GEAR CUTTER / BROACH

MITSUBISHI

MITSUBISHI MATERIALS

C004G-H

For People, Society and the Earth

The world's leading business group of customer satisfaction for quality and service.

Our unique and distinctive technologies and precise measurements support your complex manufacturing of cutting tools.

And, we strive for the highest level in a structured global marketing based on our flexibility.

Contents

Gear Cutter

Broach

1.Basics of gear cutter

1-1 Introduction

Gears are the main component parts of power transmission.

In recent years the trend of manufacturing gears is increasing needs of the following points. Achieving high efficiency (high speed and high feed rate) aiming at improvement of productivity and reduction of investment in equipments. Achieving high accuracy against noise and vibration. Reconsidering coolant and considering dry cutting, looking to the environmental betterment.

Because of these needs, gear cutting machines are rapidly advancing in its rigidity, speed, shifting to CNC, and flexibility including easy handling. On the other hand, gear cutters are also making progress in cutting speed, efficiency, accuracy and duration of tool life by developing and improving the surface treatment, tool materials, design, and manufacturing technologies.

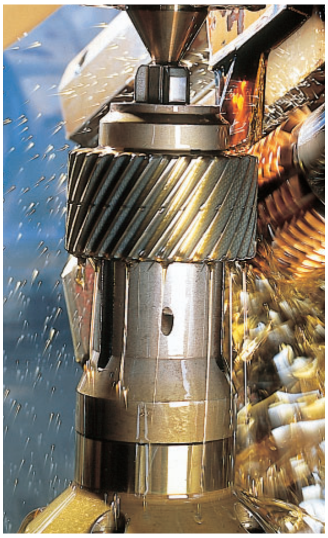
1-2 Features of our gear cutters

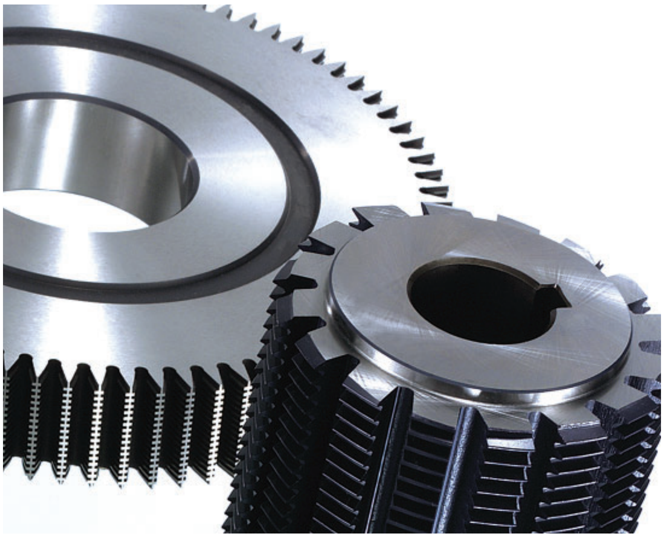
(1) Excellent tool materials in resistance to wear and chipping.

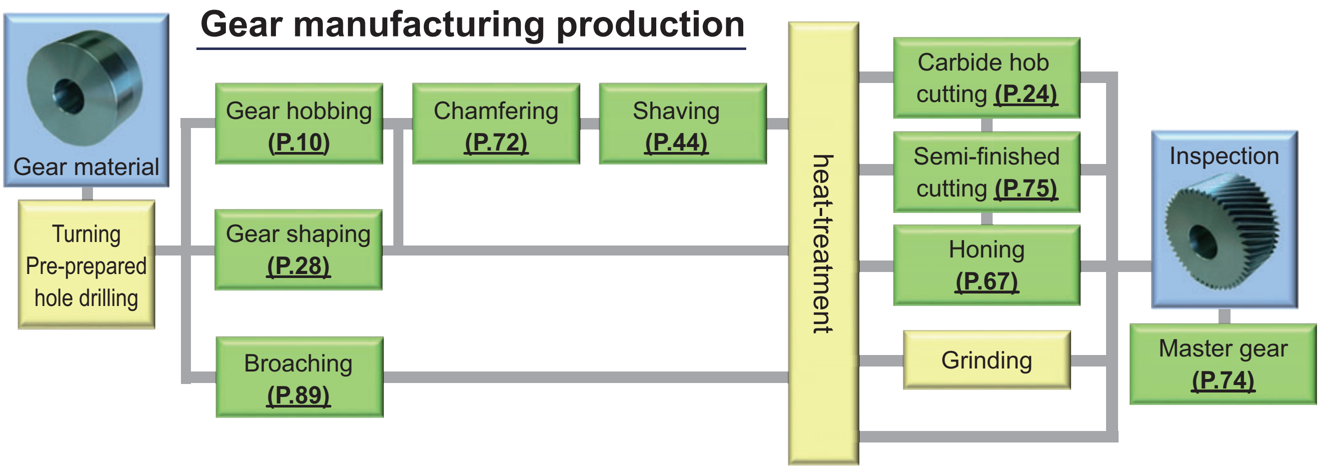
(2) Coating film and special surface treatment with high hardness and excellent heat resistant.

(3) The total design based on analysis of generating, meshing and chips' shape causing the best cutting performance.

(4) Improvement and stability of grinding accuracy owing to adoption of automatic measurement and feedback system with the newest grinding technology.







1-3 Variety of high-speed tool steels (HSS), coatings, and surface treatment

Material code		Equivalent standard		Hob	Shaper cutter	Shaving cutter	Features
		JIS	AISI				
HSS	KMC3	SKH55	M35	○	○		Standard (high Co)
HSS	KVC5	—	—	○			Improved in wear resistance
HSS	DH01B	—	—	○			Improved in heat resistance and strength For dry cutting
HSS	SKH51	SKH51	M2		○	○	Standard
HSS	KHV1	SKH53	M3-2			○	Improved in wear resistance
HSS	KHVX	—	—			○	Improved in grindability and welding resistance
HSS	HSP	—	—			○	Improved in wear resistance and grindability For high hardness material
Powder metallurgy HSS	KHA	—	—	○	○	○	Standard (powder material)
Powder metallurgy HSS	KHA30	—	—	○	○		
Powder metallurgy HSS	KHA50	SKH10	T15	○	○		Improved in wear resistance
Powder metallurgy HSS	KHAZ	—	—		○		Improved in wear resistance and strength
Coating	TiN			○	○		
Coating	Violet			○	○		
Coating	GV40			○	○		For high-speed cutting Re-coating finished
Coating	DP			○			For high-speed dry cutting
Coating	Miracle (base material carbide)			○			
Surface treatment	Nitride oxygen					○	
Surface treatment	(STH treatment)					○	Improved in wear resistance

1-4 Tools with high accuracy and efficiency

For cylinder gear

Cutting processing

Tool			
Hobs →P.10	HSS hob Carbide hob	Small diameter Multi thread Shank	Rack Sprocket Spline Worm Chamfering
Shaper cutters →P.28	Disk type Counter-bore type Shank type	For external gear For internal gear For helical gear For united teeth For lacked teeth	Sprocket Parallel spline Through
Rack cutters	MAAG type and others		
Milling cutters		Formed	Involute Sprocket Spline

Finishing (Cutting · Before heat-treatment)

Tool			
Shaving cutters →P.44	Plunge cutting Conventional Diagonal Under-pass	Inclinational serration Dissymmetry serration	Fixed installation width

Finishing (Rolling · After heat-treatment)

Tool	
Burnishing gears →P.72	

Gear honing (Grinding · After heat-treatment)

Tool		
Diamond dressing gears →P.67	Direct (positive) type	Bias tooth profile correction

Partial machining

Tool		
Deburring cutters →P.72	Two-piece type With hubs Three-piece type With a differential motion gear	Taper type Parallel type Tooth flank and bottom chamfering simultaneously

Other products

Gear measurement

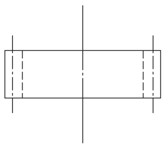
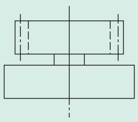
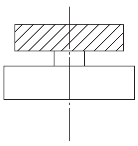
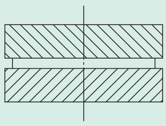
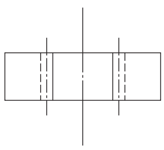
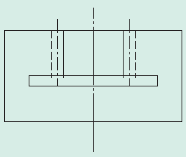
Master gear →P.74

1-5 Accuracy and manufacturing method required according to usage of gear

Recapitulation (Application equipment and device of gear)		Master gear for precise gauge measurement	Master gear for production Aircraft Machine tool Examination device	Aircraft transmission Machine tool Examination device Turbine	Aircraft transmission Machine tool Examination device Turbine Automobile Transportation equipment	Automobile Transportation equipment Machine tool	Middle and low-speed transportation equipment Machine tool Tractor for agriculture Transmission of industrial machine		Tractor for agriculture Transmission of industrial machine Gear of hoist	General agricultural machine
(1)Quality grade	DIN(2)	3	4	5	6	7	8	9	10	11—12
	AGMA(2)	–	–	15	14	13	12	11	10	9—7
	JIS(2)	–	0	1	2	3	4	5	6	7—
The final machining (3)	Hobbing					○	○	◎	◎	◎
	Shaping					○	◎	◎	◎	◎
	Shaving		○(ε=1.9 or more) (4)	○(ε=1.8 or more) (4)	○(ε=1.7 or more) (4)	◎	◎	◎		
	Finishing rolling				○	◎				
	Honing	○	○	◎	◎	◎				
	Grinding	○	○	○	◎	◎	◎			

Note (1) As for the gear noise, helical gears have the advantage of class 1 to 2 compared with spur gears.
(2) The DIN, AGMA, and JIS grade are roughly compared by chiefly tooth profile error.
(3) The quality decreases 1 to 2 classes according to the machining method, when the final manufacturing process is heat-treating.
(4) ε : Contact ratio of work piece and cutter
◎ : Quality grade in general
○ : Quality grade obtained by only excellent machining

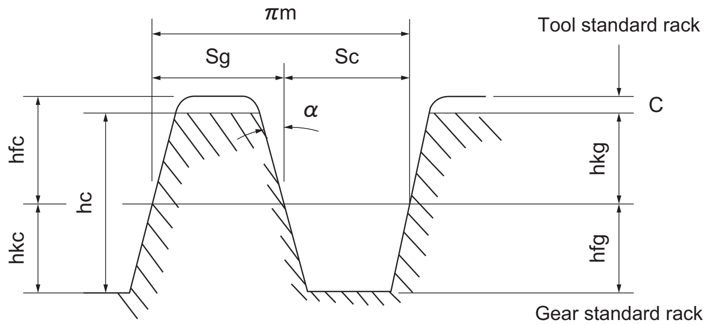
1-6 Selection of tool according to gear shape

	Gear shape	Tool name	Machining equipment	Accuracy	Process-ing efficiency	When you require the finishing	Note
External gear		Hob	Hobbing machine	○	◎	○Shaving cutter m1-m14 ○Gear roll m1-m3 ○Carbide hob cutter: High hardness material and large gear	
		Shaper cutter	Gear shaper	○	○		
		Rack cutter	Gear shaper	◎	△		
		All-shapes cutter	Milling machine	△	△		
		Shaper cutter	Gear shaper	○	○	○Shaving cutter ○Gear roll	
		Rack cutter	Gear shaper	◎	△		
		Helical shaper cutter	Gear shaper	○	◎	○Shaving cutter ○Gear roll	
		Helical rack cutter	Gear shaper	◎	○		
		Helical rack cutter	Gear shaper	◎	○		
Internal gear		Shaper cutter	Gear shaper	○	○	○Shaving cutter	○Formed milling cutter maybe used for only the gear with large diameter and large module. ○After broaching the finishing is not usually done.
		Formed milling cutter	Special gear cutter	△	○		
		Broach	Broach machine	○	◎		
		Shaper cutter	Gear shaper	○	○	○Shaving cutter	

1-7 Standard rack

Standard rack of tool is decided on standard rack of gear. Generally used standard rack of gear and tool are shown in the table.

Kind of tooth profile	Pressure angle	Tooth profile of gear			Tooth profile of tool			
	α	hkg	hfg	Sg	hkc	hfc	Sc	hc
J I S	20°	1m	1.25m	0.5 π m	1.25m	1.25m	0.5 π m	2.25m
D I N	20°	1m	1.1m—1.3m	0.5 π m	1.1m—1.3m	1.1m—1.3m	0.5 π m	2.1m—2.3m
Fellows stub tooth (Note 2)	20°	$1m_2$	$1.25m_2$	0.5 π m	$1.25m_2$	$1.25m_2$	0.5 π m	$2.25m_2$
Pre-shaving	20°	1m	1.35m	0.5 π m +Ss	1.35m	1.25m	0.5 π m -Ss	2.35m
AGMA STUB	20°	0.8m	1m	0.5 π m	1m	1m	0.5 π m	1.8m
SYKES (double helical)	20°	0.8m	1.15m	0.5 π m	1.15m	1m	0.5 π m	1.95m



hkg :Work addendum
hfg :Work dedendum
Sg :Tooth thickness
hkc :Tool cutter addendum
hfc :Tool cutter dedendum
Sc :Tool tooth thickness
hc :Cutting depth
C :Bottom clearance

(Note 1) m = module
(Note 2) The module of the Fellows stub tooth is displayed with m_1/m_2.
m_2 is module by which the tooth depth is calculated.

●Recommendation amount of shaving stock

Module	m_n≦2.25	2.25<m_n≦3.5	3.5<m_n≦5	5<m_n≦12
Shaving stock	0.05—0.08	0.06—0.10	0.08—0.12	0.10—0.15

The above mentioned shows shaving stock in tooth thickness.

1-8 Gear engagement

Involute tooth profile :

Tracks which one point of string reeling the base circle draws when it is unreeled without losing strain.

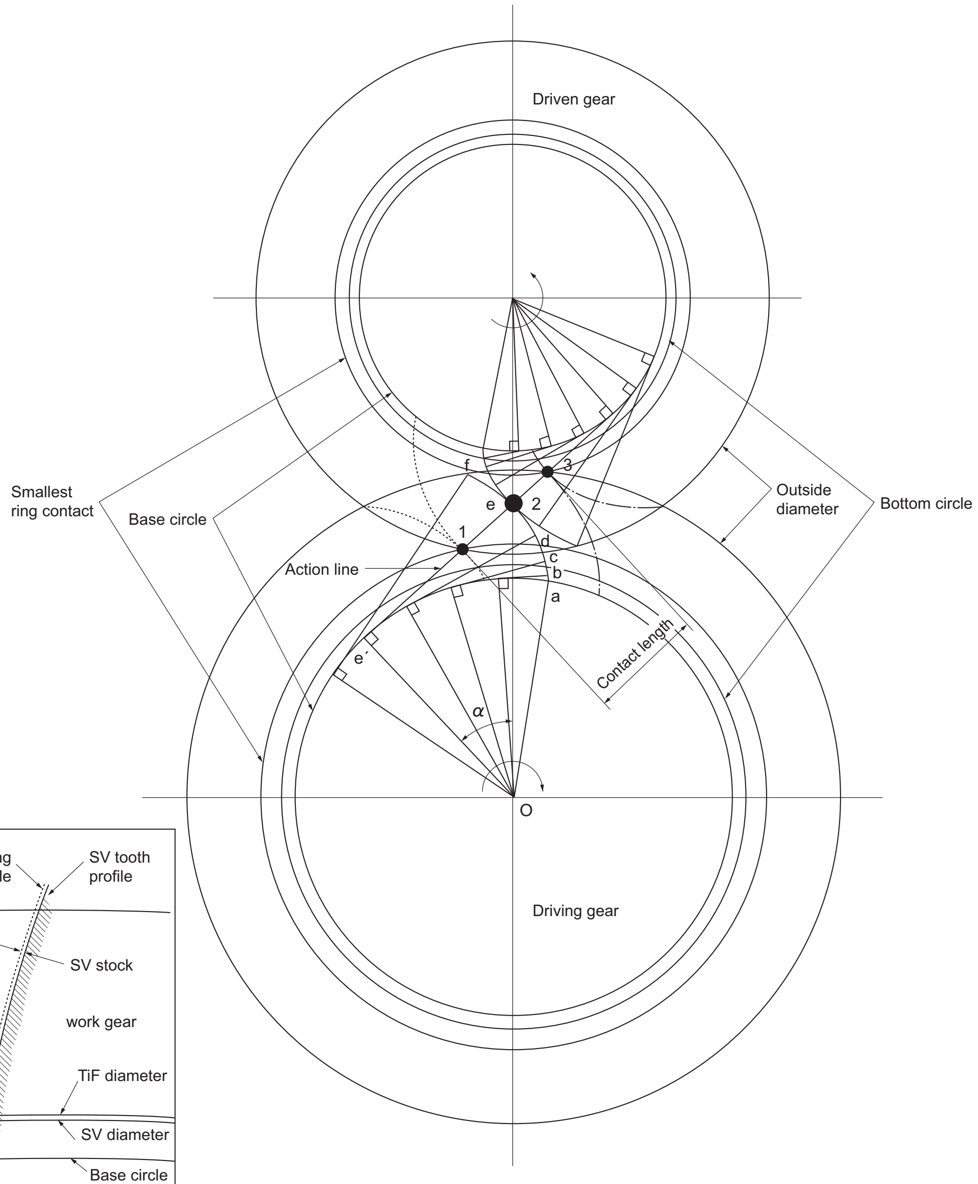
(a → b → c → d → e → f)

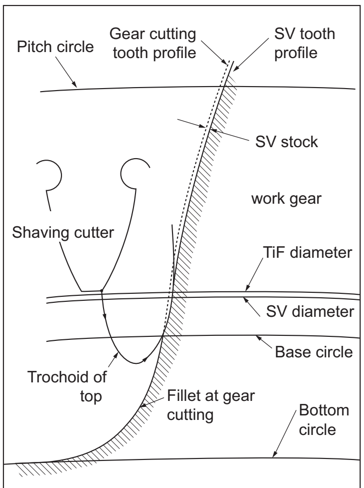
Pressure angle :

Pressure angle at e point is indicated as ∠eoe' =α.

Contact starts from point 1 on the bottom side of driving gear, through point 2(pitch point), and ends at point 3 on the top side.

Below is a track (trochoid curve) which the top of the shaving cutter (driving gear) draws when it is rolled along the involute tooth profile of the work gear (driven gear) which is fastened.



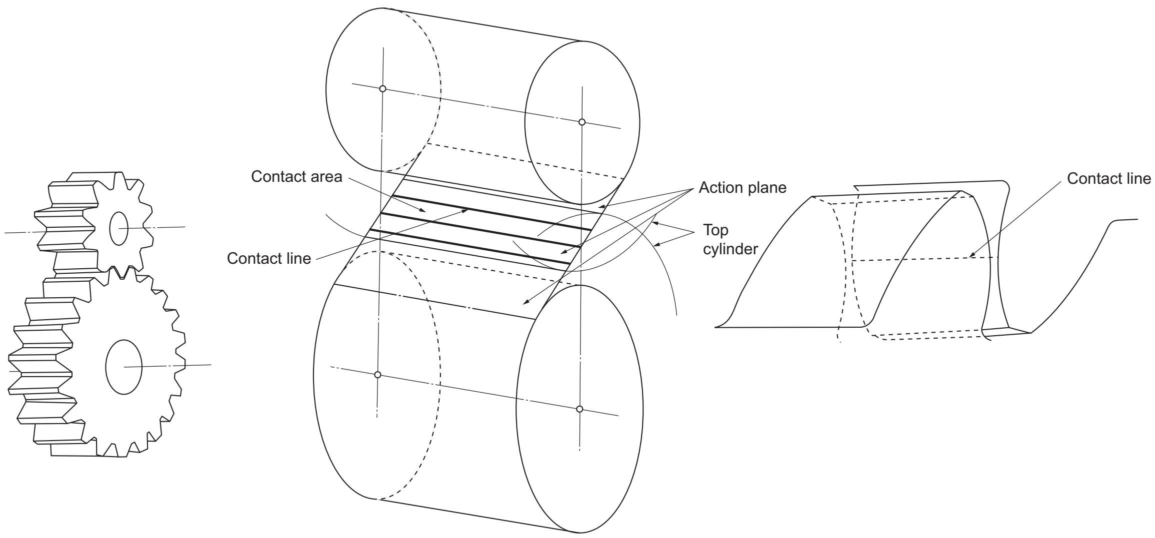


Trochoid curve of shaving cutter top

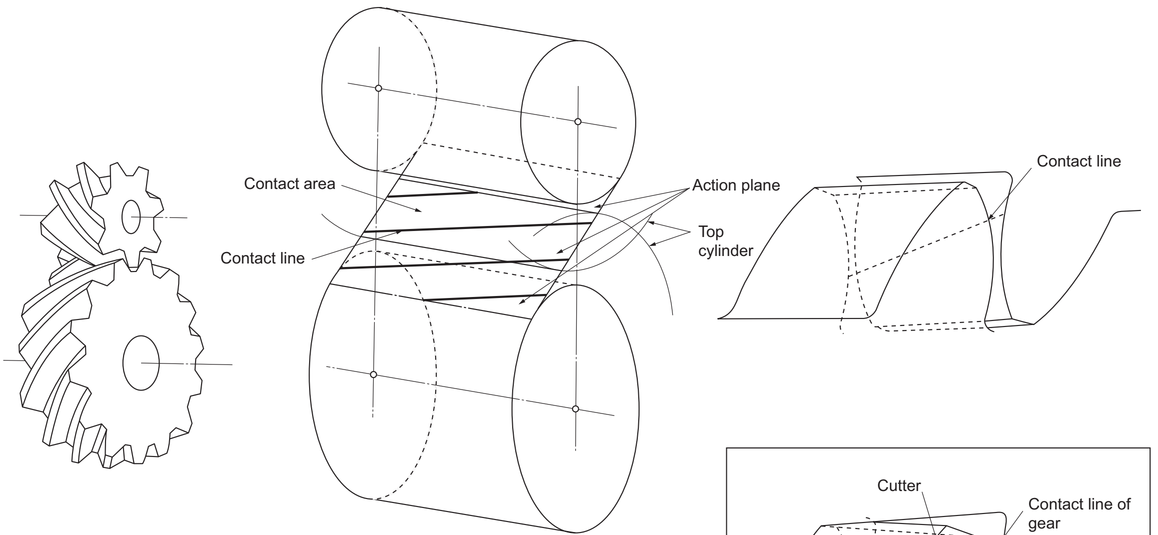
State of contact of gear

1-9 State of contact line

Within contact area of helical gears, contact line moves from the driving gear side toward the direction of the diagonal angle.

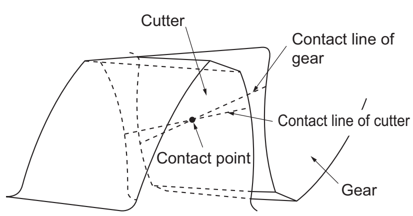


Spur gear



Helical gear

Contact of spur gears and helical gears



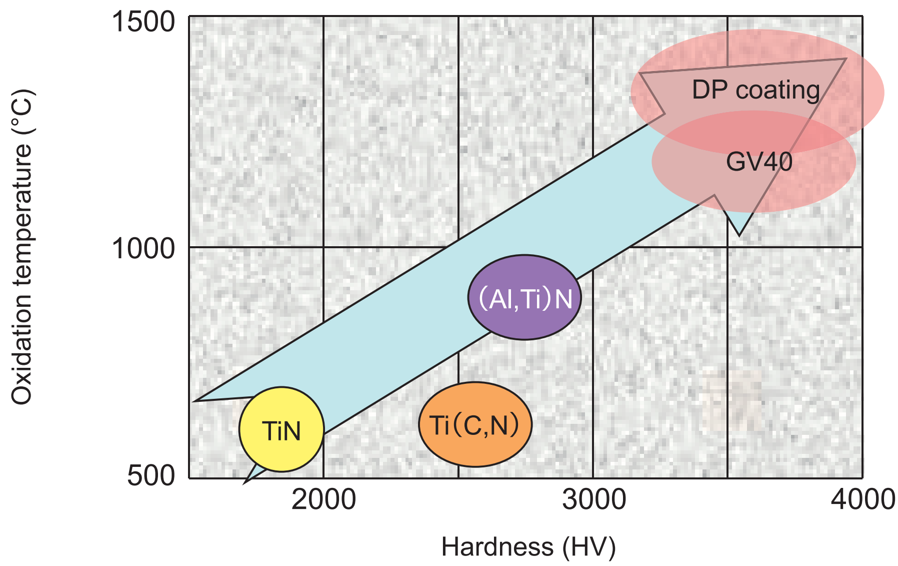
Since helix angle is different, the intersection of each contact line becomes a contact point.

State of contact of shaving cutter and work gear

1-10 Coating technology

Cutting tools must have a cutting edge those which can endure severe cutting impacts and heat, and whose shape must be kept for many hours. The advancement of the cutting manufacturing technology in recent years is remarkable. Therefore the demand for efficiency of cutting tools has risen higher than ever. Coating (surface treatment) technology is one of the most impotant factors that raise the efficiency.

The coating technology developed originally by us has succeeded in improving cutting performances without reducing the characteristics or the properties of tool materials (base material). Ever since (Al,Ti)N layer "Miracle coating" was put to practical use first time in the world, it has attracted remarkable public attention.

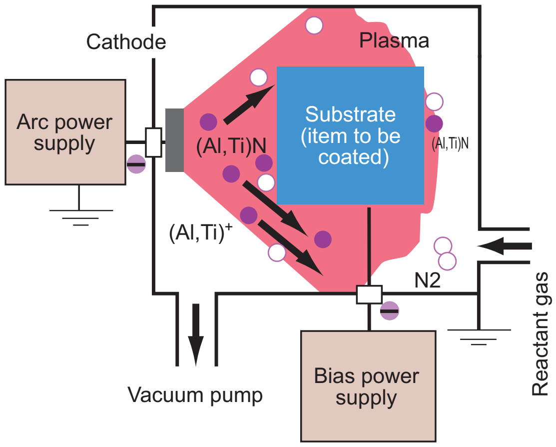


Coating trend

●Succeeded in applying (Al,Ti)N coating to cutting tools by the arc-ion plating method.

Miracle coating (Al,Ti)N is formed by means of one of the physical vapor deposition process (PVD process), that is, the arc-ion plating method.

Coating by PVD process has proved merits that it has excellent adhesion and makes flaking of a substrate or exfoliation minimum.



Concept chart of arc-ion plating device

2.Hob

2-1 Features

Hob is a milling cutter with cutting edge lined on the worm. Since the cutting mechanism is all rotation movement except feeding, it is excellent in productivity compared with other gear cutters.

Cutting mechanism of hob is shown in Fig.1. Along with rotation of hob, each cutting tooth on the imaginary screw thred surface appears one by one on to the surface where tooth profile is generated. Then, the rack, which goes straight on this surface, is projected. Gear is generated by rotating the work piece so as to mesh with this rack ideally, and at the same time, by feeding the work piece, where tooth profile is generated, in the direction of thread helix of gear. Fig.2 below shows gear generation when it is fixed.

