grey cast iron	100 – 400 (120–600 HB)	28 – 35
Alloyed grey cast iron	150 – 250 (160–230 HB)	22
Nodular cast iron	400 – 800 (120–310 HB)	24
Malleable cast iron	350 – 700 (150–280 HB)	24

Catalogue number index

DIN number index





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