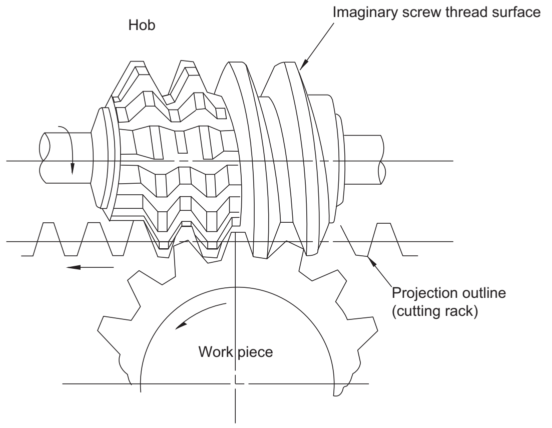
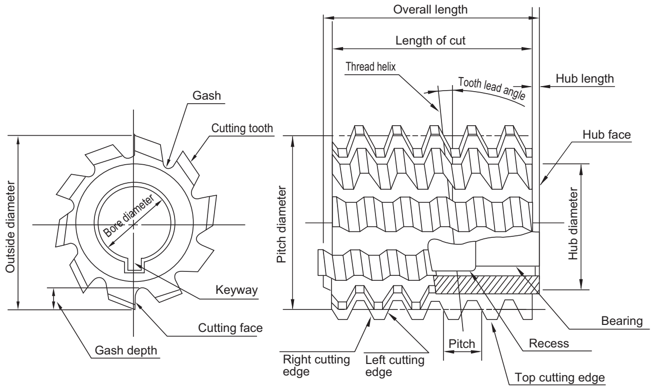


Fig.1 Gear cutting mechanism of hob

2-2 Part names



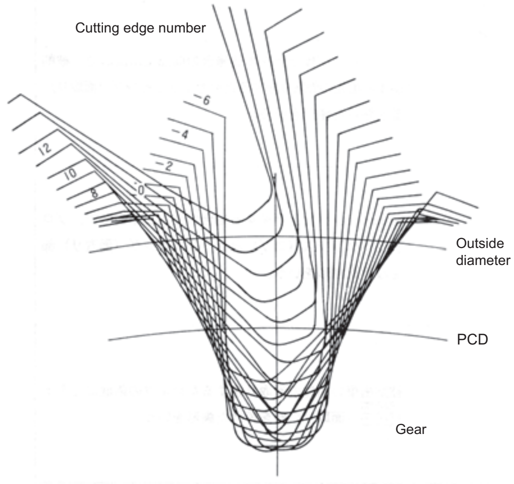
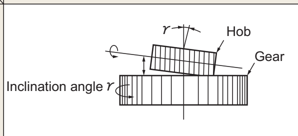
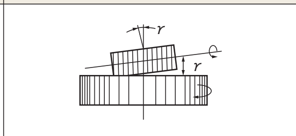
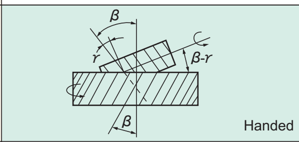
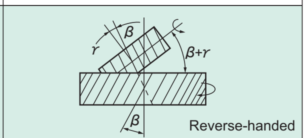
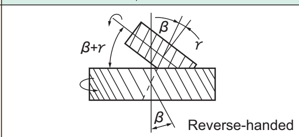
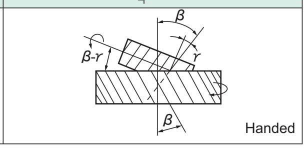


Fig.2 Gear generation line chart

2-3 Number of teeth and addendum modification coefficient of gear

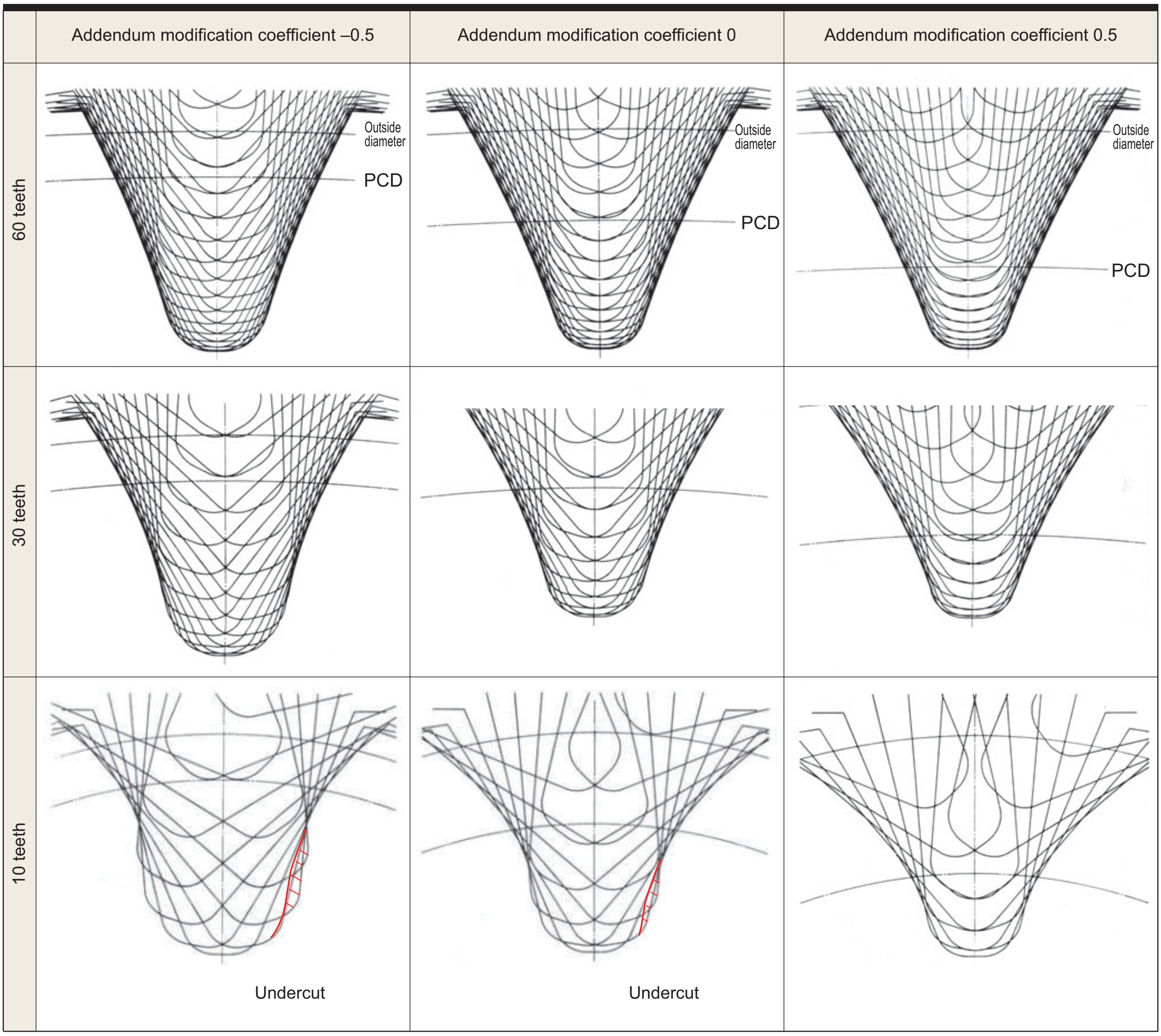
The amount of the load of the hob cutting edge changes as the number of teeth of the gear changes. That is, when number of teeth decreases, the number of acting hob teeth decreases and the chip thickness increases. Therefore multi-thread hobs cannot be used for gears with less teeth.

And the smaller addendum modification coefficient becomes 0 or below and the less number of teeth decreases, the more easily undercut happens.

Gear \ Hob		Direction of tooth lead angle of hob: Right	Direction of tooth lead angle of hob: Left
Spur gear			
Direction of helix angle of helical gear	Right	 Handed	 Reverse-handed
Direction of helix angle of helical gear	Left	 Reverse-handed	 Handed

β:Helix angle of gear
γ:Tooth lead angle of hob

Fig.3 Inclination angle of hob



Gear · · · m1, PA20°, β=30°, Cutting depth 2.4
Hob · · · Addendum 1.4, 12 gashes, 3 threads, Top corner radius 0.3

Fig.4 Number of teeth and addendum modification coefficient of gear

2-4 Sharing of semi-topping hob

When semi-topping hob is used for cutting some different gears, it is necessary to calculate the amount of the gear chamfering, considering number of teeth, addendum modification coefficient. If shaving is planned, shaving stock must be also considered.

As an example, Fig.5 shows the amount of chamfering when a hob, which is designed for a standard type spur gear with 35 teeth (x=0,C=0.1m), is shared with shifted gears with various addendum modification coefficient. The larger number of teeth becomes or the less addendum modification coefficient becomes, the larger the amount of chamfering becomes.

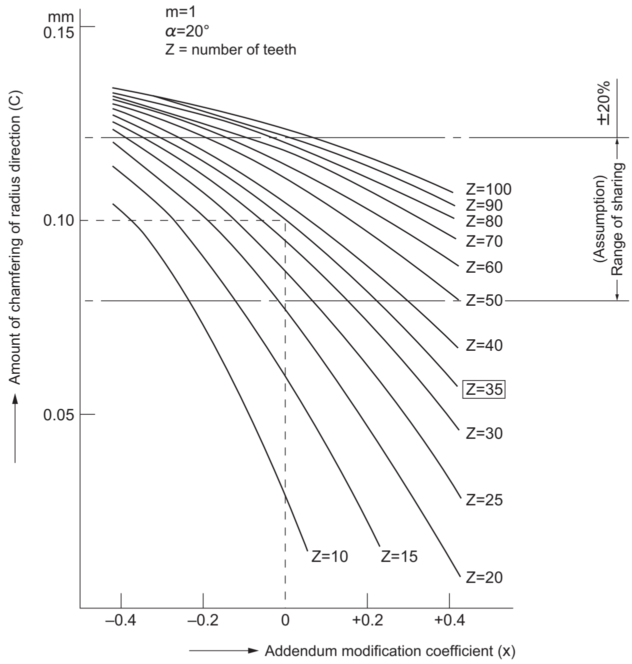


Fig.5 Relation of number of teeth, addendum modification coefficient and amount of chamfering

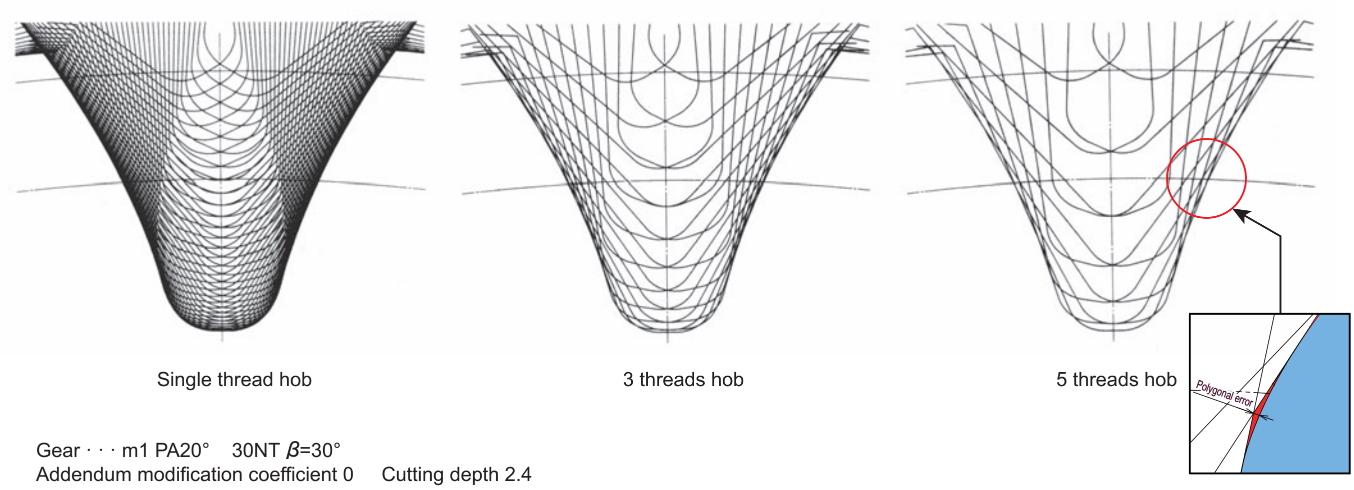
2-5 Multi-thread hob

(1) Machining efficiency and gear accuracy

Machining efficiency is improved by indexing speed's quickening. In case of single thread hob, the work piece is indexed one pitch per rotation of hob. And in case of n threads hob, since n pitches are indexed per rotation, it will be possible to cut gear at n times the speed.

However, since cutting load of the hob per tooth increases when indexing speed increases, it is necessary to reduce feed rate. Therefore, improvement of efficiency does not occur proportionally to number of thread.

Since the number of cutting edges, which finish up each tooth of the gear, decreases when multi-thread hob is used, polygonal error of tooth profile grows (A polygonal error of tooth profile is proportional to the second power of number of threads). When multi-thread hob is used cutting load grows, and when rigidity of the hobbing machine is low, the thread helix tends to bent.

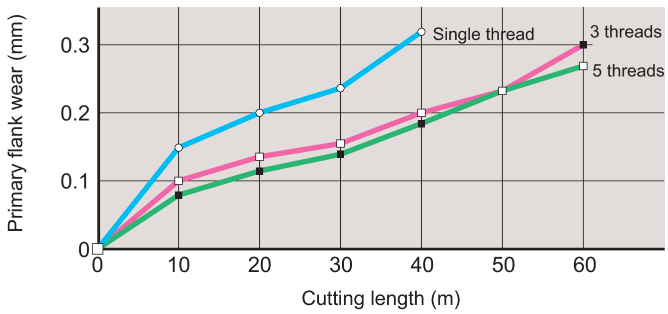


Gear · · · m1 PA20° 30NT β=30°
Addendum modification coefficient 0 Cutting depth 2.4
Hob · · · Addendum 1.4 12 gashes Top corner radius 0.3

Fig.6 State of generation of multi-thread hob

(2) Tool-life improvement by multi-thread hob

When machining with multi-thread hob, shape of chip (uncut-chip) shortens and becomes thick, and the point where the chip and the hob cutting face touch each other becomes far from the cutting edge. Moreover, improvement of machining efficiency using the multi-thread hob performs lowering cutting speed and feed per revolution while machining under the same conditions. This causes longer tool life. However, if the hobbing machine with a high rigidity, which can endure the increase of the cutting load, could not be used, sufficient effect might not be achieved.



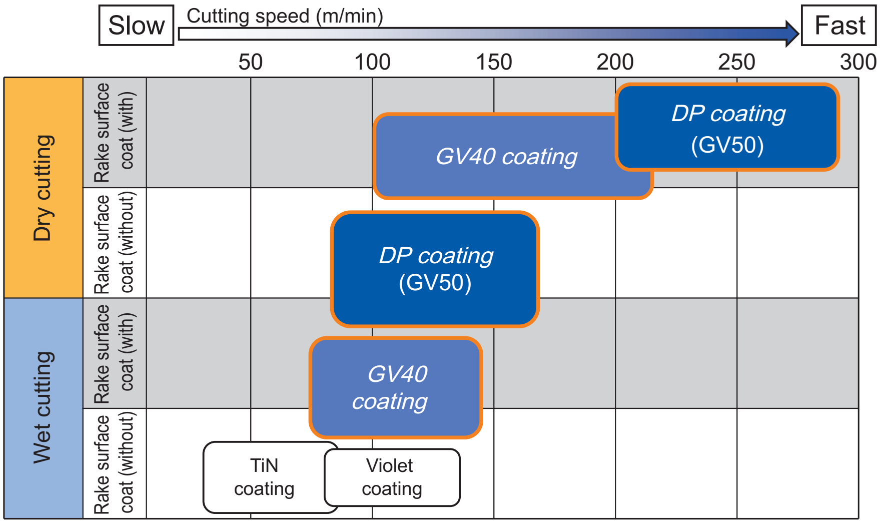
Hob : m2.5 PA20° ϕ90 12 gashes TiN coating
Gear : Number of teeth 31 Helix angle 30°34´RH Cutting depth 5.625
SCr420H(140-160HB)
Condition : Cutting speed 100 m/min Feed per rev. 3.1mm/rev Climb Non-shift

Fig.7 Number of threads and primary flank wear

2-6 Machining condition and efficiency

(1) Cutting speed

50-150 m/min is practical cutting speed in hobbing of small and medium-sized module gears. The applicable range of cutting speed depends on the kind of work material, hob material and coating.



(2) Feed per revolution

Feed per revolution is usually shown by the distance that the hob moves per rotation of the work piece.

Since feed per revolution greatly influences the finished surface, it is necessary to adopt a proper value according to the usage.

Feed mark height of gear bottom $f_R = R - \sqrt{R^2 - S^2/4}$

Feed mark height of gear tooth flank $f_S = f_R \times \sin\alpha$

R : Hob radius (mm)

S : Feed per rev. (mm/rev)

α : Pressure angle (deg)

Feed per revolution of n-threads hob : $Sn = (0.7)^{n-1} \cdot S$

S : Standard feed per rev. (mm/rev)

n : Number of threads

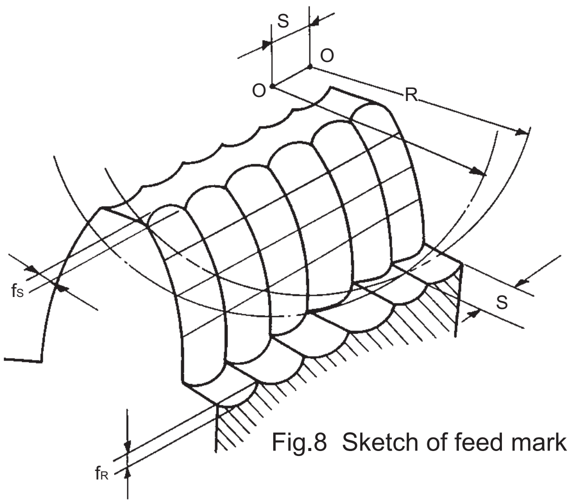


Fig.8 Sketch of feed mark

Usage	Feed per rev. (mm/rev)
Finishing	0.8～2.0
Pre-shaving	2.0～4.5
Pre-grinding	2.0～6.5

Fig.9 Standard feed

(3) Amount of shift

Timing for re-grinding is decided by the amount of maximum wear that occurs on the tooth of the leading side (in roughing area) of a hob.

This timing can be put off by moving the position of the hob to the direction of the hob axis and then dispersing maximum wear to some other teeth. In this way hob can manufacture gears as many as possible until next re-grinding.

This method is called shifting (Hob shifting). When continuously shifting, the amount of shift at least needed for one time can be obtained by expression (1) and (2).

① For straight gash hob

$$l = \frac{Zw \times m \times \pi}{\cos\gamma \times i} \quad \cdots\cdots\cdots\cdots (1)$$

② For helical gash hob

$$l = \frac{Zw \times m \times \pi \times \cos\gamma}{i} \quad \cdots\cdots\cdots\cdots (2)$$

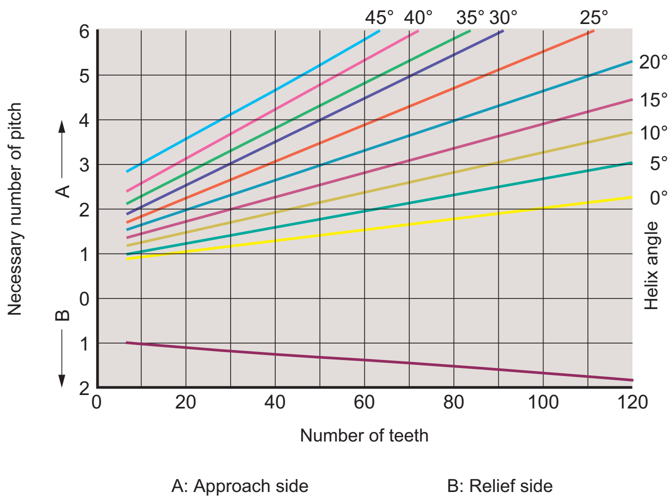


Fig.10 Necessary length of hob for both sides from center line of hobbing machine

l : Amount of shift (mm)

Zw : Number of threads of hob

γ : Tooth lead angle of hob (deg)

m : Module

i : Number of gashes of hob

Total amount of shift is calculated from necessary hob length for gear generating.

(4) Machining time

The hobbing time can be calculated from the following expression (3), including the dimension of work piece and the cutting condition.

$$T = \frac{Z \cdot l \cdot N}{F \cdot n \cdot Zw} = \frac{Z \cdot N\,(l_1 + b + l_2)}{F \cdot n \cdot Zw} \quad \cdots\cdots\cdots\cdots (3)$$

T = Gear cutting time of gear hobbing machine (minutes)

Z = Number of teeth of gear

b = Face width of gear (mm)

β_o = Helix angle of gear

d_K = Outside diameter of gear (mm)

d_C = Diameter of hob (mm)

h_K = Addendum of hob (mm)

h_e = Cutting depth of hob (D+F) (mm)

α_C = Pressure angle of hob

Z_W = Number of threads of hob

γ = Tooth lead angle of hob

ϕ = Inclination angle of hob

When hob has the same helix direction $\phi = \beta_o - \gamma$

When hob has different helix directions $\phi = \beta_o + \gamma$

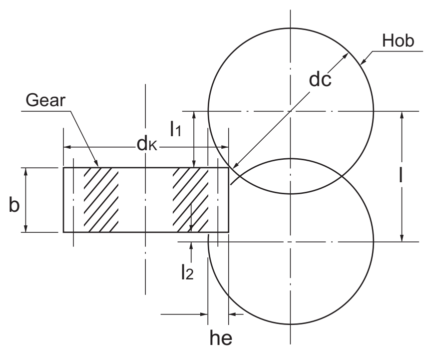


Fig.11 Sketch of feeding

l1 = Distance that hob moves in the beginning of cutting (mm)

Spur gear $l_1 > \sqrt{he\,(dc - he)}$

Helical gear $l_1 > \sqrt{he\left(\dfrac{dc + d_K - he}{\cos^2\phi} - h_K\right)}$

l2 = Distance hob moves at the end of cutting (mm)

Spur gear $l_2 > 0$

Helical gear $l_2 > \dfrac{h_K \cdot \cos\beta^\circ \cdot \tan\phi}{\tan\alpha_C}$

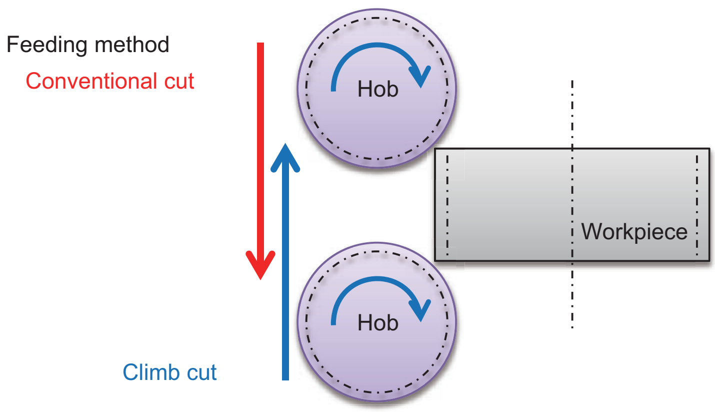
l = Distance that hob moves (mm)

F = Feed rate of hob per revolution (mm/rev)

n = Revolutions per minute of hob (min–1)

N = Number of cuttings (Number of cuts)

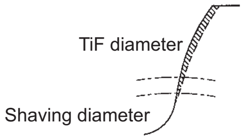
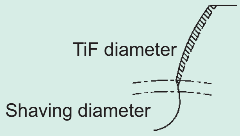
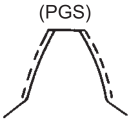
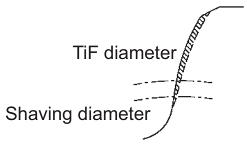
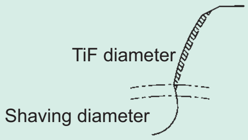
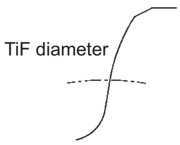
(5) Types of gear cutting methods



	Conventional cut	Climb cut
Primary flank wear	×	○
Chip biting	×	○
Finished surface roughness	○	△

2-7 Signs of cutter tooth profile

● Sign table

Kind of tooth profile	Sign and cutter tooth profile	Tooth profile of work piece	Explanation
Pre-shaving (for pre-shaving processing)	P (PG) 		It is pre-finishing tooth profile for shaving. Substract tooth thickness by the amount equivalent to shaving stock, and make cutter addendum high. In general, applied to gear with few number of teeth.
Pre-shaving Protuberance	PP (PGP) 		It is a tooth profile with the protuberance at the tooth end for pre-finishing. The contour of shaving cutter should not touch the fillet part of the bottom of the gear.
Pre-shaving Semi-topping	PS (PGS) 		It is pre-finishing tooth profile for shaving. It has semi-topping (chamfering) part for chamfering the gear's tooth top.
Pre-shaving Semi-topping Protuberance	PSP (PGSP) 		It is pre-finishing tooth profile for shaving. It has the protuberance and semi-topping (chamfering) part.
Semi-topping (for finishing)	S-TOP 		It is tooth profile with semi-topping (chamfering) part for chamfering the gear's tooth top.

Note 1. The signs in ( ) of the Table are for pre-grinding tooth profile.
2. The signs came from JIS B4350.

● Sign table

Kind of tooth profile \ Sign	The first order	The second order	The third order
Pre-shaving tooth profile	P (Pre-shaving)	S (Semi-topping)	P (Protuberance)
Pre-grinding tooth profile	PG (Pre-grinding)	S (Semi-topping)	P (Protuberance)
Tooth profile for finishing	————	S-TOP (Semi-topping)	————

2-8 Pre shaving hob (protuberance hob)

Protuberance hob is used for pre-finishing gears prior to shaving or grinding, with protuberance on the gear hob addendum. This is intended to prevent the tip of shaving cutter (or tip of grinding wheel) from interfering with the fillet of gear during shaving (or grinding).

The size of protuberance is generally determined by the shaving stock (grinding stock) and the effective working depth of the mating gear.

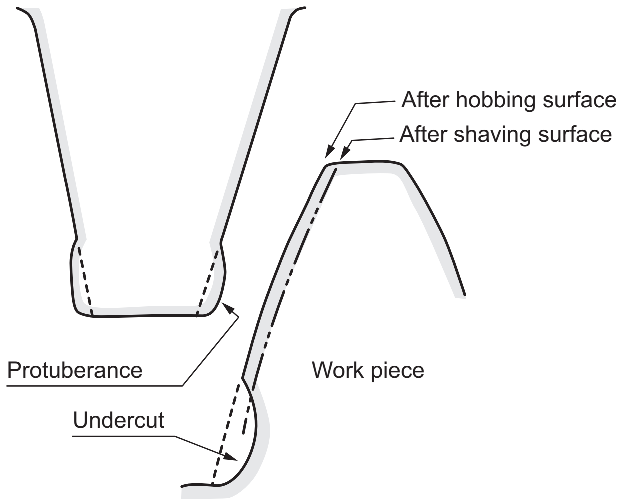


Fig.12 Protuberance hob

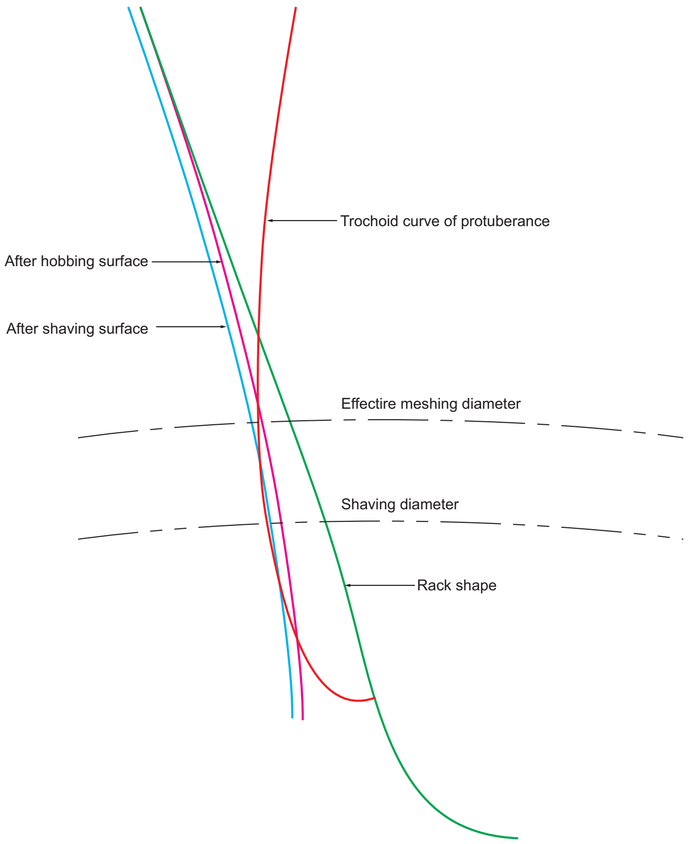
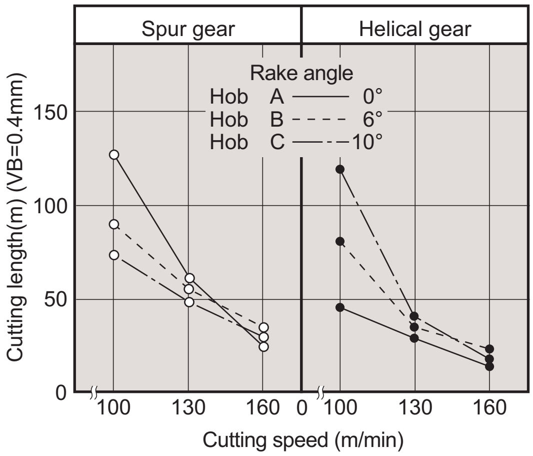


Fig.13 State of generation of tooth root of work piece

2-9 Effect of rake angle

In general, the rake angle of hob is provided for the purpose of improving the life of hob by sharpening the edge and smoothing a chip flow.

The cutting speed of 100 m/min remarkably increases the effect of rake angle, while the higher cutting speed of 130 or 160 m/min brings no effect of rake angle. The greater rake angle the gear hob has, the shallower the depth of crater (KT) gets. However, a distance between the deepest point of crater depth and the tip cutting edge (KM) will be shortened, causing the tip cutting edge to be retracted.



Hob : m2.5 PA20° 3RH ϕ180 Number of gashes 12 KMC3
Gear : Number of teeth 31T(spur) 28T(β=25°RH) SCM415(140~160HB) b=50mm
Cutting conditon : 4mm/rev Climb

Fig.14 Effect of rake angle in TiN coated hob

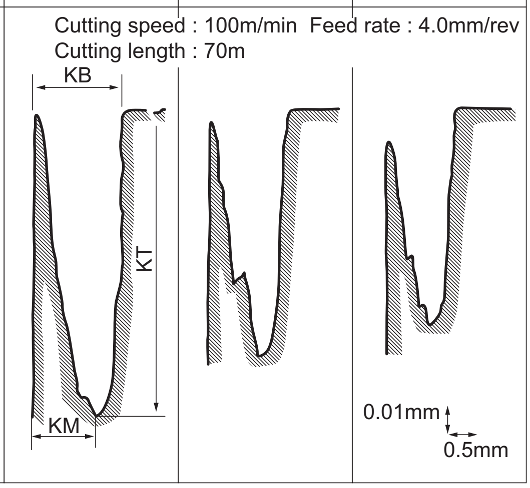
Type	Hob A	Hob B	Hob C
Rake angle	0°	6°	10°
Crater shape			

Fig.15 Craters of TiN coated hobs those which have different rake angle in spur gear cutting

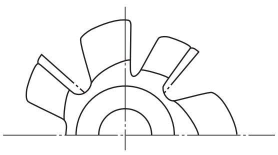
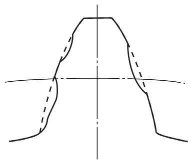
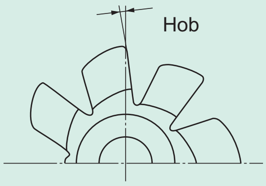
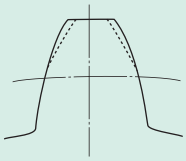
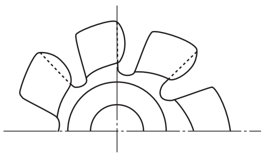
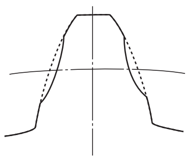
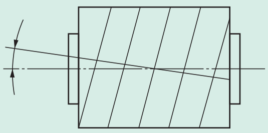
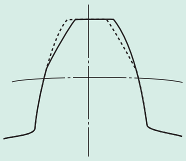
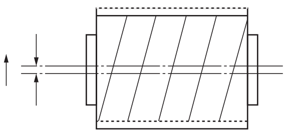
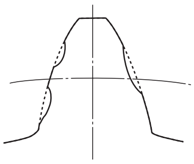
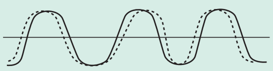
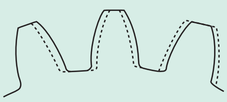
2-10 Selection of major dimensions

Classification		Merit/demerit
A. Material		• KMC3 is used for ordinary cutting. • KVC5 is recommended for high-speed wet cutting. • DH01B is recommended for high-speed dry cutting.
B. Coating		• Violet or Ti coating is used for medium / low-speed wet cutting. • DP coating is recommended for high-speed dry cutting. • GV40 with rake or DP coating is recommended for ultra high-speed dry cutting.
C. Accuracy		• A class is used for precision / pre-cutting under ordinary circumstances. • AA class is recommended when using for hob finishing.
Shape	D. Outside diameter	• Standard dimensions of catalog are used under ordinary circumstances. • Select diameter without interference, if the interference of work (shoulder gear) or hobbing machine occurs. • Rotation speed has been enhanced while maintaining cutting speed by decreasing diameter to realize high efficiency. Note: Functional width has been reduced to increase tooth lead angle. Bore diameter (hob arbor diameter) must be modified in some cases.
	E. Overall length	• Standard dimensions of catalog are used under ordinary circumstances. • In the case of mass production, possible shift range has been expanded lengthwise, and number of re-grindings per time has been increased. Number of cuts from overall length ratio has not been increased. Number of cuts from shift range ratio comparison has been increased. A dramatic effect can be obtained for large module work or work with many gear teeth and small shift range. • Check gear hobbing machine specifications or interference when shifting if altering overall length.
	F. Number of threads	• Using the proper multi-thread hob not only increases efficiency, but enables control of cutting edge retreat and collapse as well. (To move away from edge of blade by cutting crater wear by making cuttings thicker or shorter) • Since cutting load is increased by adding multi-thread hob, tooth curves, etc., that may negatively affect precision may be produced. • The limitation of adding threads is generally as follows: No. of teeth divided by 6 or less (ex.: up to 2 threads for 12 teeth); tooth lead angle 10° or less $\text{Tooth lead angle} = \sin^{-1}\left(\frac{\text{Module} \times \text{Number of threads}}{\text{Hob outside diameter} - \text{Hob addendum} \times 2}\right)$ Up to the 6-threads type has been actually used in production lines.
	G. Number of gashes	• Standard dimensions of catalog are used under ordinary circumstances. • For increase in number of gashes, feed per revolution can be increased to enhance efficiency. Deterioration of multiple thread gear hobbing precision can be mitigated. • Functional width is reduced by increasing the number of gashes.
	H. Rake angle	• 0° is used under ordinary circumstances. • Effect differs according to circumstances even if it is used to enhance sharpness. Crater wear is reduced by applying rake angle; the deepest part however tends to be near the edge.
	I. Chip space lead	• It is best to attach a lead at a right angle to the tooth for the shape of the tool if tooth lead angle increases. Difficulty of re-grinding however increases. • Effective at same timing for cutting in overall length direction such as hob for rack.

2-11 Re-grinding and tooth profile error of hob

Table 1 Re-grinding condition (CBN Wheel)

Grinding speed	Feed speed	Depth of grind
1,800–2,000m/min	150–250mm/min	0.1–0.15mm/PASS

	Shape of hob	Tooth profile of work gear	Error
Gash spacing error	Hob 	Tooth profile 	Approximately 6μm of tooth profile error when gash spacing error is 0.1mm
Radial alignment of cutting face	Hob 	Tooth profile 	Approximately 3' of pressure angle error when radial alignment of cutting face is 1°.
Bulge of cutting face	Hob 	Tooth profile 	Approximately 6μm of tooth profile error when a convex amount of tooth face is 0.1mm.
Gash lead error	Hob 	Tooth profile 	Approximately 10' of pressure angle error when gash lead error is 1°.
Runout of clamp	Hob 	Tooth profile 	Approximately 9μm of tooth profile error when runout is 0.025mm.
Multi-thread hob	Cutting face pitch error 	Tooth profile 	The cutting face pitch error causes a pitch error directly (tooth space runout).

2-12 Troubles and solutions

Trouble	Cause	Solution
A. The tooth profile error is terrible	Hob gash spacing error	● Check the indexing error during re-grinding.
	Hob lead error	● Check the hob lead error (accumlative error in some comvolution).
	Awkward hob clamp	● Check the eccentricity (runout) of the hob on the hob arbor.
	Slack in hob axial direction	● Check the thrust of hob arbor. ● Check the damage on end metal.
B. The pressure angle error is terrible	Hob radial alignment of cutting face	● Check to see if the offset quantity of grinding wheel is correct during re-grinding.
	Hob pressure angle error	● Check the hob pressure angle.
	Use in excess of effective cutting tooth width of hob	● Check the effective width of cutting tooth and residual width of cutting tooth.
	Awkward gear mounting	● Check the inclination of gear. ● Check the runout of gear end face.
	Measuring error	● Check the data on the measuring instrument. ● Check the mounting on the measuring instrument.
C. The chamfering shape error is terrible	Hob radial alignment of cutting face	● Check to see if the offset quantity of grinding wheel is correct during re-grinding.
	Hob semi-topping starting point dimension error	● Check the hob semi-topping starting point dimension.
	Gear tooth thickness error	● Check the tooth thickness of gear.
	Gear outside diameter error	● Check the outside diameter of gear.
	Hob clamp angle error (Semi-topping decreases.)	● Check the helix angle of gear and the tooth lead angle of hob. (Exercise care in case of hob designed for profile shifted method.)
D. The gear surface is rough	Deterioration of hob sharpness	● Reexamine the gear quantity for hobbing. ● Measures to prevent wear (change in hob material and coating).
	Problems with cutting oil	● Use of cutting oil that hardly allows adhesion. ● Increase of supply. ● Substitute a new oil. (Deterioration).
E. Wear is terrible	Insufficient hob wear resistance	● Adopt a coating with high wear resistance. ● Adopt materials that excel in crater resistance.
	High cutting speed	● If possible, slow down the cutting speed. If the drop in efficiency is a problem, examine the possibility of decreasing the hob diameter or increasing the number of threads.
	Problems with machining facilities/jigs.	● Check that the quantity of wear has not changed. ● Check that wear is occur in specific machining facilities or not.
F. Chipping is caused	Insufficient hob toughness	● Adopt tough materials.
	High feed speed	● If possible, decrease the feed per revolution. If the drop in efficiency is a problem, examine the possibility of decreasing the hob diameter or adopting coating that excels in wear resistance in order to increase the cutting speed.
	Terrible crater	● The measures to take to cope with chipping due to the collapse of crater wear is different. In such cases slow down the cutting speed and adopt materials that excel in crater resistance.
	Problems with machining facilities/jigs.	● Check that the state of chipping generation has unchanged. ● Check that chipping is caused in specific machining facilities or not.

2-13 Coated hob

Table 2 Comparison of coating performance

	TiN coating	Violet coating	GV40 coating	DP (GV50) coating
Hardness (HV)	1,900	2,800	3,500	3,300
Oxidation temperature (°C)	620	840	1,100	1,250
Cutting applications	Wet	Wet	Dry wet	Dry wet
Re-coat with and without	Without	Without	With	Without, With
Wear resistance	△	○	◎	◎
Heat resistance	×	△	○	◎

(1) TiN coated hob

The tool life of TiN coated hob is four times or more as long as that of a non-coated hob. Therefore TiN coated hobs are generally used these days.

Table 3 Features of coated film

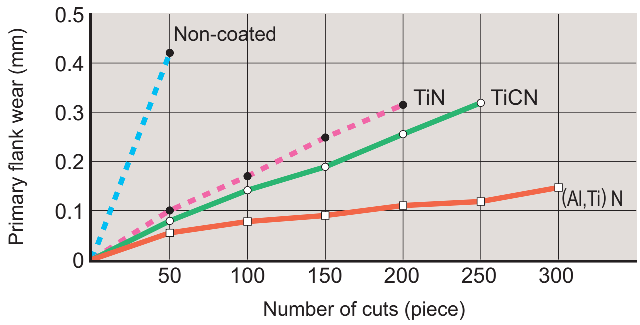
	(Al,Ti)N	TiN
Hardness of film (HV)	2,700～2,900	1,800～2,000
Oxidation Temperature r	800～900	600～700

(2) Violet coated hob

The quality of coating film for the hob is special single-layer (Al,Ti)N film originally developed in our company, and its tool life is far exceeding that of TiN or TiCN coated hobs.

● Features

1) Wear resistance has improved greatly owing to film hardness which is 1.5 times larger than that of TiN (twice or more the tool life of TiN).
2) It excels in heat resistance, and be able to high efficient hobbing.



Hob : m2.5 PA20° 3RH &80 12 gashes Tool material KMC3
non coated cutting face
Gear : Number of teeth 31 Helix angle 30° 34´RH Cutting depth 5.625
Width 25 SCr420H (140-160HB)
Condition : Cutting speed 100 m/min Feed per rev. 3.1mm/rev Climb
Non-shift Coolant HS4M

Fig.16 Amount of wear of coated hob

(3) DP coated hob

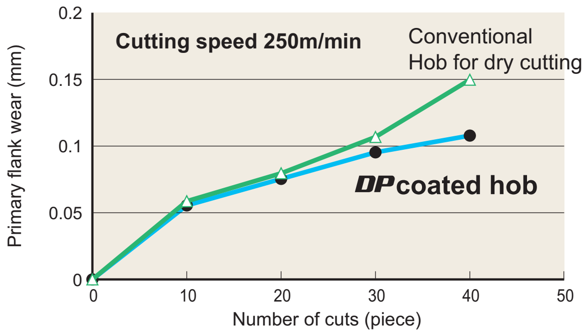
- Coated hob designed for high-speed cutting
- Re-grinding specifications

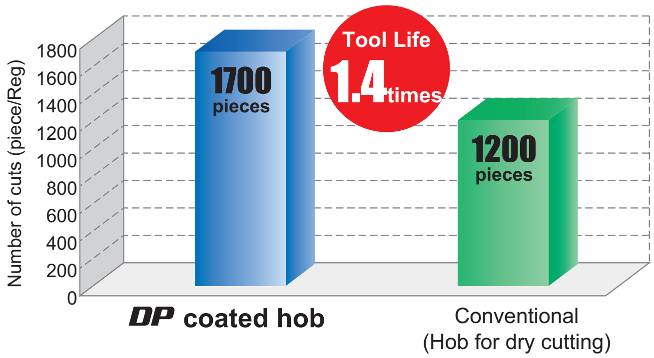
- **Features**

For use with improving heat-resistance and wear-resistance compared to conventional (Al, Ti) N-coating, and especially with high-speed dry cutting. Long product life with even high-speed machining of 200m/min. or more cutting speed, based on processing of high-speed machining design and smooth surface.

- **Cutting example (Dry cut)**

Exhibiting excellent cutting performance with dry cutting of non-coated rake surface following high-speed dry cutting at a cutting speed of 250m/min. or more.



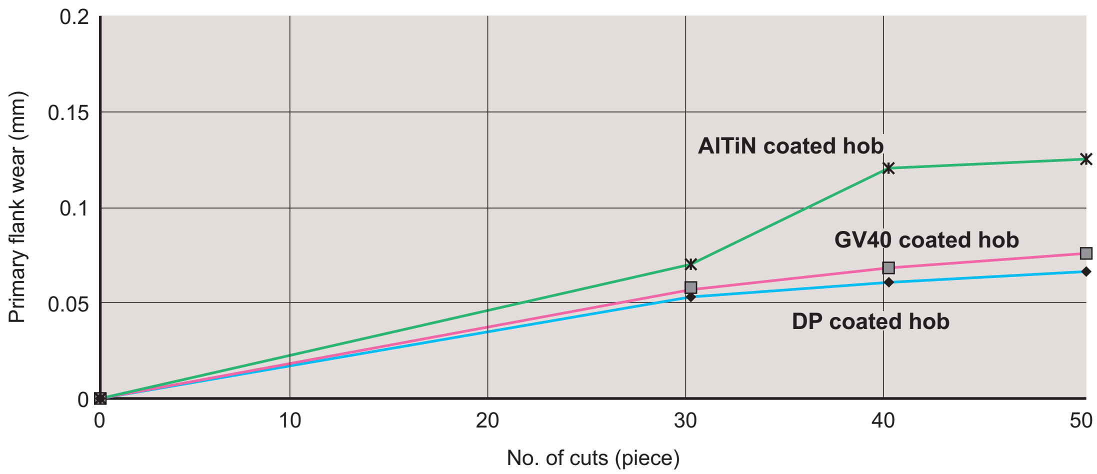


Hob	ϕ85 x 100 With rake surface coating
Gear dimension	m1.75 PA17.5° NT48 Left torsion25° Tooth width50mm SCr420H
Cutting conditions	vc=250m/min Dry cut (Air blow)

Hob	Without rake surface coating
Gear dimension	m2.7 PA18.5° NT18 automobile parts SCr420H
Cutting conditions	vc=130m/min Dry cut (Air blow)

(4) GV40 coated hob

- Coated hob designed for high-speed cutting
- Re-coating specifications



Hob	ϕ85 x 100 With rake surface coating
Gear dimensions	m1.75 PA17.5° NT48 Left torsion 21° Tooth width50mm SCr420H
Cutting conditions	vc=200m/min Dry cut (Air blow)

2-14 Carbide hob

A carbide hob is a solid type capable of smaller diameter, multiple gash, multiple thread machining. Offers superior high temperature characteristics and is provided with (Al, Ti) N coating that is ideal for dry cutting.

● Highly accurate

A highly accurate solid carbide hob have been manufactured owing to shrinkage control in sintering and superior grinding technology.

● Possible to handle small diameter/multi gash hobbing.

Since it is a solid type, it can realize small diameter and multi gash design and manufacturing as same as HSS hob.

● Multi thread hobbing

In addition to the adoption of special carbide material excelling in chipping and heat resistance, the best design is applied so as to make high efficiency multi thread hobbing possible.

● Miracle coating

Due to (Al,Ti)N coating with high hardness and excellent oxidation resistance, super-high-speed hobbing at 300 m/min or above is possible.

Hob	: m1.75 PA17.5° 3LH ϕ80 × 120mm 20 gashes
Gear	: Number of teeth 33 Helix angle 36° LH
	Cutting depth 5.86 Face width 15.5 SCr420H
Condition	: Cutting speed 320 m/min
	Feed per rev. 2.5mm/rev
	Climb Non-shift Without coolant

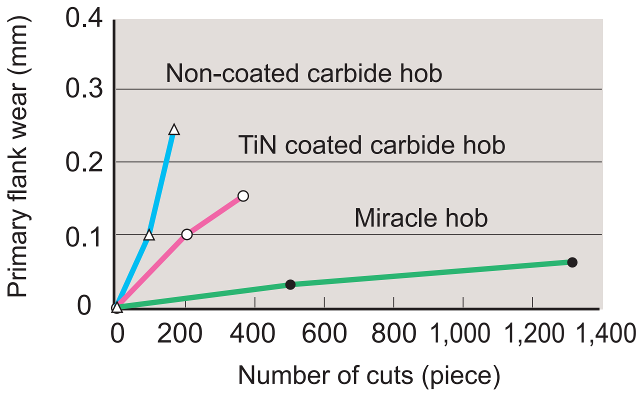
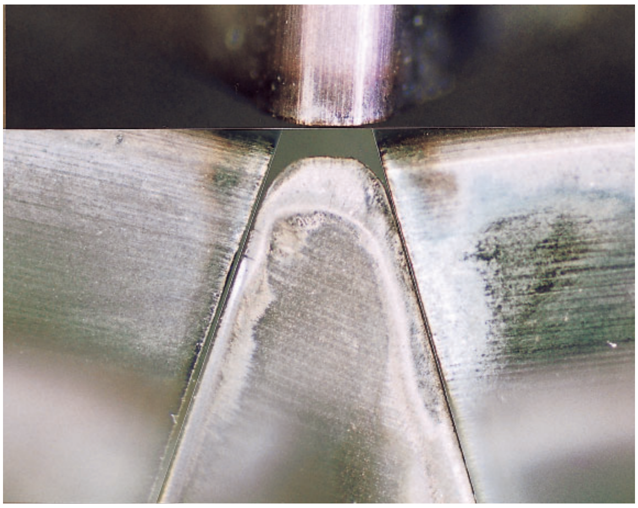
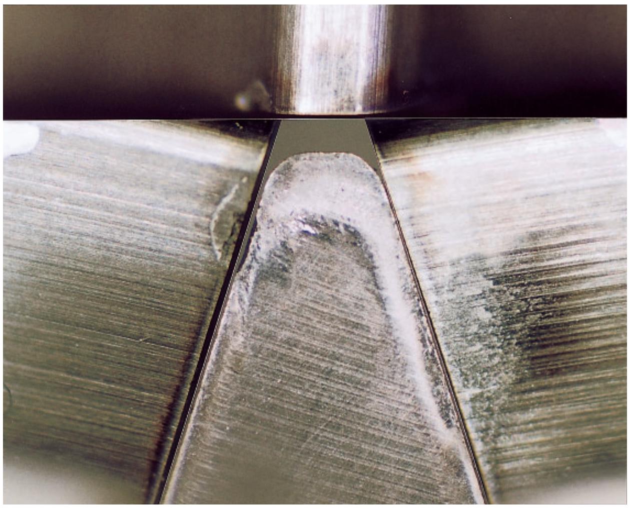


Fig.17 Comparison of the amount of wear in variety of coating

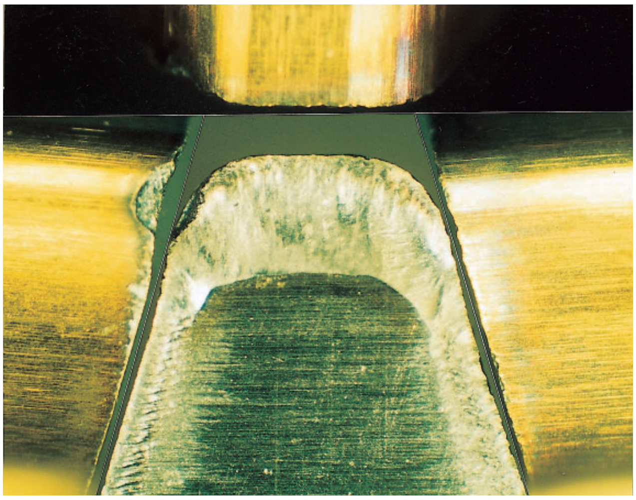


Miracle hob
(Number of cuts: 1,250 pieces)

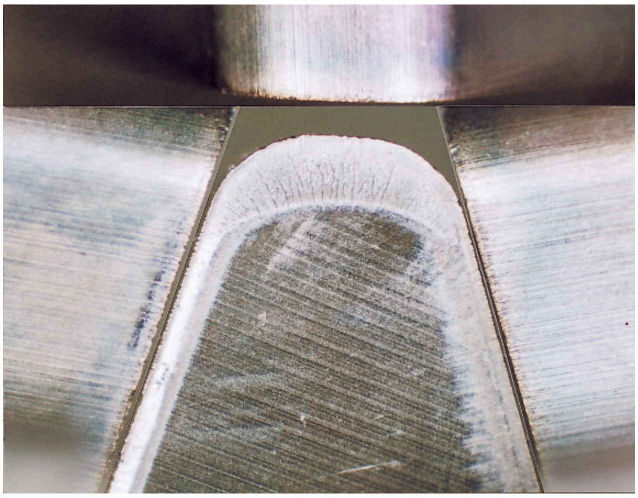


Non-coated carbide hob
(Number of cuts: 160 pieces)

Photo. 1 Comparison of the condition of wear between Miracle Hob and Non-coated carbide hob



Miracle hob
(Number of cuts: 800 pieces)



TiN coated HSS hob
(Number of cuts: 5,600 pieces)

Photo. 2 Comparison of wear condition between Miracle Hob and HSS hob

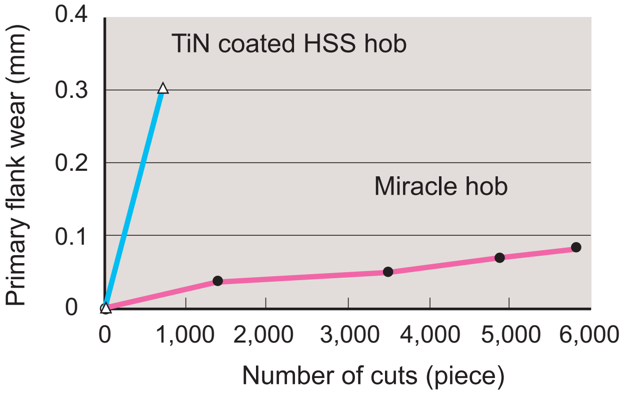
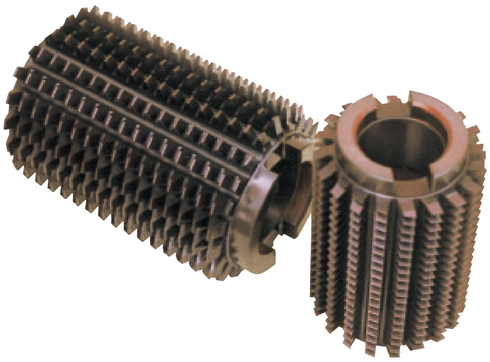


Fig.18 Cutting example of Miracle hob

Hob	: m2.4 PA17.5°	
	Miracle hob	3RH &90 × 130mm 20 gashes
	TiN coated HSS hob	1LH &90 × 150mm 12 gashes
Gear	: Number of teeth 30 Helix angle 23° LH Cutting depth 6.3	
	Face width 26 SCM420(160-200HB)	
Condition	: Miracle hob	Cutting speed 335 m/min
		Feed per rev. 1.85mm/rev
		Reverse-handed conventional
		Without coolant
	TiN coated HSS hob	Cutting speed 88 m/min
		Feed per rev. 3.0mm/rev
		Handed climb With coolant



2-15 Hob for rack

A rack of rack & pinion, which makes a part of steering device of an automobile is one of parts that are formed by relieving cutter. It is required to have high accuracy because it influences steering of a car. Hob for rack has the following features.

1)Tooth shape accuracy such as tooth thickness and pressure angle, etc. is within several micrometers.

2)It possesses 20 to 50 teeth, and the accumulative pitch error is under 20μm.

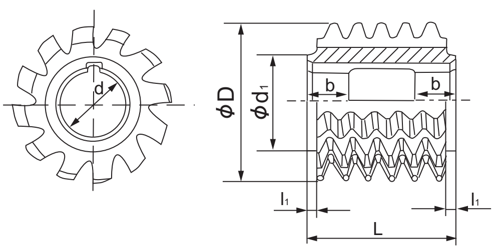
3)As for a hob for rack of variable tooth thickness, tooth thickness and pitch should be changed by several micrometers.

2-16 Solid hob size table

<table>
<tr><th colspan="3">Module</th><th rowspan="3">Diametral pitch DP</th><th rowspan="3">Outside diameter D</th><th colspan="2">Overall length</th><th colspan="2">Bore diameter</th><th rowspan="3">Hub length l_1</th><th rowspan="3">Number of gashes N</th><th rowspan="3">Hub diameter d_1</th><th rowspan="3">Bearing length b</th></tr>
<tr><th colspan="3">Series</th><th rowspan="2">L</th><th rowspan="2">L_0</th><th rowspan="2">A type</th><th rowspan="2">B type</th></tr>
<tr><th>1</th><th>2</th><th>3</th></tr>
<tr><td>1</td><td></td><td></td><td>24</td><td rowspan="2">50</td><td rowspan="2">50</td><td rowspan="2">65</td><td rowspan="8">22</td><td rowspan="8">22.225</td><td rowspan="15">4</td><td rowspan="4">12</td><td rowspan="2">34</td><td rowspan="2">12</td></tr>
<tr><td>1.25</td><td></td><td></td><td>20</td></tr>
<tr><td>1.5</td><td></td><td></td><td>16</td><td rowspan="2">55</td><td rowspan="2">55</td><td rowspan="2">70</td><td rowspan="2">36</td><td rowspan="2">14</td></tr>
<tr><td></td><td>1.75</td><td></td><td>14</td></tr>
<tr><td>2</td><td></td><td></td><td>12</td><td rowspan="2">60</td><td rowspan="2">60</td><td rowspan="2">75</td><td rowspan="11">10</td><td rowspan="4">38</td><td rowspan="2">15</td></tr>
<tr><td></td><td>2.25</td><td></td><td>11</td></tr>
<tr><td>2.5</td><td></td><td></td><td>10</td><td rowspan="2">65</td><td rowspan="2">65</td><td rowspan="2">80</td><td rowspan="2">16</td></tr>
<tr><td></td><td>2.75</td><td></td><td>9</td></tr>
<tr><td>3</td><td></td><td></td><td>8</td><td rowspan="2">70</td><td rowspan="2">70</td><td rowspan="2">85</td><td rowspan="7">27</td><td rowspan="7">26.988</td><td rowspan="2">42</td><td rowspan="2">18</td></tr>
<tr><td></td><td></td><td>3.25</td><td></td></tr>
<tr><td></td><td>3.5</td><td></td><td></td><td>75</td><td rowspan="2">75</td><td rowspan="2">90</td><td rowspan="2">45</td><td rowspan="3">20</td></tr>
<tr><td></td><td></td><td>3.75</td><td>7</td><td>80</td></tr>
<tr><td>4</td><td></td><td></td><td>6</td><td>85</td><td>80</td><td>95</td><td rowspan="3">50</td></tr>
<tr><td></td><td>4.5</td><td></td><td>5½</td><td>90</td><td>85</td><td>100</td><td rowspan="2">22</td></tr>
<tr><td>5</td><td></td><td></td><td>5</td><td>95</td><td>90</td><td>105</td></tr>
<tr><td></td><td>5.5</td><td></td><td>4½</td><td>100</td><td>95</td><td>110</td><td rowspan="7">32</td><td rowspan="7">31.75</td><td rowspan="7">5</td><td rowspan="9">9</td><td rowspan="4">55</td><td>24</td></tr>
<tr><td>6</td><td></td><td></td><td></td><td>105</td><td>100</td><td>115</td><td>25</td></tr>
<tr><td></td><td></td><td>6.5</td><td>4</td><td>110</td><td>110</td><td>125</td><td rowspan="2">28</td></tr>
<tr><td></td><td>7</td><td></td><td>3½</td><td>115</td><td>115</td><td>130</td></tr>
<tr><td>8</td><td></td><td></td><td>3</td><td>120</td><td>130</td><td>145</td><td rowspan="3">60</td><td>32</td></tr>
<tr><td></td><td>9</td><td></td><td>2¾</td><td>125</td><td>145</td><td>160</td><td>36</td></tr>
<tr><td>10</td><td></td><td></td><td>2½</td><td>130</td><td>160</td><td>175</td><td>40</td></tr>
<tr><td></td><td>11</td><td></td><td>2¼</td><td>150</td><td>175</td><td>195</td><td rowspan="4">40</td><td rowspan="4">38.1</td><td rowspan="6">6</td><td rowspan="2">65</td><td>44</td></tr>
<tr><td>12</td><td></td><td></td><td></td><td>160</td><td>190</td><td>210</td><td>48</td></tr>
<tr><td></td><td>14</td><td></td><td></td><td>180</td><td>210</td><td>230</td><td rowspan="4">8</td><td rowspan="2">70</td><td>52</td></tr>
<tr><td>16</td><td></td><td></td><td>1½</td><td>200</td><td>230</td><td>250</td><td>58</td></tr>
<tr><td></td><td>18</td><td></td><td></td><td>220</td><td>250</td><td>270</td><td rowspan="2">50</td><td rowspan="2">50.8</td><td rowspan="2">80</td><td>62</td></tr>
<tr><td>20</td><td></td><td></td><td>1¼</td><td>240</td><td>270</td><td>290</td><td>68</td></tr>
</table>

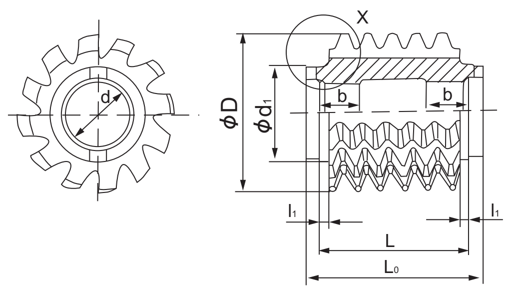
Note) Outside diameter, overall length, bore diameter are different from those mentioned above can be manufactured as well

With keyway



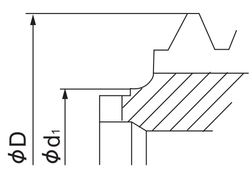
Number of gashes

With key slot



Number of gashes

X part closeup.



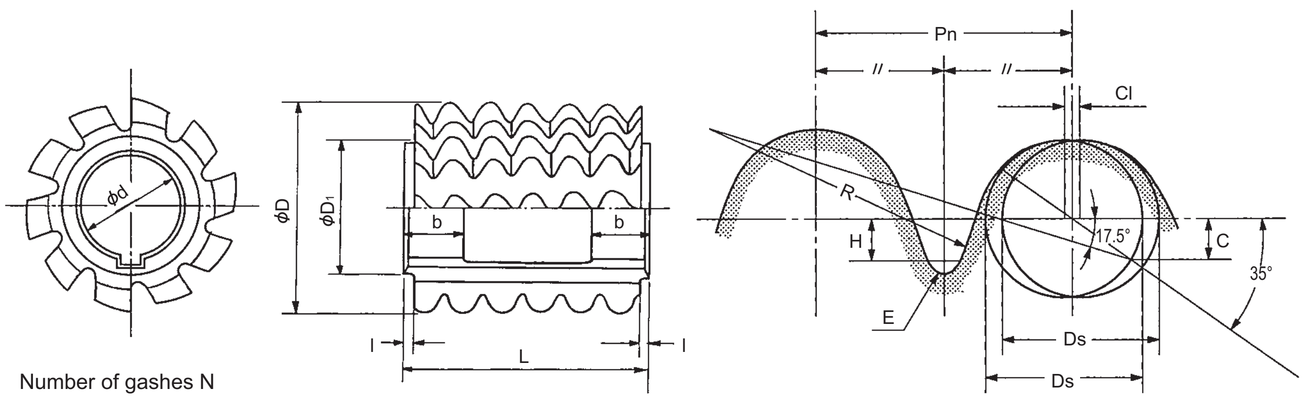
2-17 Sprocket hob size table

Unit : mm

Chain pitch (CP)	D	L	d		Reference		
			A type	B type	b	l	N
6.35	60	60	22	22.225	15	4	12
9.525	65	65	//	//	16	//	//
12.7	75	75	27	26.988	18	//	10
15.875	85	90	//	//	22	//	//
19.05	90	105	//	//	26	5	//
25.4	110	125	32	31.75	32	//	9
31.75	120	140	//	//	35	//	//
38.1	130	170	//	//	42	6	//

Standard tooth profile of sprocket hob (ASAI type)

Roller chain bearing number	CP: Chain pitch	Dr: Diameter of roller	Pn: Hob pitch 1.011P	Cl 0.07(P−Dr)+0.05	Ds 1.005Dr+0.08	C 0.287Ds	H 0.27P	E 0.03P
40	12.70	7.94	12.84	0.38	8.06	2.31	3.43	0.38
50	15.88	10.16	16.05	0.45	10.29	2.95	4.29	0.48
60	19.05	11.91	19.26	0.55	12.05	3.46	5.14	0.57
80	25.40	15.88	25.68	0.72	16.04	4.60	6.86	0.76
100	31.75	19.05	32.10	0.94	19.23	5.52	8.57	0.95
120	38.10	22.23	38.52	1.16	22.42	6.43	10.29	1.14



(Note) Cl=0 for the ASAII type.

3.Shaper cutter

3-1 Features

The principle of the gear cutting with shaper cutter can be explained as follows. The cutter reciprocates in the direction of the gear tooth line to produce one virtual gear. The relactive movement is also compulsorily given, as the gear material correctly mesh with this. Then it shaves off the part which disturbs the movement of teeth of a virtual gear from the gear material, and finally, the tooth profile of the gear is generated (Refer to Fig.1, 2).

Above process has enabled features below.

(1) It can handle gear cutting of an internal gear.

(2) It can handle gear cutting of a layered gear.

(3) It can handle gear cutting of a special gear. (united or lacked teeth gear)

Fig.3, 4 show gear cutting of spur or helical type.

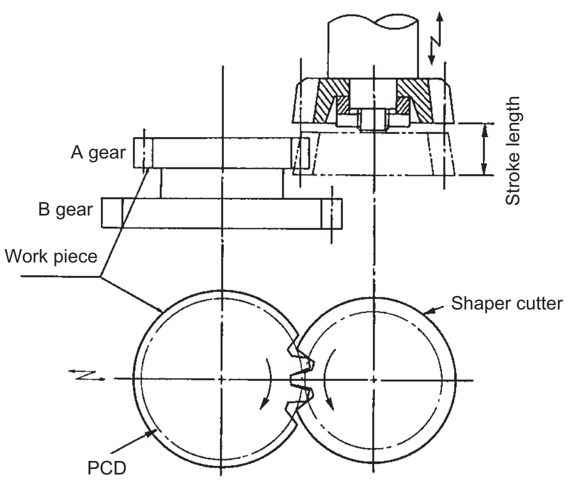


Fig.1 Gear cutting by shaper cutter

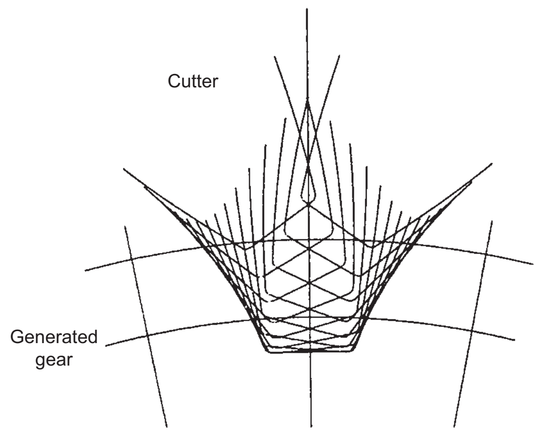


Fig.2 Generation of gear tooth profile by shaper cutter

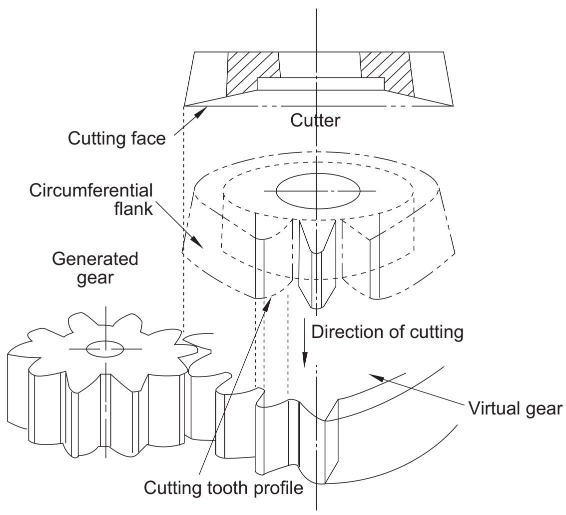


Fig.3 Gear cutting by spur type shaper cutter

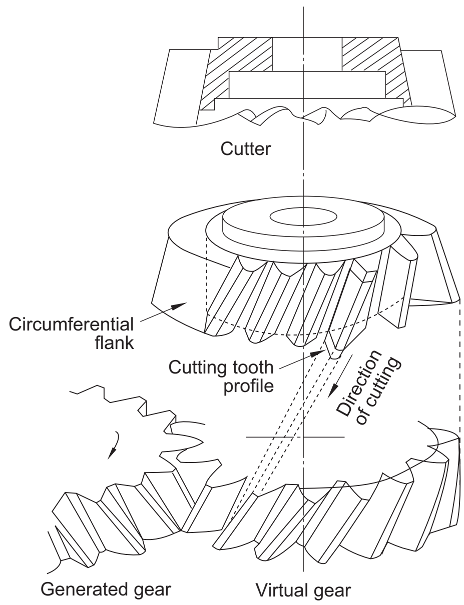


Fig.4 Gear cutting by helical type shaper cutter

3-2 Cutting mechanism of gear shaper

Fig.5 shows one example of mechanism charts of a gear shaper when it generate a gear with a shaper cutter.

The arm swings when the crank is rotated by the motor of the gear shaper. Then the cutter spindle moves vertically. There is a guide on the upper part of the cutter spindle, in the fundamental gear above. When cutting a spur gear, an untwisted straight guide should be used, and when cutting a helical gear, a helical guide should be used. The cutter spindle should be moved vertically while rotating, according to the helix angle of the work gear.

Rotation of the motor is transmitted to the fundamental gear above through the feed change gear, and gives the cutter spindle the feed in the rotating direction.

The movement from the motor diverges from the cutter conduction system, and is transmitted through the index change gear to the fundamental gear below, that rotates the gear material at a fixed speed ratio related to the cutter.

In order to protect the tooth flank from getting damaged by the return stroke of the cutter, it is necessary to keep the centers of the cutter and the work gear apart. Therefore, there is a table release mechanism though it is not shown in the figure (A cutter release mechanism is included in a large-scale mechanism).

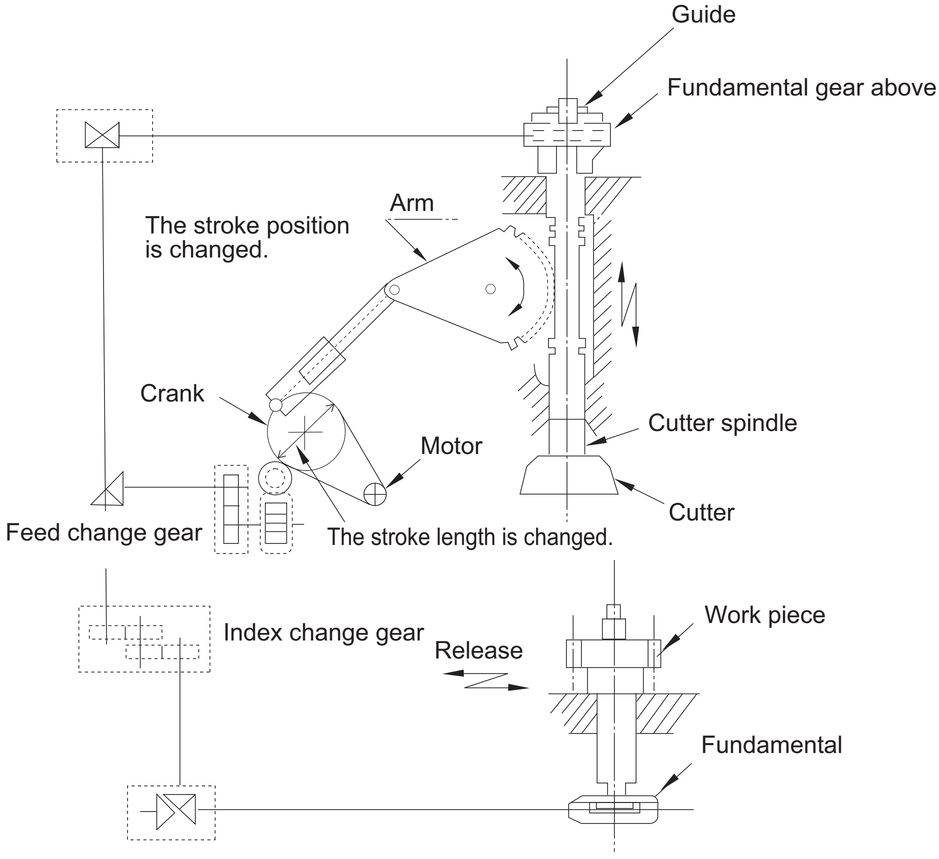
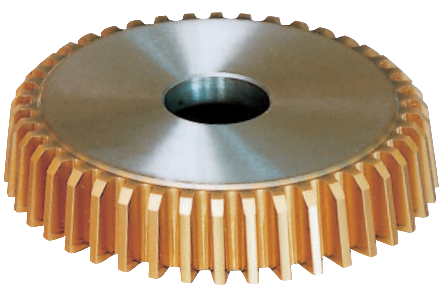


Fig.5 Mechanism chart of gear shaper



3-3 Selection of tool shape and part names

● Selection of tool shape

Type	Usage	Shape
Disk type	Gear cutting of shoulder gear and internal gear	Fig. 6-1
Counter-bore type	Gear cutting of shoulder gear (When the diameter of the layered part is large) Gear cutting of internal gear	Fig. 6-2
Shank type	When you cannot keep the cutter's number of teeth for the reason of interference etc. at the gear cutting (for internal gear chiefly)	Fig. 6-3

● Shaper cutter material selection list

Cutting mode / Tool material	Standard cutting	Heavy cutting	High speed cutting*	High hardness difficult-to-cut material
KMC3 Dissolution high-speed steel, first recommendation of material quality	○		●	
KHA Powder high-speed steel, first recommendation of material quality		○	●	○
KHAZ high-alloy powder high-speed steel		◎	●	◎

*Machining possible in high-speed cutting region based on provision of coating layer.

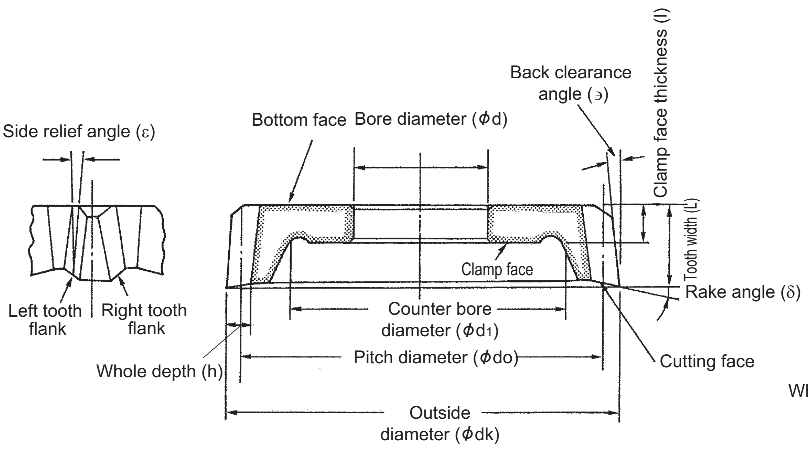


Fig.6-1 Disk type

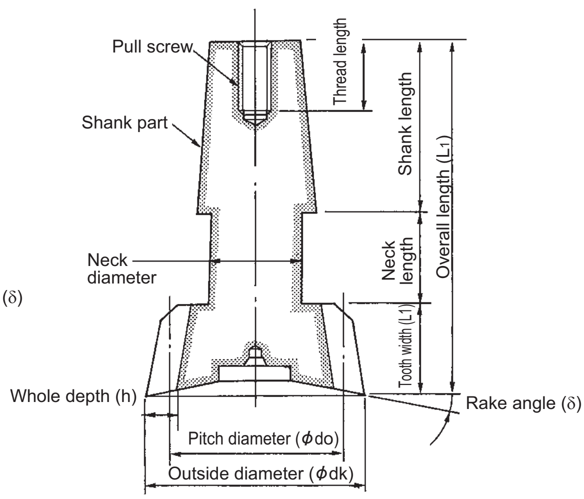


Fig.6-3 Shank type

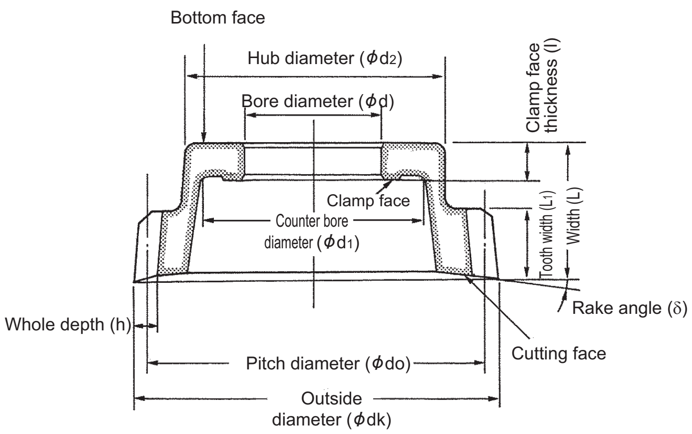


Fig.6-2 Counter-bore type

3-4 Selection of major dimensions

(1) Module and pressure angle

Normal module and normal pressure angle of the cutter should be the same as those of the work gear.

(2) Helix angle

Helix angle on the pitch cylinder of the cutter should be the same as that of the work gear.

(3) Number of teeth

Number of teeth is controlled by the helical guide in case of a helical gear (Fig.7 and Expression 1), and by the interference in case of a internal gear (5-2).

Number of teeth $(Z)=\dfrac{L \sin \beta_{\circ}}{\pi m_{n}}$ ………… (Expression 1)

(4) Helical guide

(4-1) Selection of helical guide

Lead of helical guide (L) = $\pi D°/\tan\beta°$

$\pi mnZ/\sin\beta°$

When machining the same type of helical gears by gear shaper and if changing the number of teeth of the shaper cutter, it is necessary to change the lead of helical guide accordingly (Fig.8).

e.g. Cutting a helical gear of mn2.5, PA20°, β°20° RH, 40T

1) With shaper cutter with 30T : Lead of helical guide = 688.905
2) With shaper cutter with 50T : Lead of helical guide = 1148.175

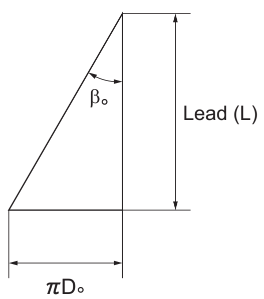
(4-2) Sharing of helical guide

Note that an error is caused between the helix angle (β'°) on the pitch cylinder of the work gear and the base helix angle (β°) on the pitch cylinder when the helical guide is shared.

$\beta'_{\circ} = \tan^{-1}\left(\dfrac{\pi D_{\circ}}{L}\right)$ Error : $\Delta\delta=\beta'_{\circ}-\beta_{\circ}$

L : Shared helical guide lead

$= \sin^{-1}\left(\dfrac{\pi m_n Z}{L}\right)$



m_n : Normal module
Z : Cutter number of teeth
$\beta_{\circ}$: Helix angle on pitch circle
$D_{\circ}$: Pitch circle diameter

Fig.7 Lead of helical guide

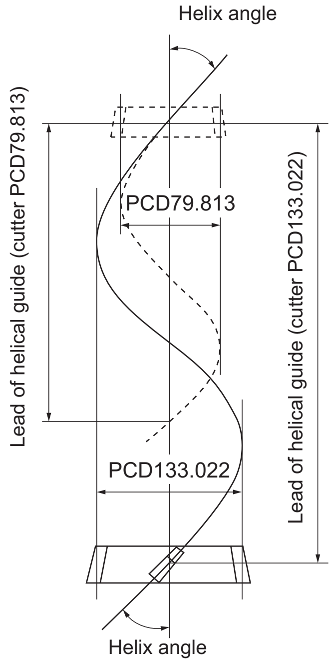


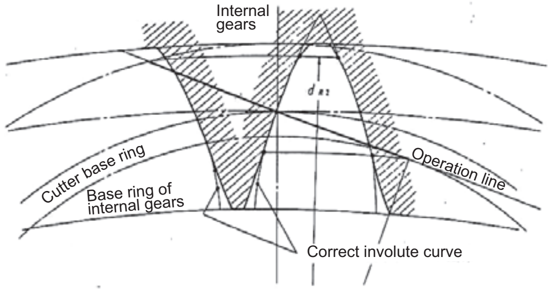
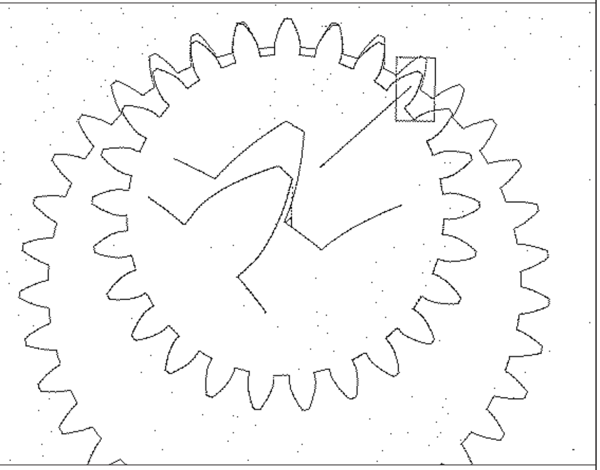
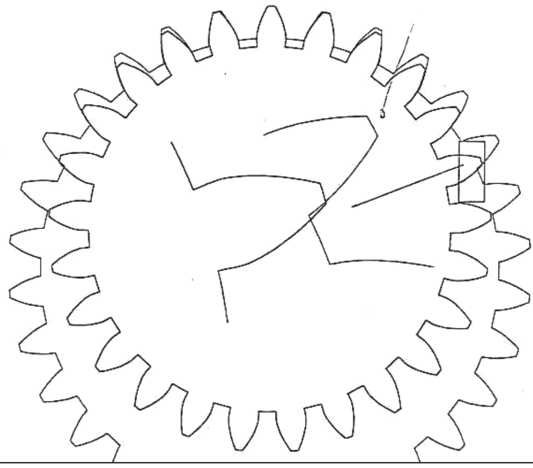
Fig.8 Number of cutter teeth and lead of helical guide

(5) Internal gear

(5-1) Interference

Major characteristic of gear cutting by shaper cutter is that it can carry out generation cutting of an internal gear. However, in cutting internal gears, interference happens more easily than in cutting external gears. Therefore types of internal gears to be cut and designs of shaper cutters are limited.

There are three types of interference caused in cutting internal gears.

Type	Phenomenon	
Involute interference	It is caused when the number of teeth difference between the internal gear and the cutter is large. Top of the internal gear is shaved off.	
Trimming interference	It is generated a lot when the number of teeth difference between the internal gear and the cutter is few. It is a phenomenon to shave off top of the internal gear with the top of the cutter at the beginning, and when the return stroke of a cutter during gear cutting.	
Trochoid interference	When the number of teeth difference is reduced less than the trimming interference limit, it is caused. It is a phenomenon that top of the cutter shaves off the tooth flank of the internal gear after completing the creation of the involute curve. (Trochoid interference does not happen if the trimming interference does not happen either)	

(5-2) Selection of number of teeth

Fig.9 shows the standard number of teeth of shaper cutter, which is necessary for cutting gear without each interference.

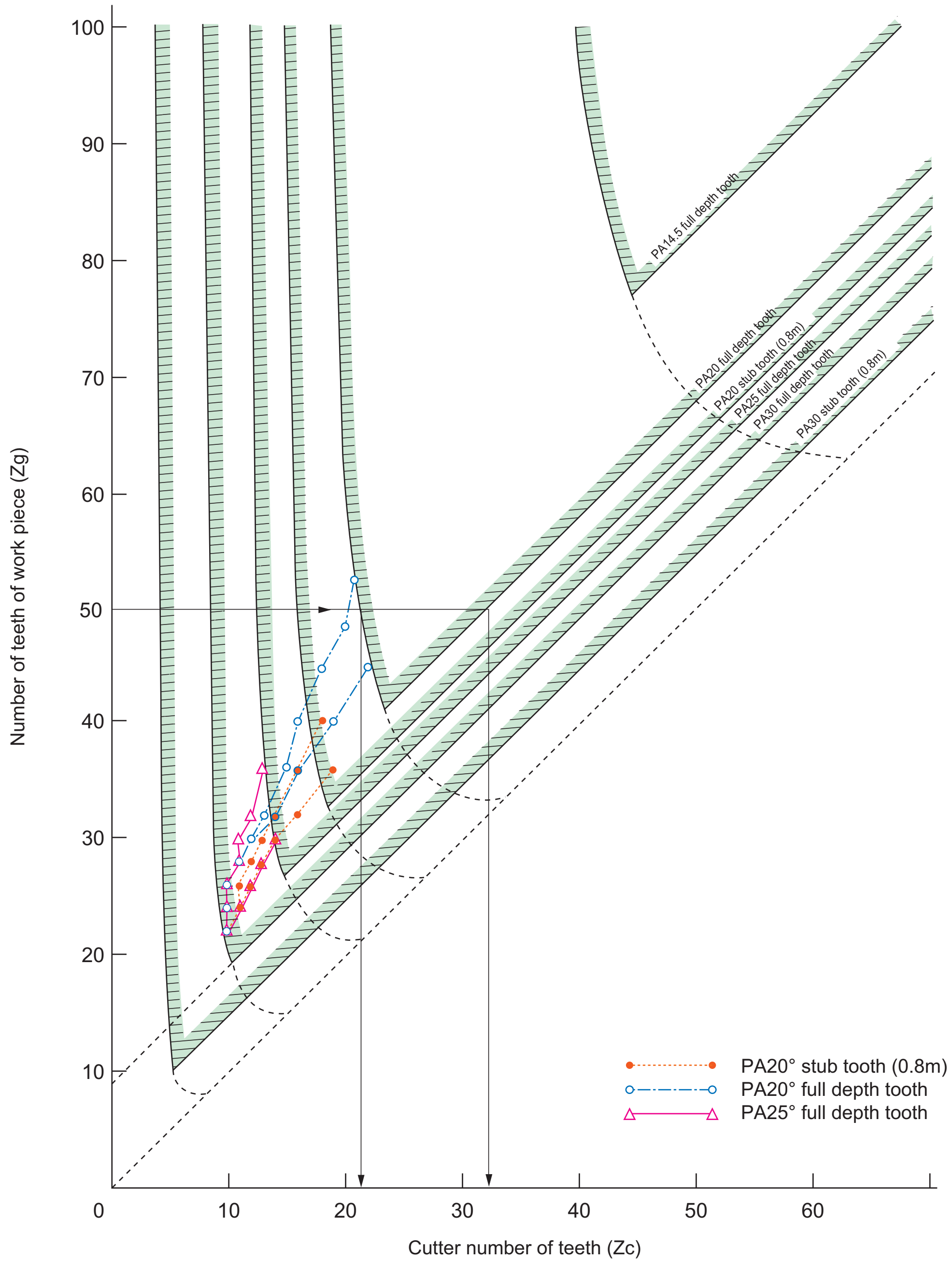


Fig.9 Standard number of teeth selection with shaper cutter for internal gear

Interference does not occur if you combine Zg with Zc in the effective range for hatching.

For PA20° full depth tooth

For Zg = 50, interference does not occur in the range of 22 ≤ Zc ≤ 32.

Selection area is also given for Zg for small number of teeth.

3-5 Standard cutting condition

Cutting conditions for each type of work material are given in Table 1.

Table 1 shaper cutter cutting condition

Work material / conditions	cutting speed (m/min)	circumferential feed (mm/str)	radial feed (mm/str)	back-off (mm)
carburizing material	40 – 80	0.2 – 3.0	0.002 – 0.01	0.2 – 0.8
S45C or more	30 – 50	0.2 – 3.0	0.002 – 0.01	0.2 – 0.8
FCD70	20 – 40	0.2 – 3.0	0.002 – 0.01	0.2 – 0.8

Note 1: Cutting speed is set according to cutting length and number of strokes.
Note 2: If cutting width of 25 mm is exceeded, reduce cutting speed by 10%.

[Reference]

Cutting speed (m/min) = (stroke length [mm] x No. of strokes [str/min] x π) ÷ 1000

3-6 Points to notice during machining

(1) In gear shaping, the runouts of cutter clamp and work piece clamp should be less than 5μm, since they influence the step of finished gear bottom, etc.

(2) The stroke length is the length that the distance between the top and the bottom of the face width of the work piece and the over stroke length are combined. The over stroke length should be changed according to the face width of the work piece. (Please refer to Fig.10.)

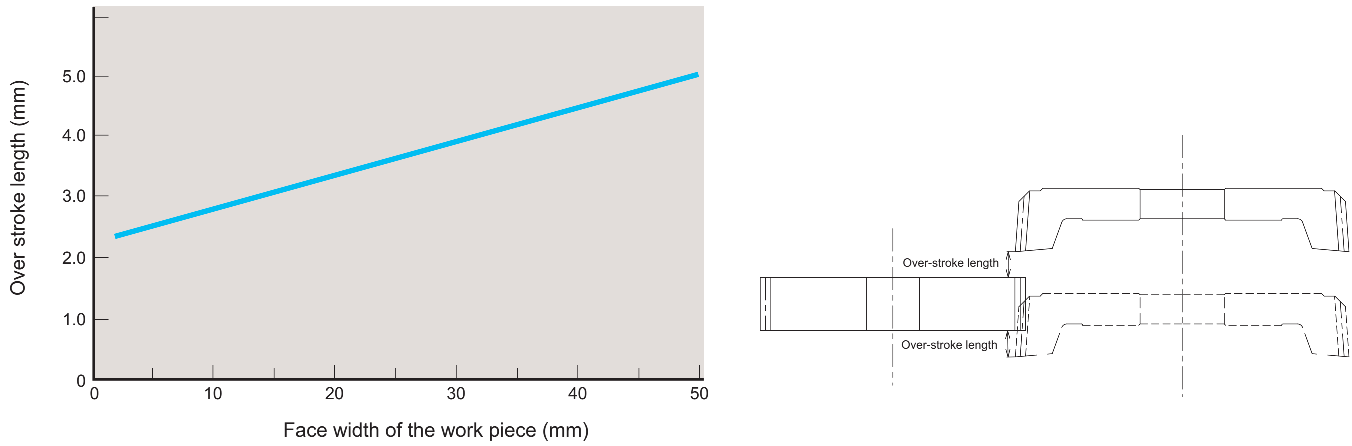


Fig.10 Relation between face width of the work piece and over stroke length

(3) Be cautious especially with chipping of teeth and abnormal wear in gear shaping, since a tooth of shaper cutter cuts a tooth of the work piece one on one.

3-7 Re-grinding

Since the method of re-grinding is easy (Refer to Fig.11), error of re-grinding shaper cutter is not so large in general. However, one must be cautious since eccentricity of a conic re-grinding surface could cause runout of the cutter, and in addition, the rake angle error could cause pressure angle error.

Although roughness of re-grinding surface shaper cutter is 3.2μmRy or less according to JIS, improving it as much as possible will extend tool life, and tear on the finished work gear face will be reduced.

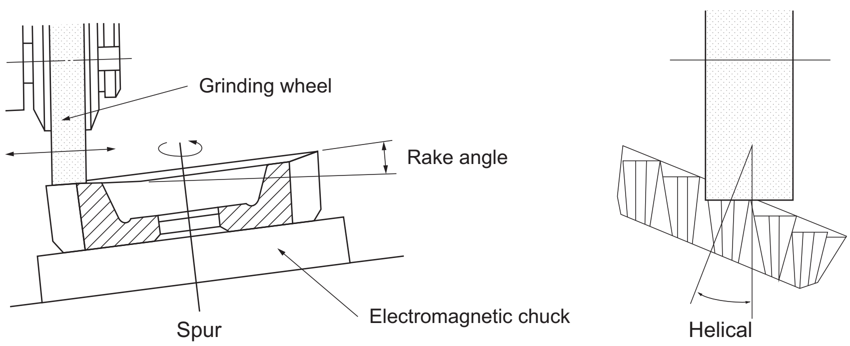
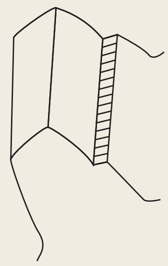


Fig. 11 Shaper cutter regrinding method

3-8 Troubles and solutions

Table 2 shows troubles and solutions of gear shaping.

Table 2 Troubles and solutions in machining by gear shaper

Trouble	Cause	Solution
Step of finished work bottom 	1. Defective cutter accuracy 2. Defective cutter clamp 3. Defective rotation accuracy of cutter spindle and defective rotation accuracy of table 4. Defective clamp of work piece	Check the runout of the tooth space and pitch error. Check the runout of cutter and arbor. Check the machine. Check the runout of the work piece.
Defective pitch error **Defective tooth space runout** **Defective tooth error profile**	1. Defective grinding of cutting face 2. Defective cutter clamp 3. Defective guide accuracy 4. Defective rotation accuracy of cutter spindle and defective rotation accuracy of table 5. Defective pre-machining of work piece	Check the runout and roughness of cutting face and rake angle. Check the runout of the cutter and arbor. Check the wear of guide. Check the backlash between the master worm and wheel and the accuracy of them. Check the accuracy of the change gears. Check the bore diameter of the work piece and the runout of end face.
Defective tooth flank roughness	1. Defective grinding of cutting face. 2. Defective machining conditions 3. Adhesion of built-up edge 4. Inappropriate depth of cut 5. Defective shape of work piece and insufficient clamping rigidity 6. Excessive play of driving unit	Check the runout and roughness of cutting face and rake angle. Reexamine the machining conditions. Chenge the cutting oil or check the way to apply it. Reexamine the machining conditions. Reexamine the clamping jig. (Setting of the rest of work piece) Check the machine.
Tool life	1. Inappropriate cutter material 2. Inappropriate cutter surface treatment 3. Inappropriate cutter clearance angle 4. The number of strokes being too large 5. The rigidity and vibration of machine	Reexamine the cutter material. Reexamine the cutter surface treatment. Reexamine cutter clearance angle. Reexamine the machining conditions. Check the machine.

3-9 Shaper cutter with high performance and long tool life

Along with popularization of high-speed gear shapers, coated shaper cutters, made of our company's original powder metallurgy HSS, demonstrate an excellent performance in high speed machining with more than 1,000 strokes/min. In addition, they contribute to the longevity improvement in machining of High hardness Difficult-to-cut Materials.

Fig.12 shows the relations among cutter material, machining efficiency and tool life.

The definition of each evaluation coefficient is as follows.

Machining efficiency evaluation coefficient CFp: Amount of average chip exhaust per second (mm^3/sec)

Tool life evaluation coefficient Lp: Machining length up to the flank wear 0.3 mm of one cutter conversion (m)

(1) KHA (Powder metallurgy HSS) shaper cutter

It excels in wear and chipping resistance, and its cutter's grindability has improved, giving a great effects on longevity.

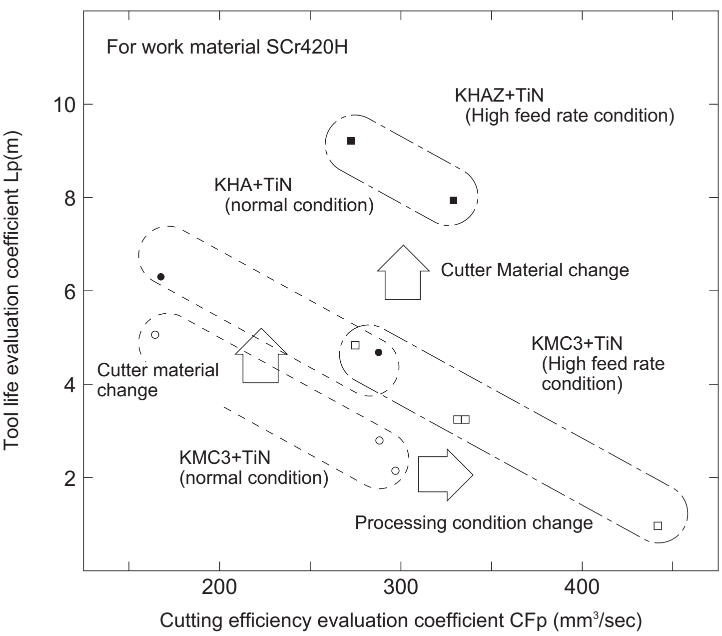


Fig.12 Tool life and machining efficiency

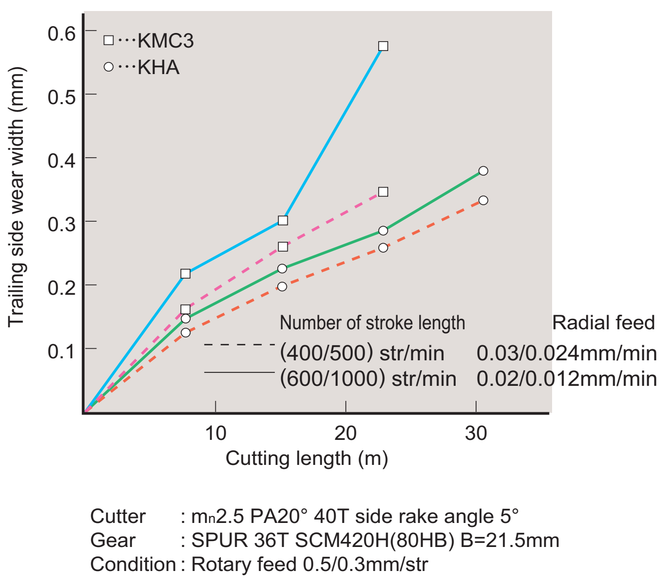


Fig.13 Effect of powder metallurgy HSS

(2) KHAZ shaper cutter

KHAZ shaper cutter with the under mentioned material characteristics gives an excellent machining performance to the gear shaver which can realize high feed rate (rotary feed) machining.

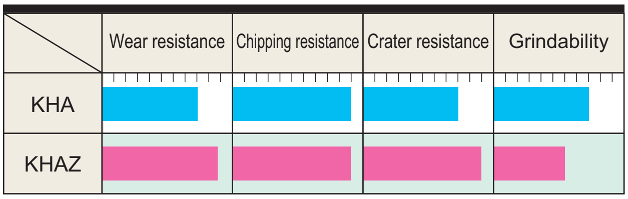
●Features

① Excellent wear resistance owing to minute high hardness carbide which is peculiar to high grade powder metallurgy HSS.

② Chipping resistance has improved remarkably owing to optimization of carbide amount by our original ingredient design.

③ Our company's state of the art heat-treatment technology has been adopted.

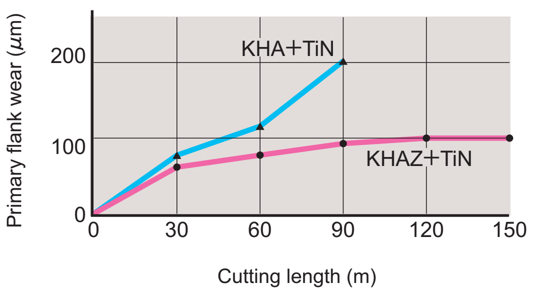
(Comparison of material characteristics)

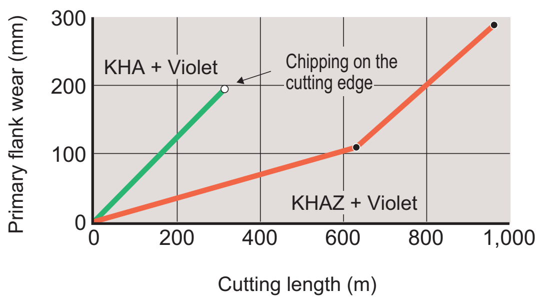


● Machining examples

① Gear: m2.5 × PA20° × 40NT(SPUR)
SCr420H
Standard cutting condition : Number of strokes 700/1,100str/min
Rotary feed 0.50/0.31mm/str
Radial feed 0.02/0.014mm/str

② Gear: m2 × PA15° × 80NT × 20° RH
AISI 1045 internal gear
Standard cutting condition : Number of strokes 500str/min
Rotary feed 1.70mm/str
Radial feed 0.01mm/str



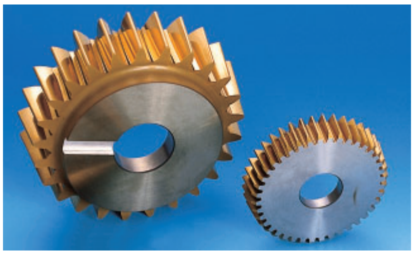


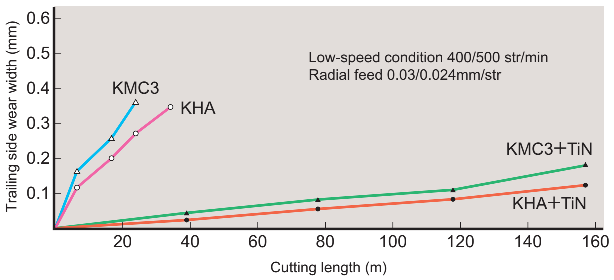
3-10 Coating Lineup

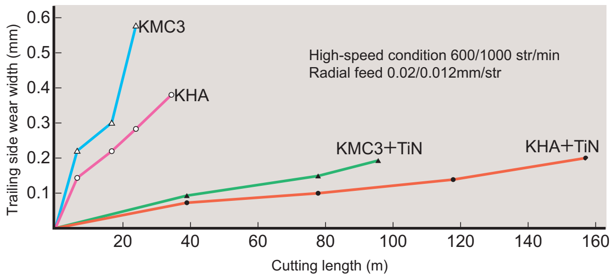
	Violet	TiN
Hardness of film HV	2,700～2,900	1,800～2,000
Oxidation Temperature C	800～900	600～700

(1) TiN coating

Its longevity has improved remarkably compared with a non-coated product, and it is considerably effective especially in high-speed heavy cutting field.







Cutter : m_n2.5 PA20° 40T side rake angle 5°
Gear : SPUR 36T SCM420H(180HB) B=21.5mm
Condition : Rotary feed 0.5/0.3mm/str

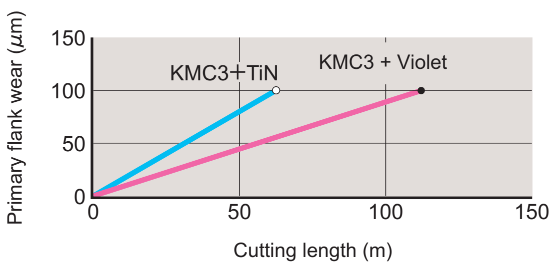
(2) Violet coating

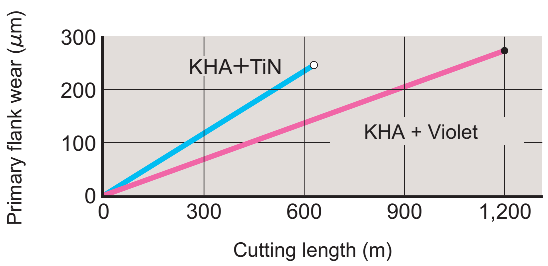
Wear resistance is improved approx. 1.5 times by hardness of TiN coating. (2 times or more tool life) also offers superior heat resistance and enables high efficiency.

● Machining examples

① Gear : m2×PA20° ×15NT (SPUR)
SCM415 (150HB)
Standard cutting condition : Number of strokes 750str/min
Rotary feed 0.15mm/str
Radial feed 0.05mm/str

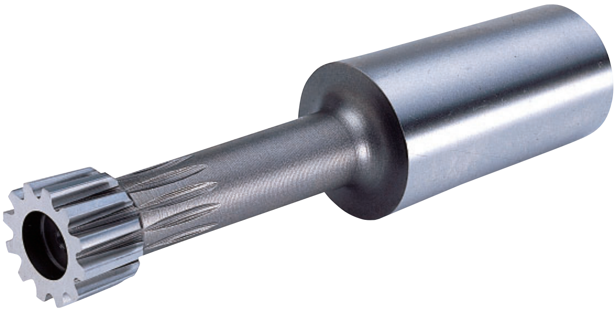
② Gear : m3×PA20° ×23NT×33° RH
SCr420H (180HB)
Standard cutting condition : Number of strokes 450/900str/min
Rotary feed 1.60/0.40mm/str
Radial feed 0.010/0.005mm/str





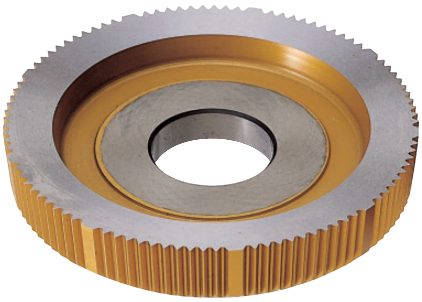
3-11 Small diameter shaper cutter-shank type

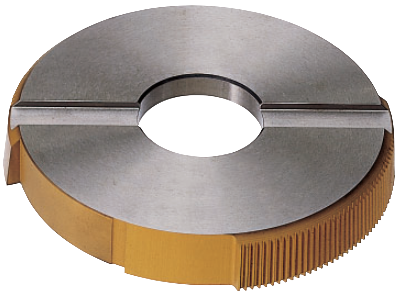
Shaper cutter-shank type is used to cut internal gear of small diameter.



3-12 Shaper cutter with special tooth profile

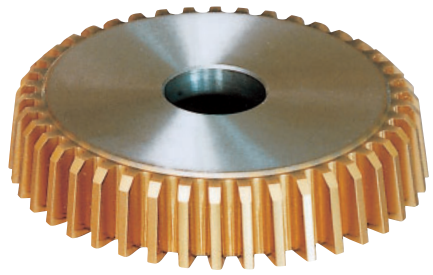
There are various shapes of ratchet gears used for recliners in cars due to combination of gears and cam shapes, and it is preferable to process these gears and cams at the same time. A shaper cutter with united teeth handles this machining, and it is a kind of topping shaper cutters. Module is mostly between 0.5mm and 1.0mm. Can also handle shaper cutter other than involuted tooth shape (contact us).

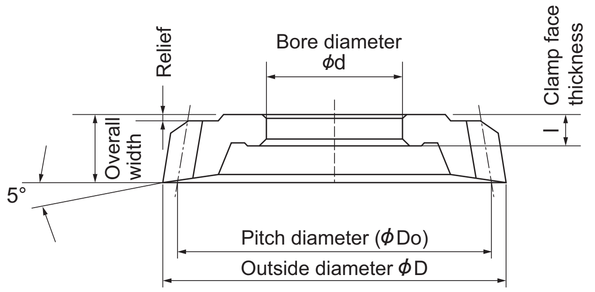




3-13 Various cutters size table

(1) Disk type





Nominal diameter	Module	l	d	Nominal diameter	Module	l	d
50 type	0.75–4 (DP34–DP6.5)	8	19.05	125 type	1.5–3.5 (DP17–DP7)	10	44.450
					3.75–8 (DP6–DP3)	12	
75 type	0.75–3.5 (DP34–DP7)	8	31.742	150 type	1.75–3.5 (DP14–DP7)	12	44.450
	3.75–5 (DP6–DP5)	10			3.75–10 (DP6–DP2.5)	14	
100 type	1–6 (DP24–DP4.5)	10	31.742	175 type	2–10 (DP12–DP2.5)	14	44.450
	6.5–7 (DP4)	12	44.450		11–12 (DP2)	16	

Table 3 Size of disk type cutter

Unit:mm

75 type				100 type				125 type				150 type				175 type			
Module m	Number of teeth Z	Pitch diameter Do m x z	Overall length L	Module m	Number of teeth	Pitch diameter Do m x z	Overall length L	Module m	Number of teeth	Pitch diameter Do m x z	Overall length L	Module m	Number of teeth	Pitch diameter Do m x z	Overall length L	Module m	Number of teeth	Pitch diameter Do m x z	Overall length L
0.75	100	75	16	1.00	100	100	18	1.50	84	126	22	1.75	86	150.5	24	2.00	88	176	26
0.80	94	75.2		1.25	80	100	20	1.75	72	126		2.00	75	150		2.25	78	175.5	28
0.90	84	75.6		1.50	67	100.5		2.00	63	126		2.25	67	150.75	26	2.50	70	175	
1.00	75	75		1.75	58	101.5		2.25	56	126	24	2.50	60	150		2.75	64	176	
1.25	60	75	18	2.00	50	100		2.50	50	125		2.75	55	151.25		3.00	58	174	
1.50	50	75		2.25	45	101.25	22	2.75	46	126.5		3.00	50	150		3.25	54	175.5	
1.75	43	75.25		2.50	40	100		3.00	42	126		3.25	47	152.75		3.50	50	175	
2.00	38	76		2.75	37	101.75		3.25	39	126.75		3.50	43	150.5		3.75	47	176.25	30
2.25	34	76.5	20	3.00	34	102		3.50	36	126		3.75	40	150	28	4.00	44	176	
2.50	30	75		3.25	31	100.75		3.75	34	127.5	26	4.00	38	152		4.50	39	175.5	
2.75	28	77		3.50	29	101.5		4.00	32	128		4.50	34	153		5.00	35	175	
3.00	25	75		3.75	27	101.25	24	4.50	28	126		5.00	30	150		5.50	32	176	
3.25	24	78		4.00	25	100		5.00	25	125		5.50	28	154		6.00	29	174	
3.50	22	77		4.50	23	103.5		5.50	23	126.5		6.00	25	150	32	6.50	27	175.5	34
3.75	20	75	22	5.00	20	100		6.00	21	126		6.50	24	156		7.00	25	175	
4.00	19	76		5.50	19	104.5		6.50	20	130	30	7.00	22	154		8.00	22	176	
4.50	17	76.5		6.00	17	102		7.00	19	133		8.00	19	152		9.00	19	171	
5.00	16	80		6.50	16	104	28	8.00	17	136		9.00	17	153		10.00	18	180	
				7.00	15	105						10.00	15	150		11.00	16	176	36
																12.00	15	180	

(Note) Cutter whose number of teeth, face width, bore diameter and shape are different from those mentioned above can be manufactured as well.
(Note) Production is possible even for missing or connected teeth.

(2) Bell type

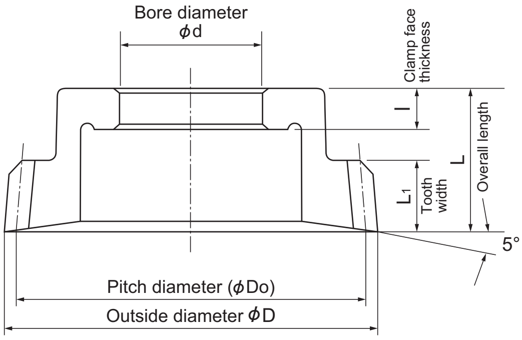


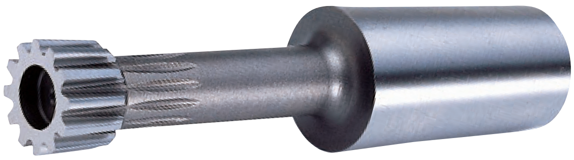
Table 4 Size of bell type cutter

Unit:mm

50 type					75 type					100 type					125 type				
Module m	Number of teeth Z	Pitch diameter Do m x z	Overall length L	Tooth width L_1	Module m	Number of teeth Z	Pitch diameter Do m x z	Overall length L	Tooth width L_1	Module m	Number of teeth Z	Pitch diameter Do m x z	Overall length L	Tooth width L_1	Module m	Number of teeth Z	Pitch diameter Do m x z	Overall length L	Tooth width L_1
0.75	67	50.25	30	12	0.75	100	75	34	16	1.00	100	100	38	18	1.50	84	126	42	22
0.80	63	50.4			0.80	94	75.2			1.25	80	100	40	20	1.75	72	126		
0.90	56	50.4			0.90	84	75.6			1.50	67	100.5			2.00	63	126		
1.00	50	50			1.00	75	75			1.75	58	101.5			2.25	56	126	44	24
1.25	40	50	32	14	1.25	60	75	36	18	2.00	50	100			2.50	50	125		
1.50	34	51			1.50	50	75			2.25	45	101.25	42	22	2.75	46	126.5		
1.75	29	50.75			1.75	43	75.25			2.50	40	100			3.00	42	126		
2.00	25	50			2.00	38	76			2.75	37	101.75			3.25	39	126.75		
2.25	23	51.75	34	16	2.25	34	76.5	38	20	3.00	34	102			3.50	36	126		
2.50	24	60			2.50	30	75			3.25	31	100.75			3.75	34	127.5	48	26
2.75	22	60.5			2.75	28	77			3.50	29	101.5			4.00	32	128		
3.00	20	60			3.00	26	78			3.75	27	101.25	44	24	4.50	28	126		
3.25	19	61.75			3.25	24	78			4.00	25	100			5.00	25	125		
3.50	18	63			3.50	23	80.5			4.50	23	103.5			5.50	23	126.5		
3.75	16	60	38	18	3.75	21	78.75	42	22	5.00	21	105			6.00	21	126		
4.00	15	60			4.00	20	80			5.50	19	104.5			6.50	20	130	50	30
					4.50	18	81			6.00	18	108			7.00	19	133		
					5.00	16	80			6.50	17	110.5	50	28	8.00	17	136		
										7.00	16	112							

(Note) Cutter whose number of teeth, face width, bore diameter and shape are different from those mentioned above can be manufactured as well.
(Note) Production is possible even for missing or connected teeth.

(3) Shank type



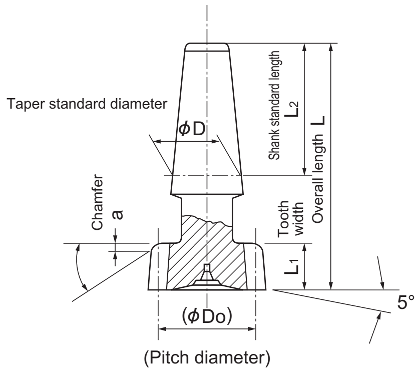


Table 5 Size of shank type cutter

Unit:mm

25 type					38 type				
Module m	Number of teeth Z	Pitch diameter Do m x z	Overall length L	Tooth width L_1	Module m	Number of teeth Z	Pitch diameter Do m x z	Overall length L	Tooth width L_1
0.75	34	25.5			0.75	51	38.25		
0.80	32	25.6		10	0.80	48	38.4		12
0.90	28	25.2			0.90	43	38.7		
1.00	25	25			1.00	38	38		
1.25	20	25		12	1.25	31	38.75		
1.50	17	25.5	80		1.50	26	39		15
1.75	15	26.25			1.75	22	38.5	100	
2.00	13	26		15	2.00	19	38		
2.25	12	27			2.25	17	38.25		
2.50	10	25			2.50	16	40		
					2.75	14	38.5		
					3.00	13	39		18
					3.25	13	42.25		
					3.50	13	45.5	125	
					3.75	13	48.75		
					4.00	13	52		

(Note) Cutter whose number of teeth, face width, bore diameter and shape are different from those mentioned above can be manufactured as well.
(Note) Production is possible even for missing or connected teeth.

4.Shaving cutter

4-1 Features

Shaving is a precise finishing method by using a shaving cutter.

By forming lots of serration gashes on the tooth flank of a kind of gear, cutting edge is formed on the shaving cutter, and the engagement movement of gear is applied. Below are its features.

(1) Machining time is short and productivity is high.

(2) Improvement of accuracy is remarkable.

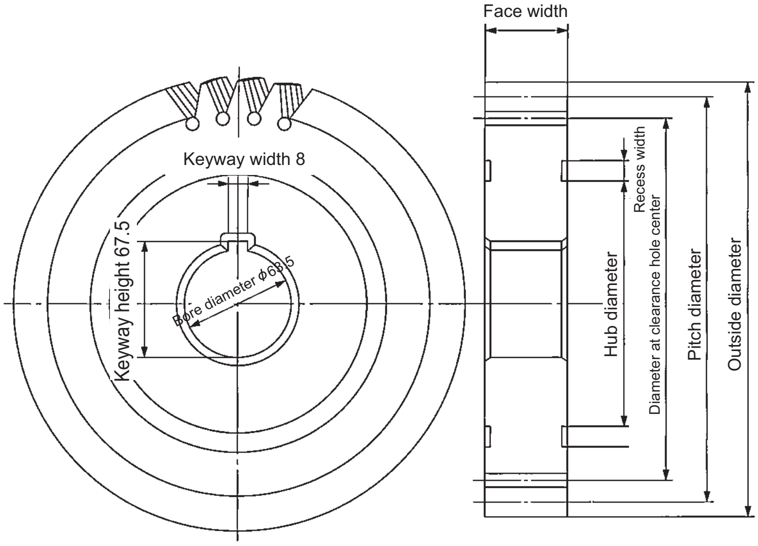
(3) Tool cost for finishing each gear is low.

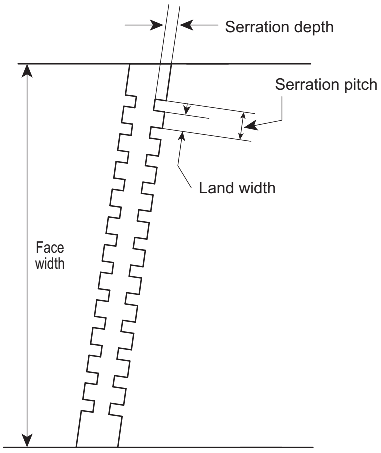
(4) Tooth profile modification of gear is possible.

(5) Crowning in thread helix direction of gear is easy.

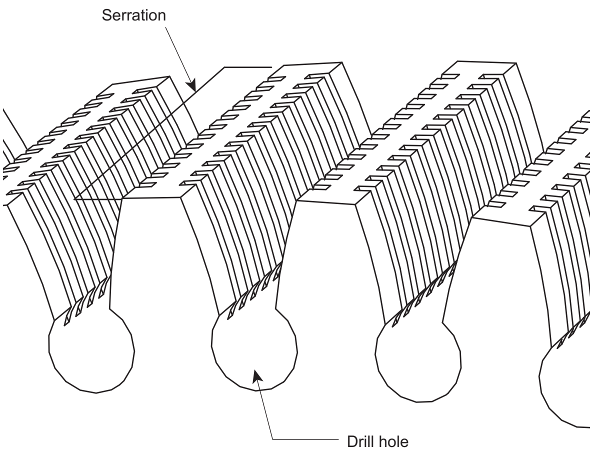
(6) Skill is not necessary for operation.

4-2 Part names





Serration detail



4-3 Machining principle

Work gear and shaving cutter are rotated with no backlash while keeping a fixed crossed axes angle as shown in Fig.1-1. Then, cutting action is done by opposing sliding motion in the thread helix direction of shaving cutter and work gear.

Fig.1-2 shows the cross section on the contact pitch cylinder.

Fig.2 shows the movement of cutting edge on gear tooth flank.

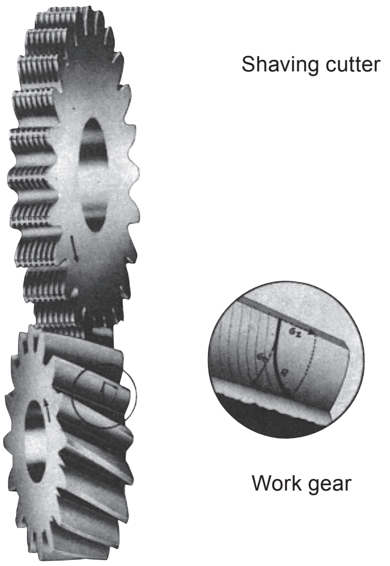


Fig.1-1 State of mating of shaving cutter and work gear

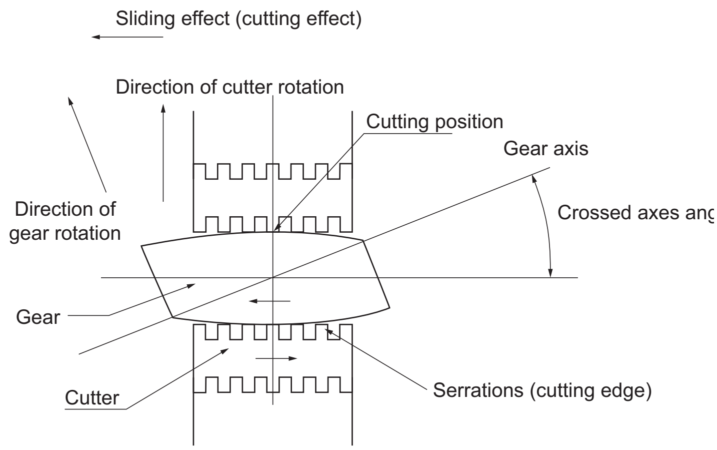


Fig.1-2 State of cutting action on the mating pitch cylinder

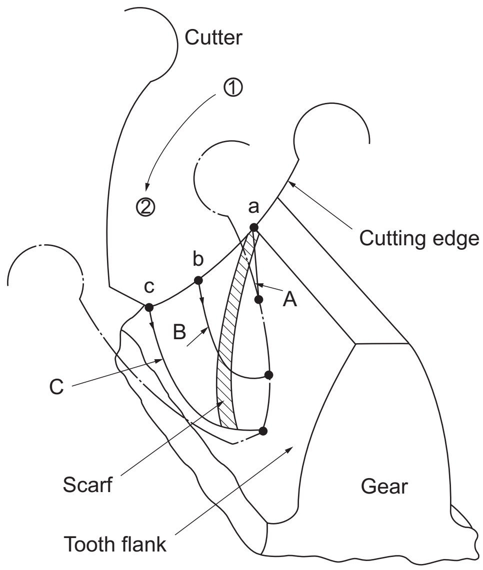


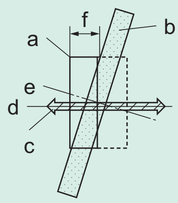
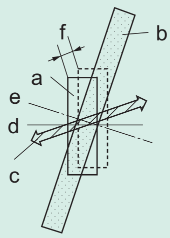
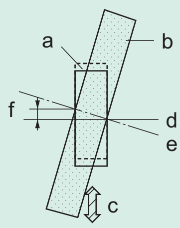
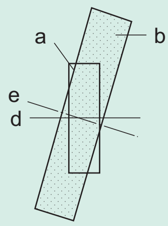
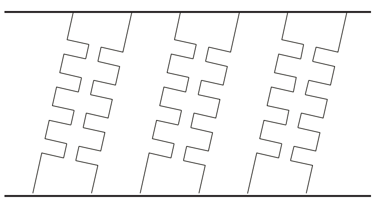
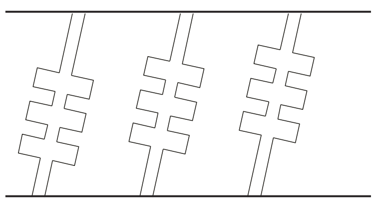
Fig.2 Movement of cutting edge on gear tooth flank

a : Bottom point of cutter
b : Point on mating circle of cutter
c : Top point of cutter
A, B, and C show tracks of each point (trochoid curve).

4-4 Shaving method

Shaving methods are defined by relative feed directions of cutter and work gear. There are four methods as shown in Table 1. Suitable method is selected depending on shape, size, and production amount etc. of work gear.

Table 1 Shaving methods

Shaving method	Conventional	Diagonal	Under-pass	Plunge cut
Usage	It is the most general method. It is suitable for shaving a gear with a wide face width and a large-scale gear.	It is used for shaving gear whose face width is a little wider than the cutter width. It is suitable for mass production.	It is used for shaving layered gears.	It is suitable for high efficiency machining of mass production of gears.
[Machining time Ratio when cutting time for plunge cut is 1]	3	2	2	1
Feature	○ Traverse to the gear axis direction. ○ The feeding length is almost the same as the face width of the gear.	○ Traverse to diagonal direction for the gear axis. ○ The feeding length is shorter than the face width of the gear.	○ Traverse to the vertical direction for the gear axis. ○ The feeding length is shorter than the following two methods.	○ Only the in-feed
a. Work gear b. Shaving cutter c. Direction of feed motion d. Gear axis e. Cutter axis f. Feeding length				
Serration arrangement	 Normal serration		 Differential serration	

4-5 Plunge cut shaving

It is a shaving method only by infeed, and the best for high efficiency machining in gear mass production.

Our company has been responding to the demand for improvement of machining efficiency and gear accuracy by our accumulated technology, as the first Japanese manufacturer who successfully developed and started distributing plunge cut shaving cutters.

[Features]

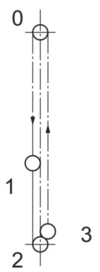
1. High efficiency Machining time is shortened to approximately 1/2 because infeed only (no cross feed).
2. High accuracy Thanks to a special serration array, roughness on the gear tooth flank has improved to 1/2.
   Improvement of gear finishing accuracy owing to back-movement mechanism
3. Long tool life Tool life has improved owing to uniformity of cutting amount of each serration cutting edge

[Machining cycle]

Plunge cut shaving method is different from conventional shaving methods. It processes only by continuously cutting the cutter in the radius direction of work gear, without needing a relative cross feed movement of work gear and the cutter.
Cutting edge of the cutter is moved to differential serration because there is no relative cross feed movement. That is, cutting edge of serration is moved in order so that one tooth of work gear mesh with edge of the cutter. Following are shaving cycle and machining chart.

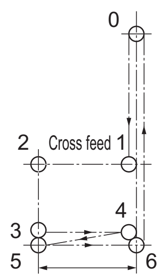
Cycle of plunge cutting method	
0 :	Start position
0-1 :	High feed approach
1-2 :	Cutting (amount which corresponds to shaving stock)
2 :	To do shaving completely, preparation is stopped at this position (T_1 second).
2-3 :	The cutting is returned for the elasticity deformation correction. Max 0.05 (mm).
3 :	Cutting stop (T_2 second)
3-0 :	High feed separation, return to the start position.

Machining chart of plunge cut shaving



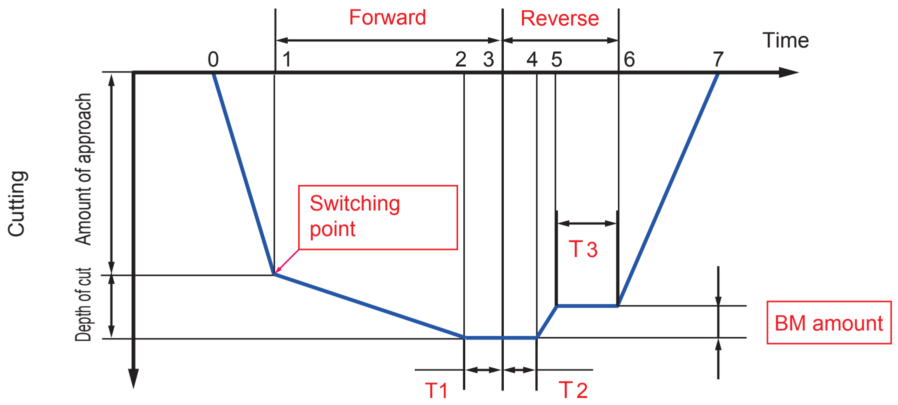
Cycle of the other method	
0 :	Start position
0-1 :	High feed approach and the first cutting
1-2 :	Cross feed
2-3 :	Preparation of the second times
3-4 :	Cross feed
4-5 :	Cross feed for finishing
5-6 :	〃
6-0 :	High feed separation, return to the start position.

Machining chart of conventional shaving



Face width of work piece

Fig.3 Comparison of shaving cycle



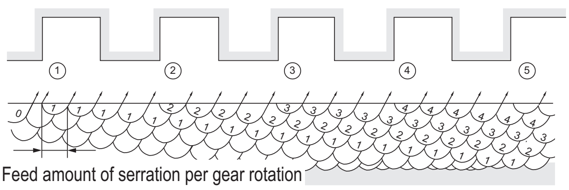
0 : Cutter stop / Start position
0 — 1 : Cutter stop / Fast forward to switching point
1 : Cutter forward / Approach complete
1 — 2 : Cutter forward / Plunge feed
2 : Cutter forward / Depth of cut is completed
2 — 3 : Cutter forward / Dwell during T1 Unevenness of finished surface removed
3 : Cutter reverse
3 — 4 : Cutter reverse / Dwell during T2
4 — 5 : Cutter reverse / Cutter retreat (back movement) Retreat amount is 0 to 0.05 mm
5 — 6 : Cutter reverse / Dwell during T3 Elastic distortion removed
6 — 7 : Cutter stop / Return to start position by fast forward

Fig.4 Machining chart with plunge cut shaving on time axis

[State of Shaving]

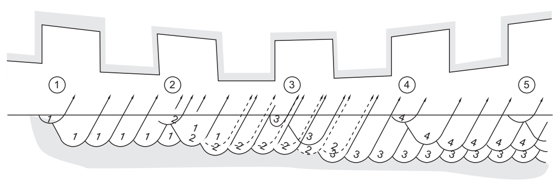
Fig.5 shows the depth cut of cutting edge and the state of cross feed in different shaving methods.

1) Plunge cut shaving



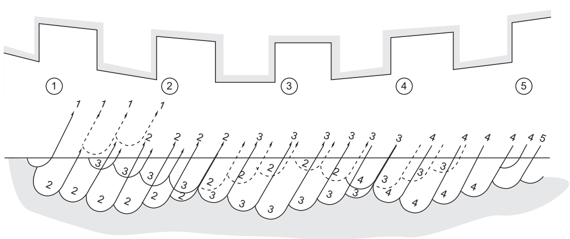
Each serration cutting edge uniformly effects on tooth flank, and cutting amount is uniform

2) Conventional shaving



Nonuniform amount of cutting for each serration cutting blade
③ is deepest (most deeply cut), followed by ②, ④ and ③, ⑤, in that order.

3) Under-pass/diagonal shaving

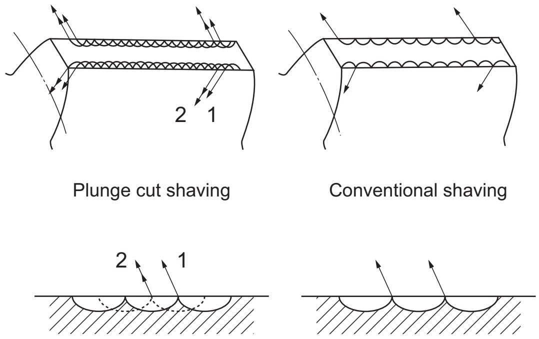


Nonuniform amount of cutting for each serration cutting blade

Fig.5 Cutting operation with Shaving methods

[Tooth flank roughness]

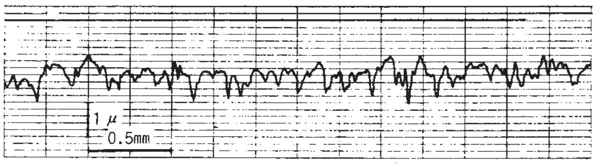
Fig. 6 shows the cutting operation of a tooth surface of the work piece. With plunge-cutting, the tooth surface is improved with diagonal shaving by 1/2.



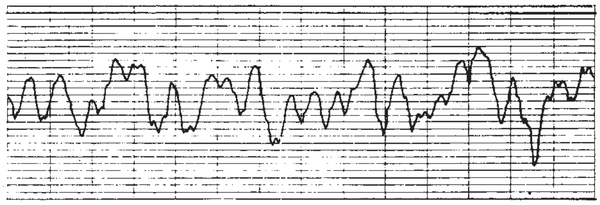
Conventional, diagonal
No matter how much number of finishing times is increased, cutter blade feed mark not only stays the same, but tooth surface roughness is not improved as well.

Plunge cut shaving
Feed mark of cutter blade is positioned in the center of the previous feed mark, so tooth surface roughness is significantly improved.

Fig.6 Feed mark of cutting edge

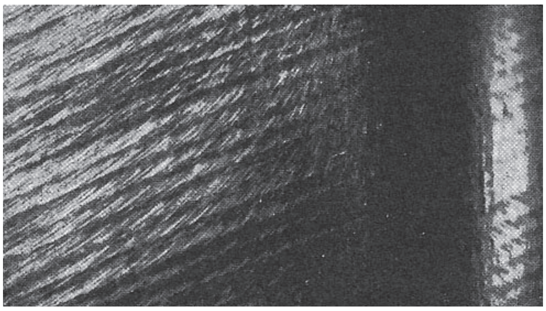


(a) Plunge cut shaving

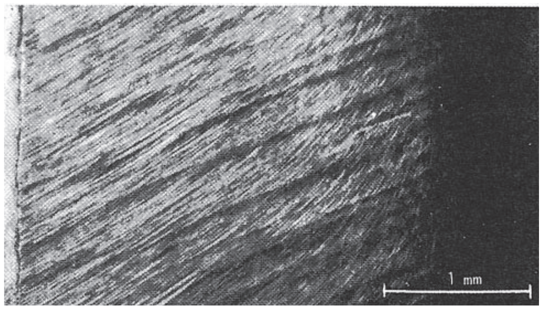


(b) Under-pass shaving

Fig.7 Comparison of surface roughness of work gear

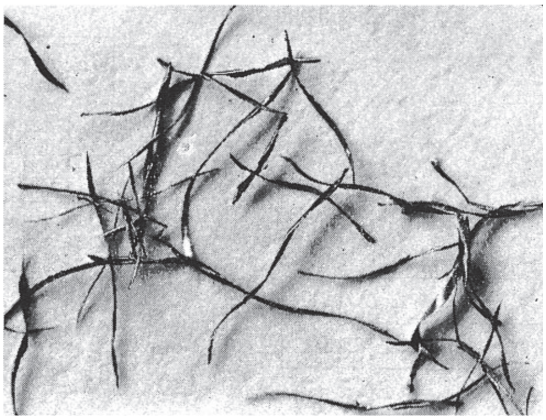


Plunge cut shaving



Under-pass shaving

Photo. 2 State of cutting surface



Plunge cut shaving

Conventional shaving

Photo. 3 State of chip

4-6 Machining condition

(1) Circumference speed of cutter

Cutter rotation speed Nc(min^{-1}) is,

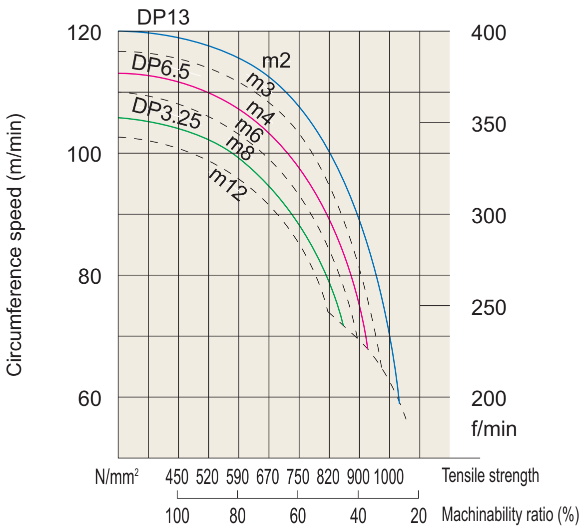
$Nc = 1000 \times Vc/(\pi \times dc)$.

Vc : Cutter circumference speed (m/min) (calculated from Fig.8 and 9).

dc : Cutter out side diameter (mm)

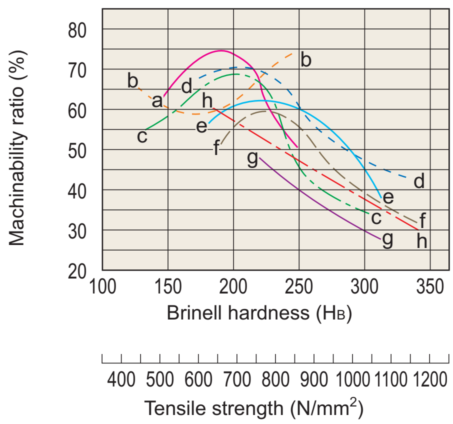
In plunge cut shaving, the number of reversal rotation is only once, so that a user can adopt higher circumference speed by 20%.

Since the rotational speed of work gear becomes excessive when the gear ratio of work gear and cutter becomes large. So rotational speed should be decreased a little.



(Note) 20%up from the above-mentioned circumference speed in case of plunge cut shaving

Fig.8 Rotational speed of top of shaving cutter



a is the structural steel of 0.3%C or below, cold deformed and drawn.
b is a structural steel of 0.3-0.4%C, annealed.
c is a structural steel of 0.4-0.5C, annealed or heat treated.
d is NiMo steel.
e is CrMo steel.
f is CrV steel.
g is SiMn steel.
h is CrNi steel.

Fig.9 Relation between machining of material and brinell hardness and tensile strength

(2) Traverse

- Traverse for conventional shaving should be between 0.15 and 0.3mm per rotation of a work gear.
- For diagonal shaving, approximately 70% of the speed in conventional shaving.
- For under-pass shaving, approximately 50% of the speed in conventional shaving.

(3) Depth of cut

Depth of cut into direction of the center of work gear should be done gradually in conventional, diagonal, and under-pass shaving. A depth of cut is between 0.02 and 0.06mm, and decided in consideration of shaving stock.

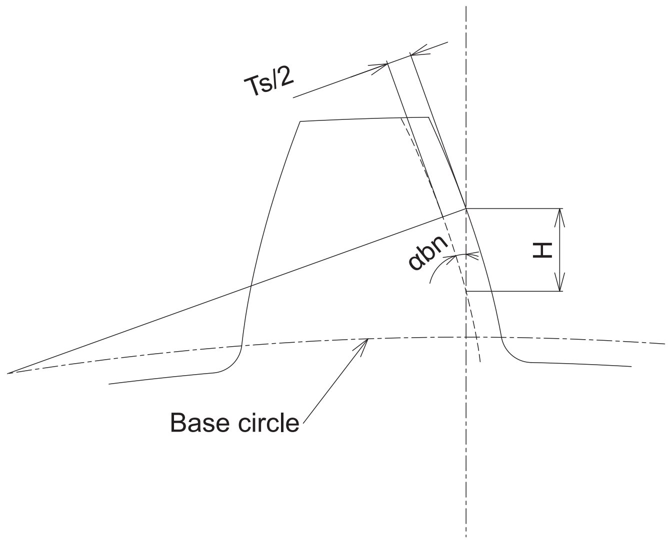
If a depth of cut at one time is H,

$H \fallingdotseq ts/2\sin\alpha bn$,

ts : removal amount of shaving at one time (normal tooth base tangent length),

α bn : a working pressure angle (normal).

It is continuously cut in plunge cut shaving on the machine . However, it is preferable that as for plunge feed rate, about 0.007mm in the direction of tooth thickness is cut while the action of serration progresses by one pitch.



(4) Adjustment of back movement in plunge cut shaving

Reverse cutting and finishing with little elastic deformation in order to correct the work piece when shaving and/or with arbor elastic deformation.

The relationship of the finished tooth surface of the work piece and the amount of back movement normally manifests as in figure 10 requiring regulation of the amount of back movement while assessing tooth surface conditions.

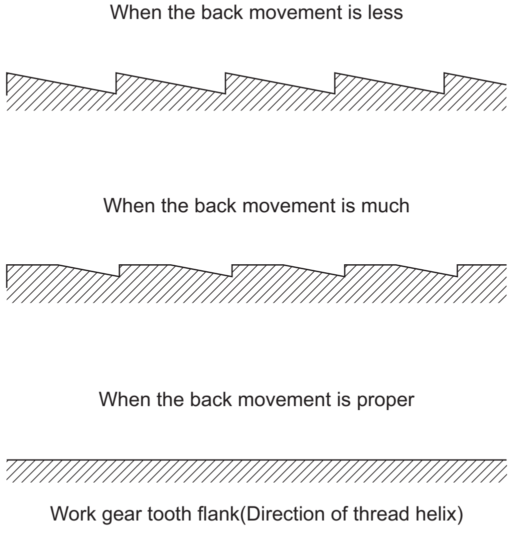


Fig.10 Relation between state of work gear surface and amount of back movement

Amount of back movement is generally between 0 to 0.05 mm.

4-7 Selection of major dimensions

(1) Module and pressure angle

Normal module and normal pressure angle of cutter should be equal to that of work gear.

(2) Helix angle

The pitch cylinder helix angle of the cutter should be chosen to make crossed axes angle of cutter and gear the most suitable. Crossed axes angle in general is the difference of helix angle between cutter and work gear. Size of crossed axes angle exerts a big influence on sharpness and finishing accuracy of the gear.Therefore, it is necessary to well consider finishing accuracy and machining efficiency of the gear when deciding crossed axes angle.

The range of proper crossed axes angle is shown in Table 2.

- If crossed axes angle is larger, sharpness is improved.
  Small contact surface of tooth surface → guidance reduction (could result in tooth trace error)
- If crossed axes angle is smaller, sharpness decreases (finished surface is varnished).
  Tooth surface contact surface increase → Improved in Guidance

(3) Face width

In general, face width of cutter shown in Table 3 are used according to shaving methods. (Expression 1,2)

(4) Number of teeth

Nominal size of cutter is decided according to the specification of shaving machine used and the size of work gear. Then, number of teeth should be decided so that the pitch circle diameter may become close to nominal size while considering helix angle and cutter module. As a general rule, a prime number should be selected for the number of teeth of shaving cutter.

Table 2 Range of proper crossed axes angle

Type of work gear	Crossed axes angle
The spur gear and the helical gear (excluding the cast iron)	12°～15°
Spur gear and helical gear (cast iron)	15°～20°
Shoulder gear	4° or more (Take maximum within the range but not interfere with the shoulder part.)
Large diameter gear (outside diameter 500 or more)	6°～10°
Internal gear	6°～10°

Frequently used cutter number of teeth

23, 29, 31, 37, 41, 43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97, 101, 103, 113, 127, 131, 137, 149, 151, 157, 173, 179, 197

(Note) The one with the underline is number of teeth not included in JIS B4357.

Table 3 Face width of shaving cutter

Shaving method	Cutter face width
Conventional shaving	m≤1.75 19.05 1.75<m≤6 25.4 6<m 31.75
Diagonal shaving	Designed individually according to the diagonal angle. Expression (1)
Under-pass shaving	Designed in consideration of the work gear face width and the crossed axes angle. Expression (2)
Plunge cut shaving	

Ordinary cutter width

19.05, 22.225, 25.4, 31.75, 38.1, 44.45, 50.8

(Note) The cutter width is requested from Expression (2) for the plunge cut and the under-pass.

Refer to the expression for cutter width of diagonal shaving.

$bc \geq bce+5$ ———————— Expression (1)

$bce = bg \cdot \sin\theta d / \sin(\theta d+\psi)$

bc : Cutter face width

bce : Effective face width

bg : Face width of work gear

ψ : Crossed axes angle

θd : Diagonal angle (30° in general)

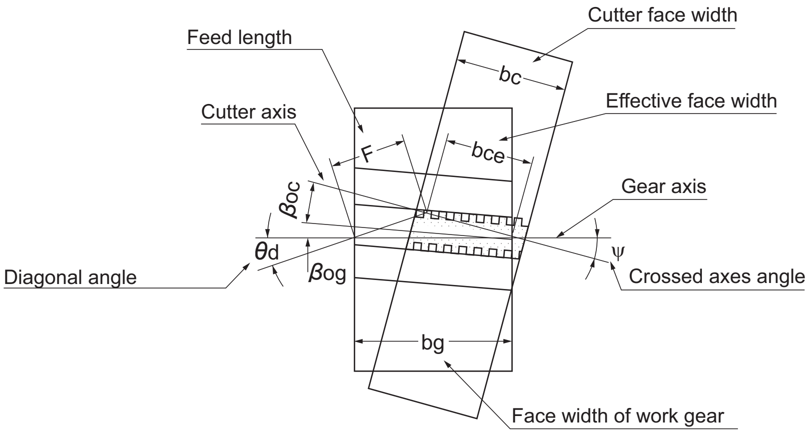


Fig.11 Relation of diagonal angle and face width

Refer to the expression for cutter width of plunge cut and under-pass shaving.

$bc \geq (bg+3 \cdot tg \cdot \tan\psi)\cos\psi+\alpha$ ———— Expression (2)

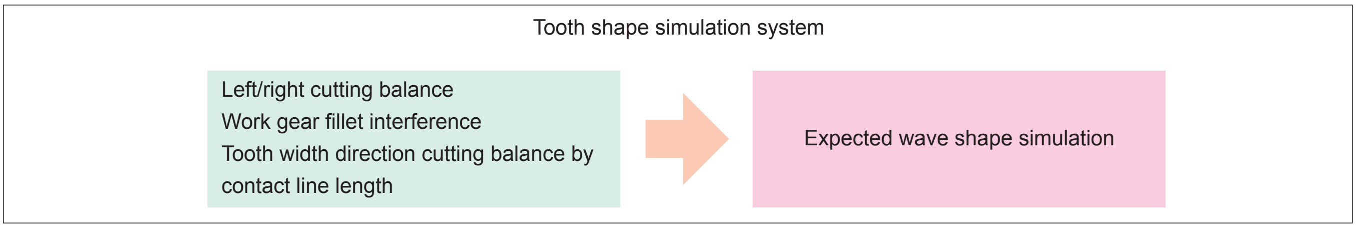
tg : Axial normal pitch of work gear

α : Decided according to serration array and existance of shoulder part of work gear. (Standard 4 to 5)

(5) Selection of working pressure angle

- Because there is no forced transfer mechanism for shaving, tooth shape of the work piece is impacted by contact fluctuation.
- Work pieces with a low contact ratio are subject to significant contact fluctuation, resulting in unstable tooth shape.

In order to get a stable tooth shape for work pieces with a low contact ratio as well, we have developed our own original tooth shape simulation system so you can select the best pressure angle.



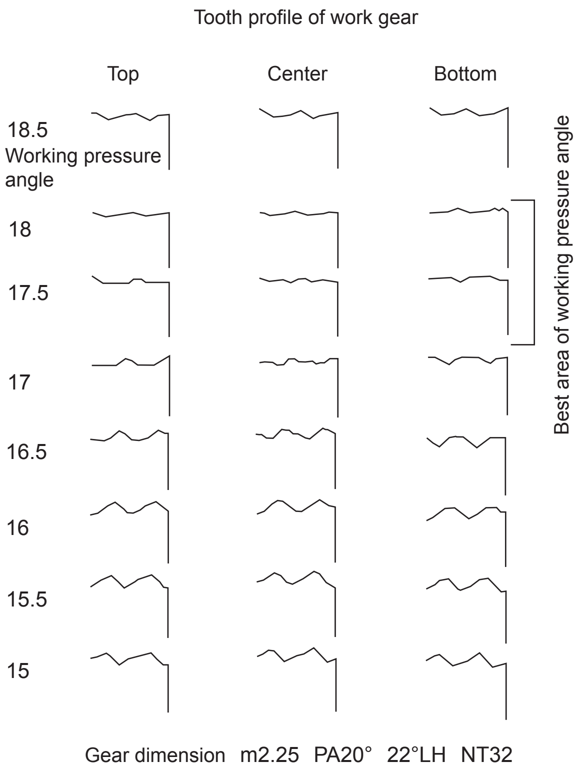
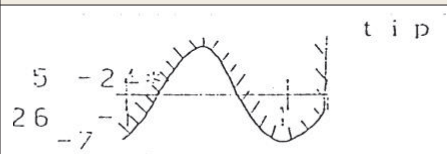
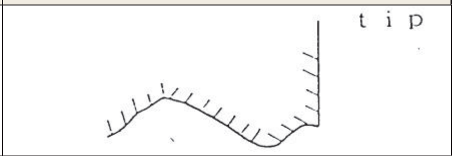
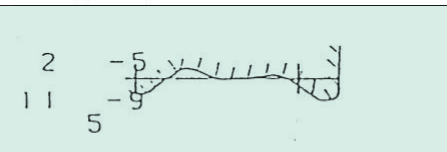
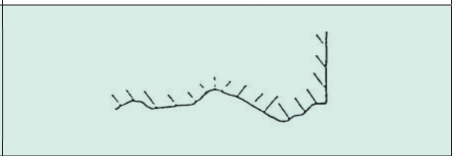


Fig. 12: Tooth shape simulation results

Table 4: Comparison between actual tooth shape and simulation tooth shape

Work dimension M3.15PA25 13NT SPUR	Actual tooth shape	Calculated tooth shape
Intermeshing pressure angle = 18°		
Intermeshing pressure angle = 22°		

(6) Setting of shaving diameter

Shaving diameter setting standards

① Smaller than the starting active profile diameter machined gear with the mating gear (TIF diameter),
② Larger than the filet producing diameter that it may not interfere with the filet portion of the previously cut tooth profile
Note: There are also cases where it does not satisfy the requirement (2) because of priority given to (1).

The reserves of ① and ② are determined by the trochoid chart which illustrates the shaving cutter and the trochoid of the tooth tips of the mating gear (See fig. 13 and 14.)

Required to be drawn in trochoid chart

- Tool shape before processing
- Shaving allowance
- The number of mating gear teeth, the outside diameter, and the distance between the axis are required for illustrating the trochoid of the tooth tips of the mating gear

Things to be checked in trochoid chart

"Since the cutter develops a negative profile shift when regrinding the shaving cutter, the trochoid of the cutter moves away from the work piece according to the mating gear in the same shaving diameter and may interfere with the mating gear in the life of the cutter (See fig. 13.)

If interference occurs, it can be prevented by making the sequential shaving diameter deeper (setting the outside diameter of the cutter larger) when the cutter develops a negative profile shift (See fig. 14.)"

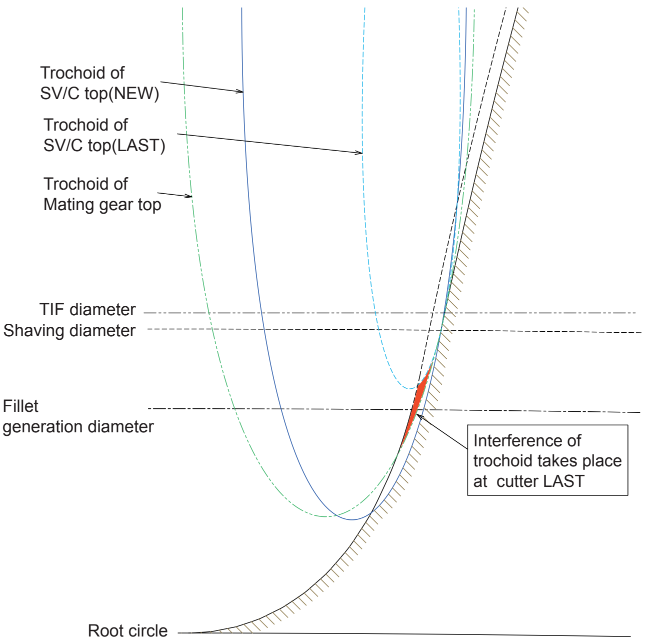


Fig.13 Trochoid chart (with interference of cutter LAST)

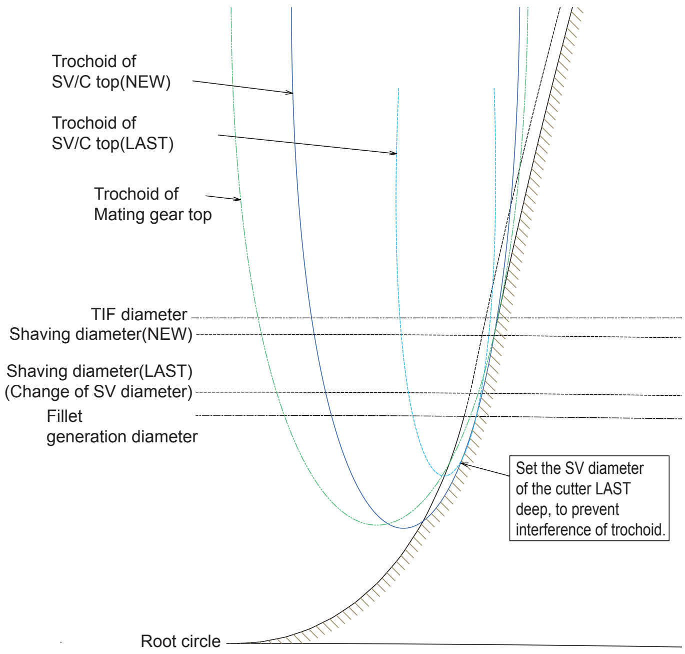


Fig.14 Trochoid chart (without interference of cutter LAST)

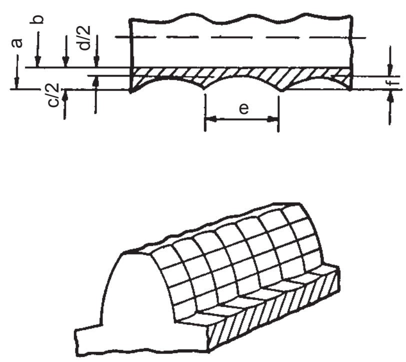
4-8 Points to notice when shaving

(1) Pre-shaving accuracy

Pre-shaving accuracy is usually about 2 to 3 classes lower than desired accuracy after shaving in JIS gear accuracy standard.

(2) Shaving stock

Fig. 15 shows the best shaving stock with considering hobbing feed rate in pre-shaving process.
Table 5 shows recommended value of general shaving stock.



a : Tooth thickness after hobbing
b : Tooth thickness after shaving
c/2 : Shaving stock (one side)
d/2 : Shaving stock at minimum feed (one side)
e : Feed per a gear rotation
f : Depth of feed mark

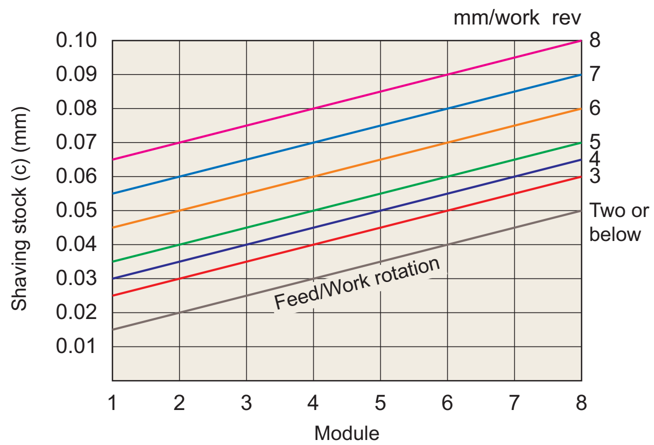


Fig.15 Relation of hobbing feed rate in pre-shaving and shaving stock

Table 5 Recommendation amount of shaving stock

Module	$m_n \leqq 2.25$	$2.25 < m_n \leqq 3.5$	$3.5 < m_n \leqq 5$	$5 < m_n \leqq 12$
Shaving stock	0.05~0.08	0.06~0.10	0.08~0.12	0.10~0.15

The above mentioned shows shaving stock in tooth thickness.

(3) Selection of pre-shaving tools

①A high addendum of 1.35 module or more is necessary for the addendum of pre-shaving tool.
②A clearance of 0.15 module or more should be secured between top of shaving cutter and bottom part of work gear.
③Select an appropriate pre-shaving tool so that the top part of shaving cutter will not interfere the fillet of work gear.

(4) Relation between direction of rotation and feed

Fig. 16 shows the state of serration cutting edge, by rotation direction of cutter and feed direction of work gear. It is necessary to set the serration cutting edge so as to act up cut (Refer to Fig. 17).

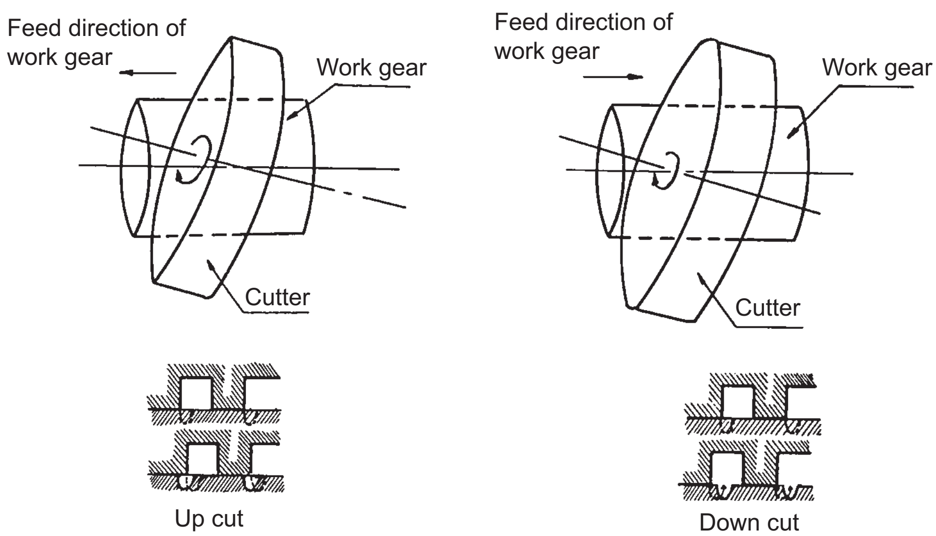


Fig.16 Action for cutting edge by rotational direction of cutter and traverse direction of work gear

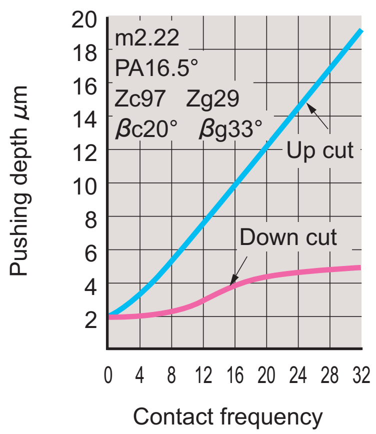


Fig.17 Pushing depth of serration in the same load

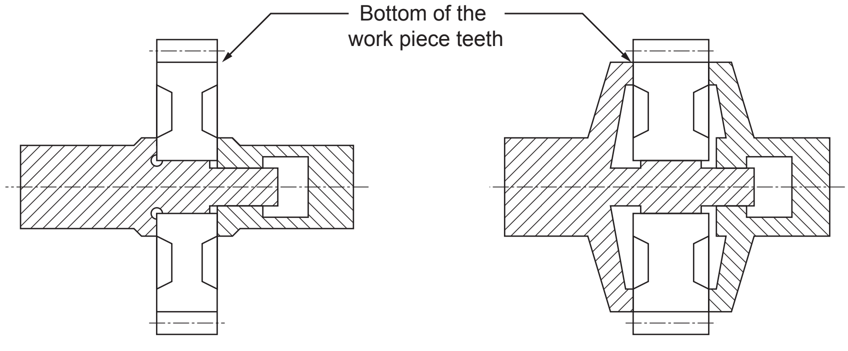
Shows press-in depth for pressing with same force as given in Fig. 17

The figure shows that the "up-cut" is much more useful and has good machinability.

(5) Shape of cutter-arbor for shaving

A shaving arbor is recommended for preserving around the bottom of the work piece teeth that are near the point of processing.

Maintained near bottom of teeth to prevent vibration by cutting resistance, as well as deterioration of gear precision and shortening of tool life.



Type of the arbor of work gear for shaving (bad example)

Type of the arbor of work gear for shaving (good example)

(6) Accuracy of the arbor of work gear for shaving

When based on the cutter-arbor diameter, the allowance of bore should be limited between about H6 and H7, and runout of the arbor of work gear for shaving should be limited to 5μm or below.

(7) Burr removal on end face of work gear in pre-shaving.

Burrs might adhere to the end face of gear. If shaving is done under such a condition, burrs get stuck in the serration gash and causes the cutter fracture. So it is necessary to remove burrs completely.

(8) Judgment standard of tool life

① Tooth profile of work gear lose the shape.

② "Burr," by which your fingers are caught when touching, is caused around tooth flank of work gear.

③ It makes a groan sound during shaving.

④ Short chips like file powder come out instead of long chips like needles.

⑤ Tooth thickness of shaved gear is not equal, even shaving by sending all the way up to the constant center distances.

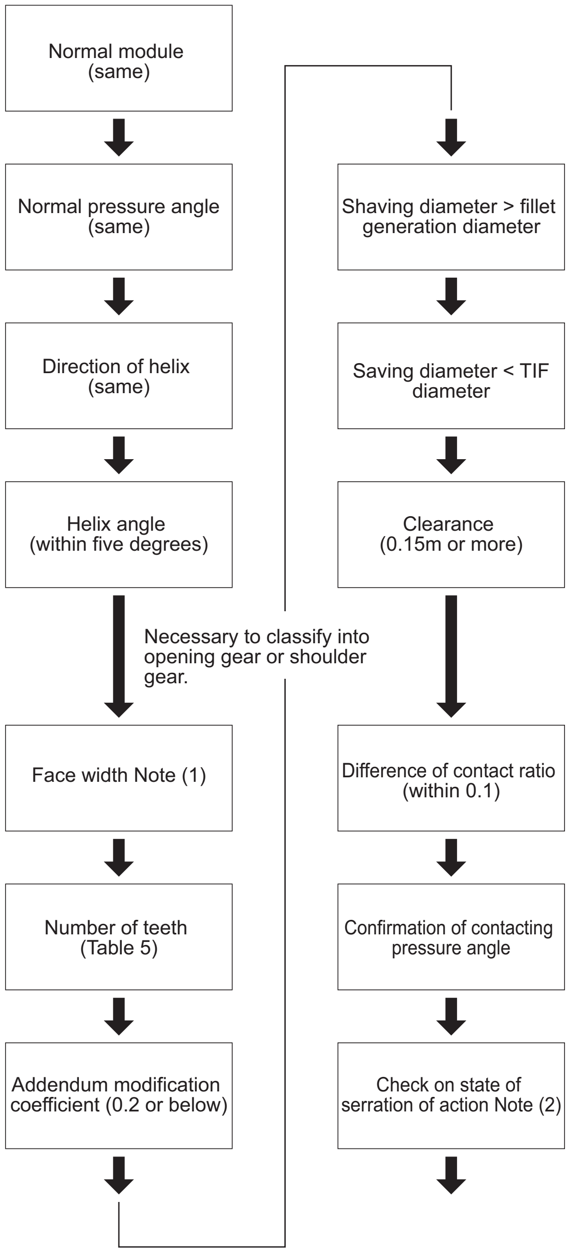
⑥ Tooth profile of the cutter lose the shape.

4-9 Sharing of shaving cutter

When one cutter is shared by gears that have the same modules and pressure angles but different numbers of teeth, balance of the contact ratio and action power is different due to difference in the numbers of teeth and addendum modification coefficient. This causes tooth profile error, so that it remains questionable whether cutter tooth profile can be shared or not. Therefore, it cannot be decided precisely whether it is possible or not, until a trial shaving is done. However, for your information, the examination procedure and the range of sharing are provided in Table 6 and Fig. 18.

Table 6 Numbers of teeth for sharing (work gear)

	Group No. Number of teeth (work gear)			
Module	1	2	3	4
1.25	13~22	20 or more	–	–
1.5~2	13~18	17~34	25 or more	–
2.25~3	14~18	17~29	27 or more	–
3.25~5	14~17	17~26	23~40	35 or more
5.25~8	15~17	17~25	24~37	35 or more



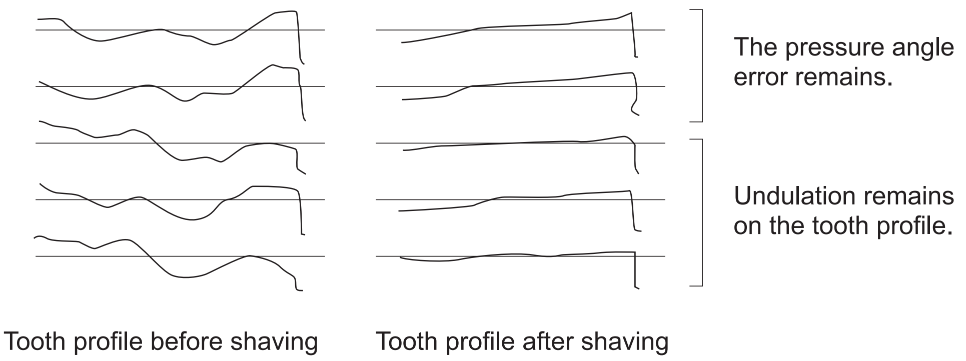
Note(1) Examine in case of diagonal, plunge cut, and under-pass cutting.
Note(2) Examine in case of the plunge cut and the under-pass cutting.

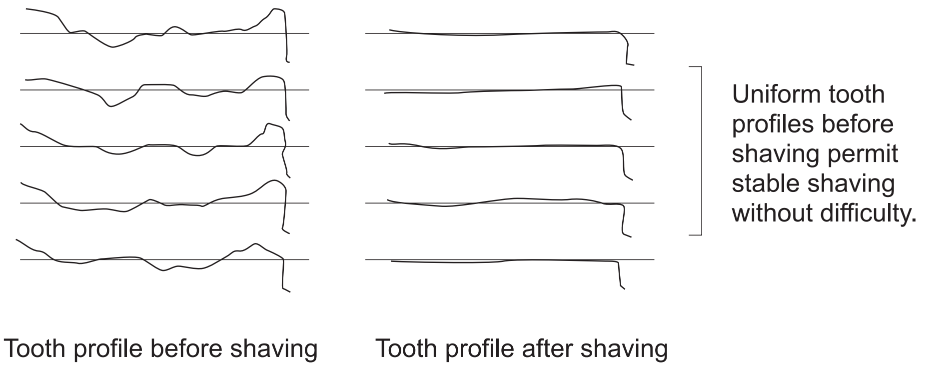
Fig.18 Flow chart of shaving examination

4-10 Troubles and solutions of shaving process

(1) Influence of tooth profile before shaving

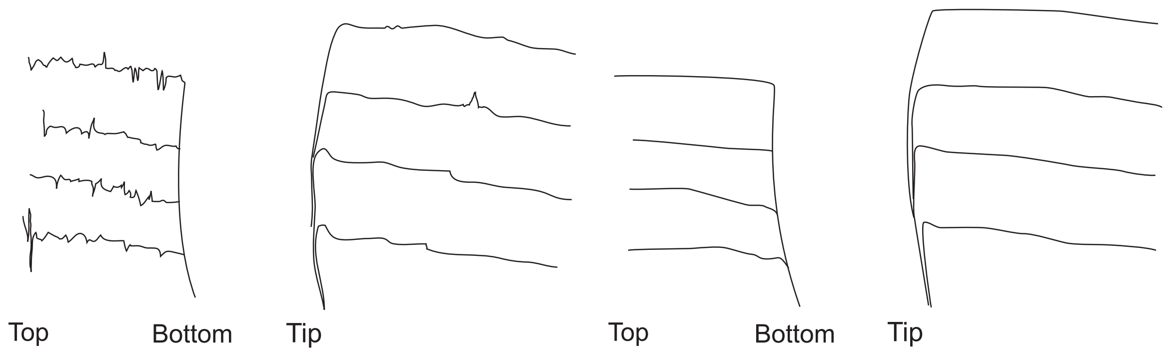
Please note that the major features of pre-shaving tooth profile could influence the newly shaved tooth profile.





(2) Influence of cutter tooth space runout

The tooth space runout at the time of grinding the shaving cutter tooth flank can cause undulation on the work gear tooth profile.



Tooth trace of work gear (x 500.2); tooth profile of work gear (x 500.4); tooth space runout of shaving cutter is 75μm

Tooth trace of work gear (x 500.2); tooth profile of work gear (x 500.4); tooth space runout of shaving cutter is 9μm

●Troubles and solutions in shaving processing

Trouble	Cause	Solution
A. Scratch of gear's tooth flank	1. Degradation of the shaving oil	Check and change of the shavng oil.
	2. Cutter's involute tooth flank is rough	Re-grinding the cutter (Be careful in sparking out).
	3. Shaving stock is too much	Check and reexamine the tooth thickness of work gear before shaving (Refer to 4-8-(2)).
	4. Dent of the work gear	Handle with care the work gear.
	5. Inappropriate cutter's design	Reexamine the cutter's materials and surface treatment.
	6. Cutter became magnetized	Demagnetize from cutter.
B. Roughness of gear's tooth flank	1. Degradation of the shaving oil or inappropriation	Check and change of the shaving oil.
	2. Shaving stock is too much	Check and reexamine the tooth thickness of work gear before shaving (Refer to 4-8-(2)).
	3. Share of cutter (plunge, under-pass)	Design the cutter's for respective gears.
	4. The tooth space runout of cutter in grinding	Refer to 4-10-(2).
	5. The fillet interference of cutter's circumference	Appropriate slection of the pre-shaving tools (Refer to 4-8-(3)).
	6. Inappropriate serration arrangement	Reexamine the cutter's design.
C. Defective tooth profile of work gear	1. Defective tooth profile before shaving	Refer to 2-11,2-12(hob), 3-8,4-8-(1),4-10-(1)(shaper cutter).
	2. Inappropriate cutter's design	Reexamine the cutter's design.Check the cutter's relation of outside dia-tooth thickness.
	3. The fillet interference of cutter's top	Appropriate slection of the pre-shaving tools (4-8-(3)).
D. Uneven tooth profile of work gear	1. Defective tooth profile before shaving	Refer to 2-11,2-12(hob), 3-8,4-8-(1),4-10-(1)(shaper cutter).
	2. Defective turning accuracy	Advancement in accurucy of work gear. (Bore dia, the parpendicularity of bore and end face.)
	3. Work gear runout	Check the arbor runout and fitting with work gear's bore (Refer to 4-8-(5),(6)).
	4. Decrease of cutter's edge sharpness	Re-grinding the cutter.
	5. The oscillation in shaving	Check the oscillation of shaving machine.
	6. Inappropriate cutter's design	Reexamine the cutter's design.
E. Short tool life	1. The same is D.Uneven tooth profile of work gear	
	2. Inappropriate machining conditions	Refer to 4-6.
	3. Inappropriate cutter's design	Reexamine the cutter's design (Rigidity, Serration arrangement etc).
F. Chipping of cutter	1. The burr from process before shaving	Refer to 4-8-(7).
	2. Shaving stock is too much	Check and reexamine the tooth thickness of work gear before shaving (Refer to 4-8-(2)).
	3. The fillet interference of cutter's circumference	Check the cutter's relation of outside dia-tooth thickness. Appropriate selection of the pre-shaving tools (Refer to 4-8-(3)).
	4. Inappropriate cutter's design	Reexamine the cutter's materials and surface treatment.
	5. Inappropriate machining conditions	Refer to 4-6.

4-11 HSP Shaving cutter with Long life / high efficiency

Offers better wear resistance, strength and hardness than conventional shaving cutters.

● Features

① Cobalt high-speed which is high Co (cobalt)

→Improved in heat resistance and hardness

② High hardness offers better sharpness

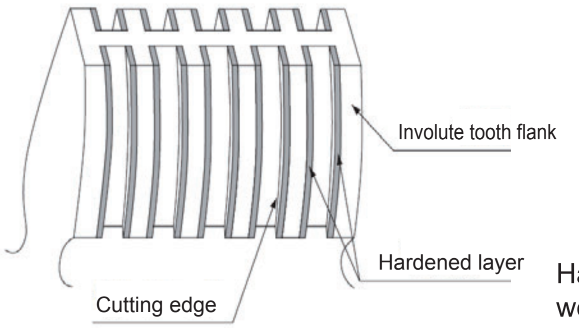
→Improved in wear resistance

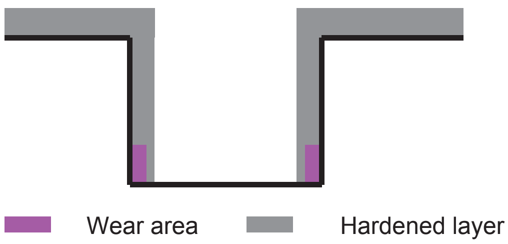
③ Vanadium (V) content is minimized to offer good grindability

→Facilitates tooth shape grinding

Enhanced strength by optimization of heat treatment conditions

→Improved in chipping resistance





Hardened layer, which is deeper than wear range, enhances tool life (compared with conventional cutter)

● HSP shaving cutter cutting performance

[Example 1] Ring gear

		Average machining qty/REG	Effect
(Work dimension) m1.5 PA14.5° 80NT 30° RH (Cutter dimension) 121NT 15° LH Plunge cut	Usual shaving cutter (SKH51+Nitride oxidation)	3000	—
	HSP	9000	3 times

[Cutting example 2] High hardness work

		Average machining qty/REG	Effect
(Work dimension) m2.9 PA14.5° 30NT 15° LH (Cutter dimension) 67NT 5° RH Conventional	Usual shaving cutter (SKH51+Nitride oxidation)	500	—
	HSP	1150	2.3 times

4-12 High-performance steel KHVX shaving cutter

Tool material of shaving cutter is in the tendency that Cobalt rich material is used, like HSS in the above-mentioned. Our company has succeeded in achieving practical application of new material KHVX, which V(vanadium) along with Co is added to improve wear resistance.

● Features of new steel KHVX

①The wear resistance improves with a rich vanadium and rich cobalt.

②Chipping resistance is maintained by making the VC carbide of high hardness minute and even.

[Comparison of material characteristics]

	Division	Wear resistance	Chipping resistance	Heat resistance	Grindability
SKH51 AISI M2	Dissolution material				
KHA	Powder material				
KHVX	Dissolution material				

[Cutting example]

	Material	Number of average processing/REG (N=5)	Effect
Work dimension m2.5 PA17.5° 30NT 30° RH SCr420 (Cutter dimension) 79NT 15° LH Plunge cut	SKH51 AISI M2	1,900	—
	KHA	3,800	2.0 times
	KHVX	4,032	2.1 times

4-13 Shaving cutter technical lineup

Various problems can be eliminated by special serration array.

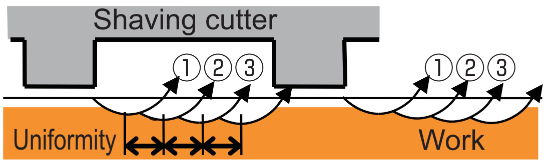
(1) Multi-pattern serration / improvement of circumferential twist of tooth shape

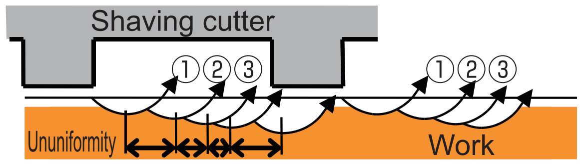
• Optimization and disproportionation depth of cut in work tooth trace direction

→ Controls vibration that occurs when cutting

• Original serration array that suppresses disparity in tooth shape and tooth trace in same work

Array comparison

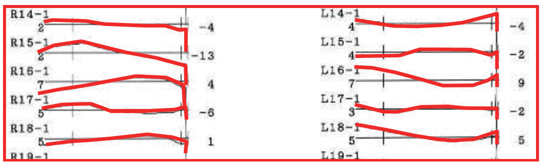


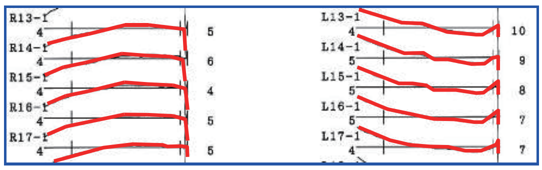


Conventional serration

Multi-pattern serration

Tooth shape precision comparison



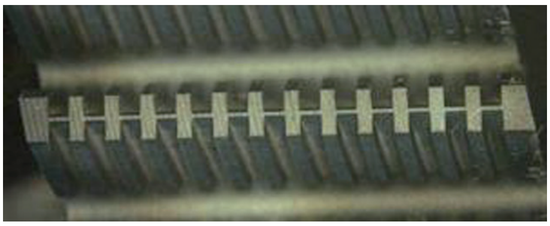


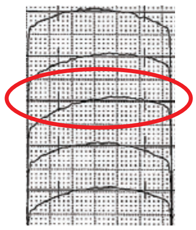
(2) Fine pitch serration / improved tooth surface roughness

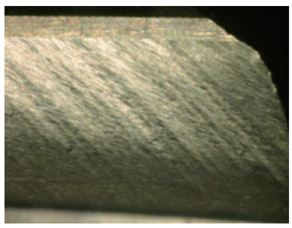
• Makes the serration array closely-spaced

→ Tooth surface roughness improvement by increasing cutting edge that affects work tooth surface, fine pitch serration

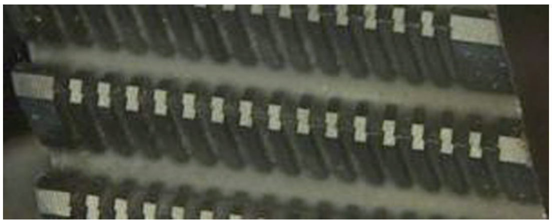
Conventional serration

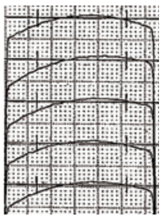


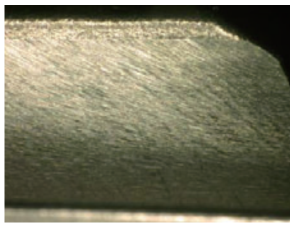




Fine pitch serration

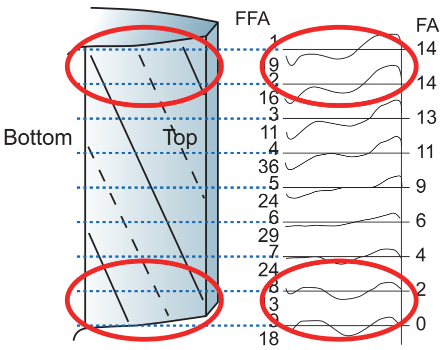


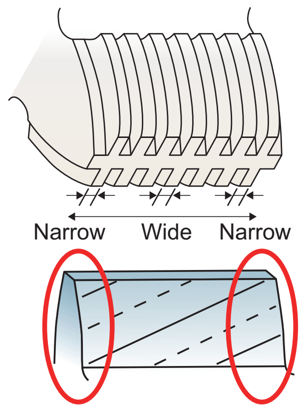


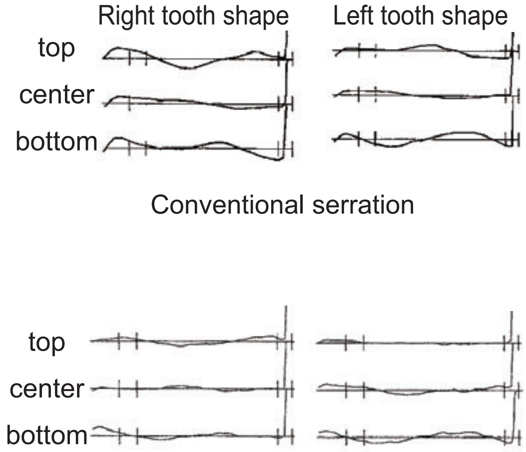


(3) Variable-land serration/ improved in upper / middle / lower tooth disparity

• Unequal serration land at upper lower position of tooth shape where contact fluctuation tends to occur







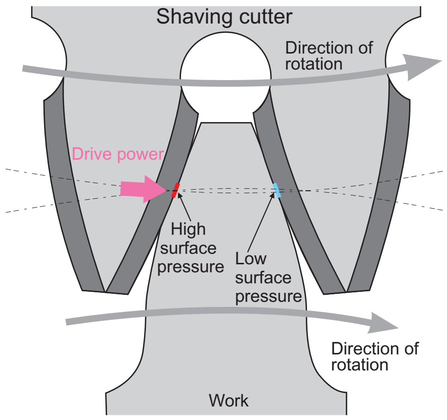
Contact is unstable in parts where generating bus is short.
Eliminated disparity by improving some unstable sharpness.

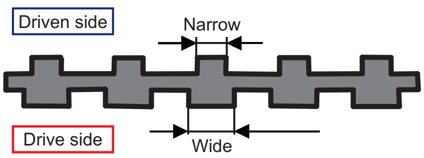
Variable-land serration

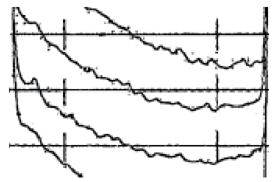
(4) Dissymmetry serration / Left/right tooth shape disparity improvement

• Asymmetrization of serration land of drive side and driven side

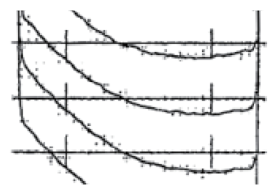
→ Enhancement of drive side tooth surface precision by design taking unbalance of cutting stock due to difference in surface pressure into account







Conventional serration



High surface pressure
→ Tooth surface precision deteriorates from excessive cutting

Change due to surface pressure of land width reduces excessive cutting

Dissymmetry serration

4-14 Standard size table

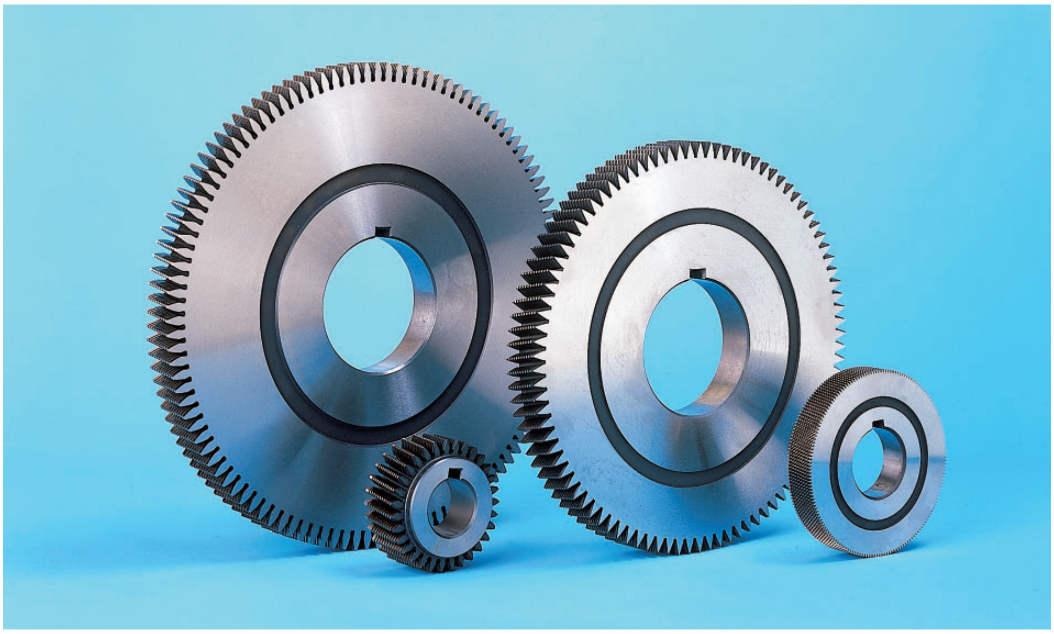


Table 7 Standard size of rotary type shaving cutter

Nominal size	Module m	Number of teeth z	Width b
175	1.25	137	
	1.5	113	
	1.75	97	19.05
	2	89	
	2.25	79	
	2.5	67	
	2.75	61	25.4
	3	59	
	3.5	47	
	4	43	
200	1.5	137	
	1.75	113	
	2	97	
	2.25	89	
	2.5	79	19.05
	2.75	73	
	3	67	
	3.5	59	
	4	47	25.4
	4.5	43	
	5	41	
	5.5	37	
	6	31	

Note: Custom dimensions other than the following are available Please inform us of the desired dimensions.

Nominal size	Module m	Number of teeth z	Width b
225	2	113	
	2.25	97	
	2.5	89	
	2.75	79	
	3	73	19.05
	3.5	61	
	4	53	
	4.5	47	
	5	43	25.4
	5.5	41	
	6	37	
	7	31	
	8	29	
300	4	73	
	4.5	67	
	5	59	
	5.5	53	25.4
	6	47	
	7	41	
	8	37	
	9	31	31.75
	10	29	
	11	27	
	12	23	

Pitch circle diameter is a value close to nominal size. （JISB4357）

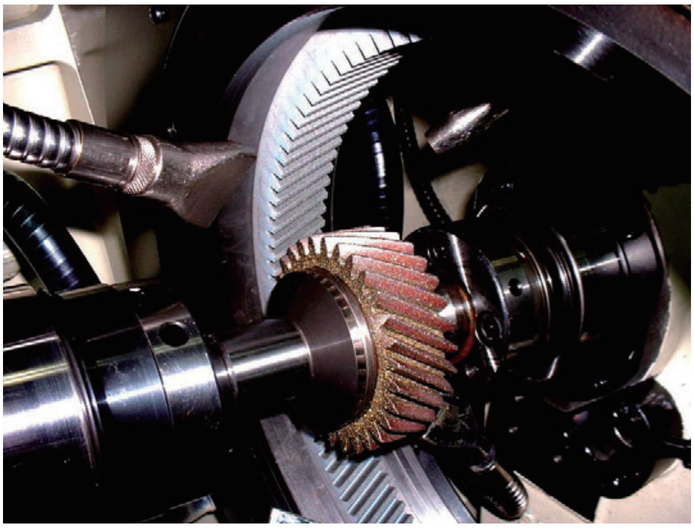
5.Diamond dressing gear

5-1 Features

• Shape tool for work piece (gear) with tooth surface with diamond abrasive grain electrodeposition for forming and dressing grindstone for grinding gears.

• By copying the shape of the dressing gear to a grind stone, and with the grind stone grinding the tooth surface of the gear, the cycle time is shortened and mass production of gears is accommodated.

• Re-electrodeposition supported



Diamond dressing gears have the same shapes as work piece gears as shown in Fig.1.

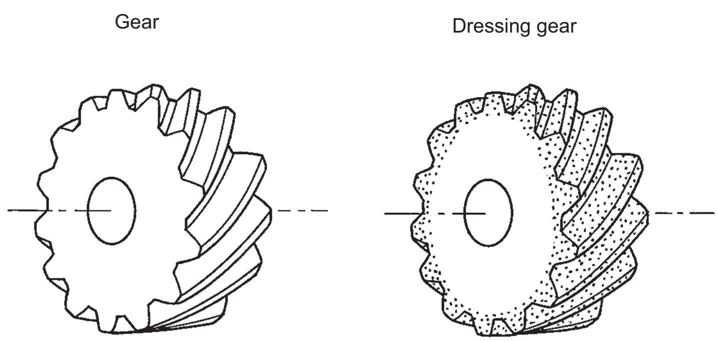


Fig.1 Shape of Diamond dressing gear

Dressing gear is produced as following. Diamond grains are adhered to the surface of gear shaped alloy steel in an electroplating method (electrodeposition), then gear tooth flank is ground with a diamond grinding wheel, and the dressing gear is completed. Its tool life depends on required accuracy of work piece and grinding condition, etc, however, generally one dressing gear is capable of dressing 400 to 500 times and producing 10,000 to 20,000 gears. In order to re-use it, old diamond grains electrodeposited on the surface of the dressing gear should be removed, then new diamond grains applied.

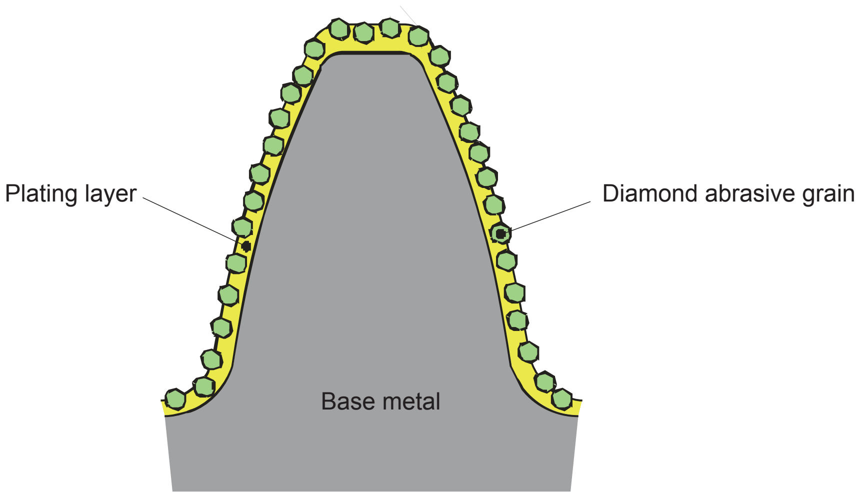


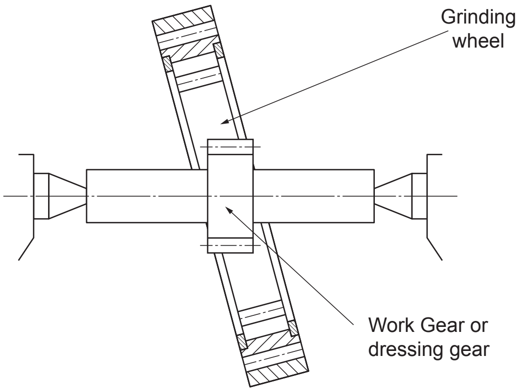
Fig. 2: Diamond dressing gear tooth construction

5-2 Machining principle

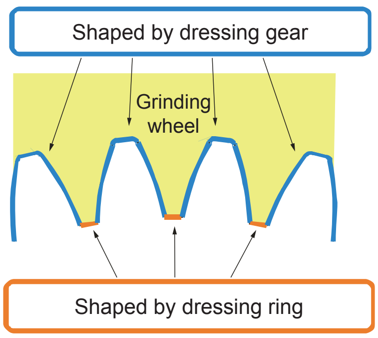
"Gear honing is generally accomplished by grinding gears with grindstone with internal gear shape. Tooth surface of grindstone is shaped to small diameter by dressing gear.

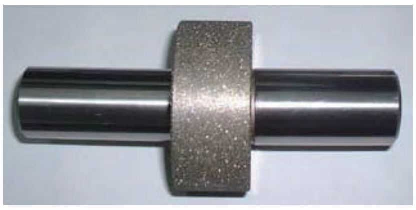
Dressing grindstone in a short time by installing the dressing gear at the same abrasive gear position."

Since the accuracy of a dressing gear is transcribed through the grinding wheel as it is in this method, the dressing gear requires tooth profile accuracy by μm order.



Gear honing method





Dressing ring

5-3 Bias modified tooth profile dressing gear

In order to ensure teeth to mesh well with each other, transmission gears often adopt a bias modified tooth profile whose tooth profile is continuously changed along the lead of the gear tooth as shown in Fig.3. A bias modified tooth profile is obtained by eccentric of rolling block that is used for tooth profile generating motion, when grinding tooth profile. In this grinding method, a grinding wheel with large outside diameter is used. For tooth profile grinding of a dressing gear, a diamond grinding wheel is used. But it is difficult to manufacture a highly accurate grinding wheel with large outside diameter so that inevitably it is not possible to obtain a dressing gear with high accuracy.

Our company has developed three dimensional CNC gear grinding machine with a small diameter grinding wheel, and realized highly accurate bias tooth profile truing of a dressing gear. A dressing gear tooth profile after truing is shown in Fig.4, and a gear tooth profile after honing is shown in Fig. 5.

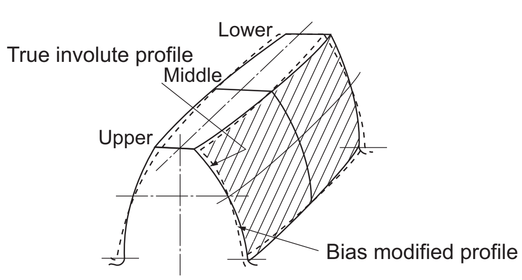


Fig.3 Bias modified tooth profile

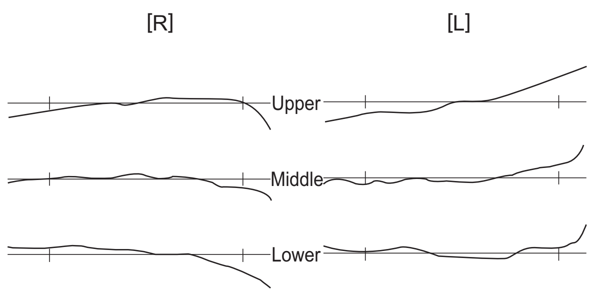


Fig.4 Tooth profile of dressing gear ground

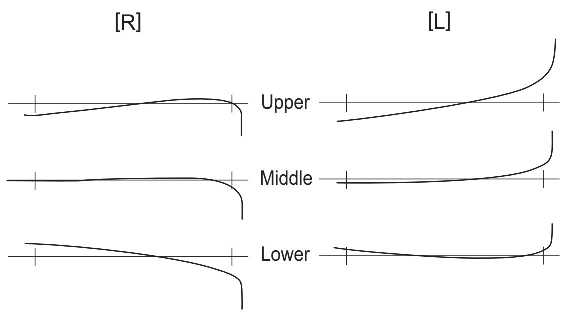
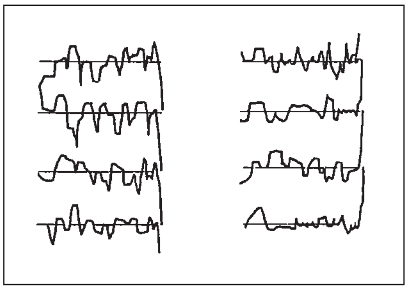


Fig.5 Tooth profile of gear after honing

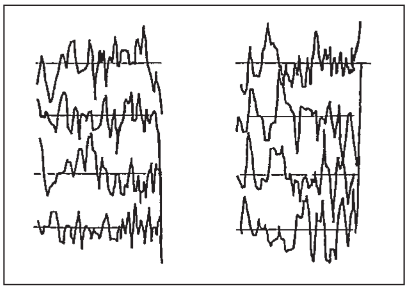
5-4 Precise electrodeposition technology

When diamond grain is electrodeposited to a base metal of a dressing gear, affected by uneven size of diamond grain, the height of diamond grain on dressing gear surface is also uneven. Also these grains are not completely bonded with the surface of the base metal.

Based on close observation of electrodeposited diamond grain behavior, our company has designed and adopted a advanced precise electrodeposition method by which precisely classified abrasive grain can be adhere to the base material. Photograph 1 is a SEM photograph of a dressing gear tooth flank. Fig.6 is a comparison of electrodeposited tooth profiles of dressing gears after conventional electrodeposition method and advanced precise electrodeposition method.



Advanced method



Conventional method

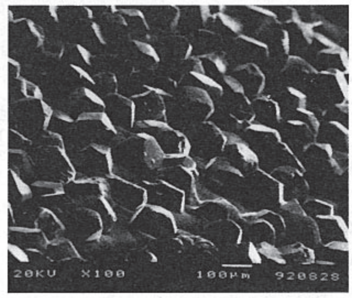


Photo. 1 SEM photograph of tooth surface of dressing gear

Fig.6 Tooth profile of dressing gear after electrodeposition

5-5 Dressing gear Abrasive grain lineup

The following abrasive grain sizes are available for diamond dressing gear used for gear honing.

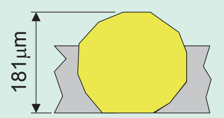
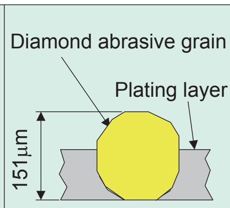
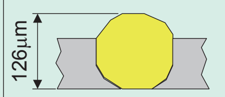
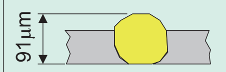
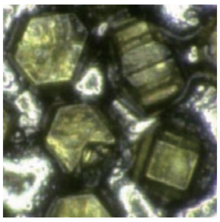
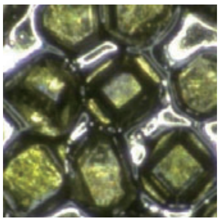
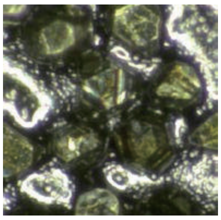
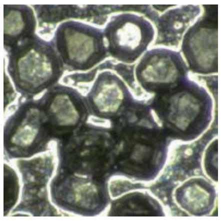
Diamond abrasive grain	#80	#100	#120	#170
Abrasive grain size comparison	2	1.7	1.5	1
Abrasive grain surface area comparison	4	3	2	1
Grain retentivity	Big ←	→	→	→ Small
Average diameter of grain				
Electrodeposition abrasive grain photograph				

Fig.7 Abrasive grain lineup

Dressing gear	Number of work gear
#80	11,500gear
#170	6,000gear
	Gear dimension : m3.0 PA17.5° 28° LH 20NT width40
#80	21,000gear
#120	14,500gear
	Gear dimension : m2.25 PA17.5° 30° RH 50NT width30

Fig.8 Example of machining

#80 abrasive grain, in particular, has twice the diameter and 4 times the surface area of #170 abrasive grain. It has dramatically improved abrasive grain hardness and retention. The tool life is 1.5 or 2 times longer than that of conventional tool with #170, #120 grain.

By our original precise electrodeposition technology and semi truing method, tooth profile of work gear equals with that of conventional products.

6.Other products

6-1 Burnishing gear

This tool removes dent or burr of a heat-treated gear, by pushing in and rotating a tool with correct pressure angle and helix angle. Machining is usually done with a set of three burnishing gears.

Burnishing gear

6-2 Deburring cutter

It is a gear shaped tool which chamfers the end face of a cut and manufactured gear in a short time, by crushing the gear along the direction of involute. The following 2 types are available for chamfered parts (see Fig. 1).

- Type that chamfers only one side of a tooth surface
- Type that chamfers the end surface of the left and right tooth surfaces

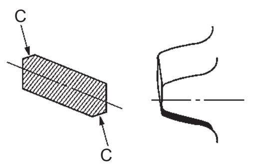
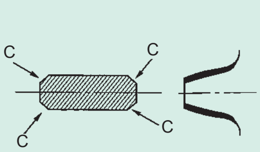
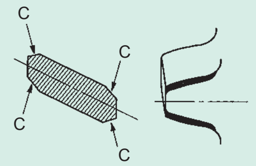
Gear type / Chamfering type	Spur gear	Helical gear
One side	―――	
Both sides		

Fig. 1 Type for chamfered parts

Fig. 2 Deburring cutter and gear

Deburring cutter

The following 3 types are available for chamfered parts (see Fig. 3).

- Taper shape in which the amounts of chamfer on the tooth tip and tooth base differ
- Parallel shape in which the amount of chamfer on the tooth tip and tooth base are the same
- Parallel shape in which the tooth bottom is simultaneously chamfered.

Inclining end face can be chamfered, too although a gear end face is usually right-angled to the axis. Confirmation bycalculation is necessary when exceeding 15˚.(see Fig. 4).

Change phase of the 2 blades for adjusting amount of chamfering. Combination of eccentric pins enables phase to be adjusted by bolt (see Fig. 5).

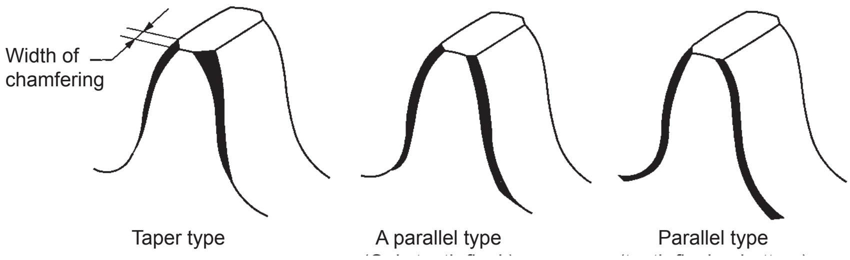


Fig.3 The chamfering shape

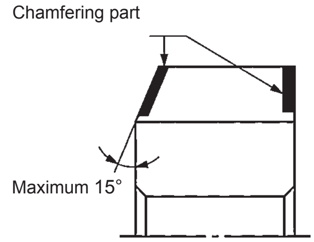


Fig.4 Gear whose end face inclines

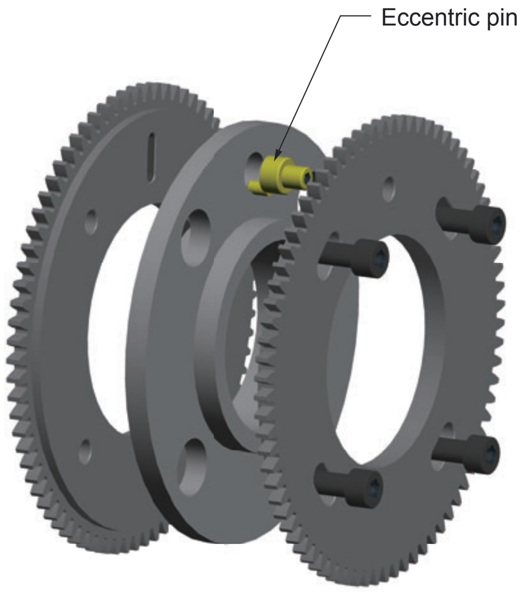


Fig. 5 Phrasing cutter with eccentric pin

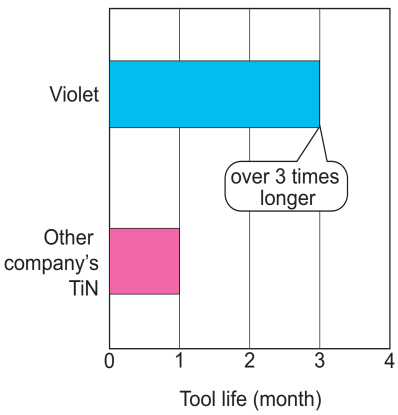
6-3　Master gear

It is rotated with a measured gear and judges the gear accuracy from the state of contact. It is also used as a gear which detects eccentricity, tooth thickness and dent etc., when set in an automatic sorter for two tooth flank engagement.

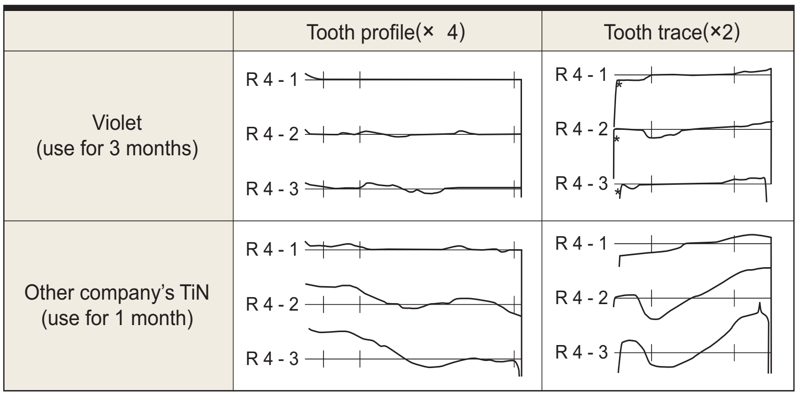
Our company manufactures TiN or Violet coated master gears whose coating techniques have already been applied to other various cutting tools.

Master gear

Comparison of tool life



Tooth profile of master gear (×500)



Master gear : Number of teeth 45　Tooth width 19mm　Powder metallurgy Hss
Gear : m2.4　PA17°　Number of teeth 37　Helix angle 25°RH　Tooth width 17mm　Material SCM415

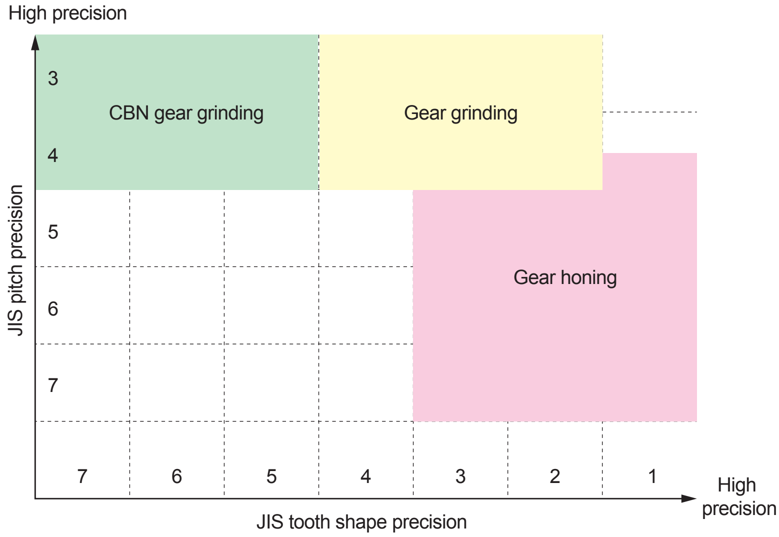
Fig.6　Effect of Violet coating

6-4 TRG-Tool (Triple R Gear Grinding Tool)

Worm wheel with CBN grains electrodeposited for high speed and high efficiency gear grinding.

●Features

- ●Rough High correction ability of pitch error(suitable for pre-gear honing)
  Effective for extending gear honing grindstone life and dress cycle
- ●Rapid Employs worm shape to support continuous generating gear grinding that enables high-speed cutting.
  Doesn't require machine upper stress for crafting tooth shape during fabrication.
- ●Reliable Product technology of high precision worm body and precise electrodeposited technology
  and design technology of gear cutting tools (high reproducibility of installation accuracy of tool)



Cutting method for various gears and target

●Machining example

Table 1 Gear grinding condition

Work dimension		Tool spec		Grinding condition	
Module	2.3	Diameter	120mm	Tool revolution	4.000min^{-1}
Number of teeth	43	Grain size	cBN#170	Feed rate	0.5–1.0mm/rev
Pressure angle	17.5 deg	Number of thread	2	Machining time	60sec

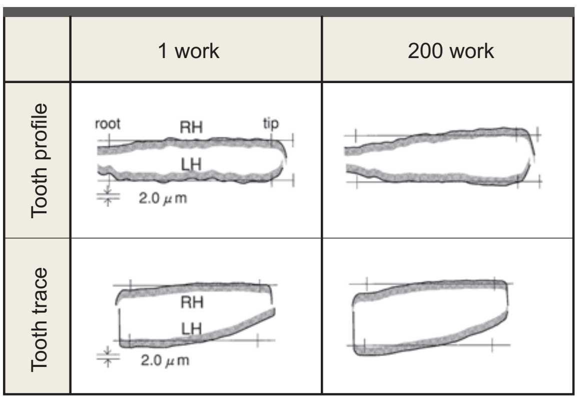


Fig.7 Profile and lead error

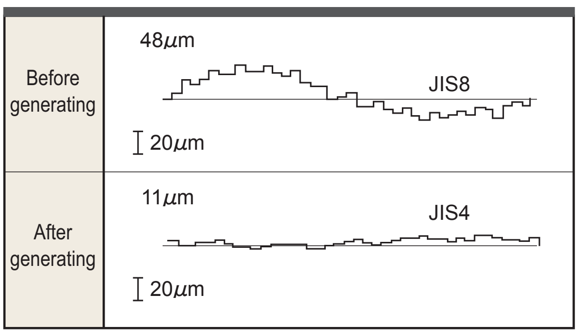


Fig.8 Accumulative pitch error

7.Reference

7-1 Order specifications

Gear Cutting Tools Section

Date ’ . .

☐ Solid ☐ Carbide Hob Design Specification	Order No.	Quantity	Standard Design Plan		Sales Dep.
	Customer		Date	Name	Name
Supplied Drawing	☐Nothing ☐Gear Drawing ☐Our Company Drawing ☐Another Company Drawing ☐Customer Spec ☐Others				
Gear Spec	☐ As In The Supplied Figure ☐ Add or Change the following A				
Cutter Spec	☐ As In The Supplied Figure ☐ Add or Change the following B				
Date of Delivery	☐ Ordinary ☐ Certain ☐ Advanced (Date of Delivery)				

☐ Standard Design ☐ Improvement Design ☐ Comparison Article	Remarks	☐ The material has previously arranged.

A	Working gear spec	
	Part Name	Drawing ☐ Need ☐ Unneeded
	Part No	Drawing ☐ Need ☐ Unneeded
☐	Material	
☐	Hardness	
☐	M or DP	
☐	PressureAngle	
☐	No of Teeth	
☐	Helix Angle	☐RH ☐LH
☐	Outside Dia	
☐	Root Dia	☐ Root Dia ☐Tooth Height ☐ Addendum
☐	Tooth Thickness	☐ Arc Tooth Thickness ☐ Base Tangent Dim and Z ☐ OBD Measurement and ϕ
	☐ After Finishing	
	☐ After Hobbing	
	☐ Shaving (Grinding) Stock	☐ Arc ☐ Base Tangent ☐ OBD
☐	☐Tooth Profile Length	☐ Contact Length ☐ TIF Dia ☐ Rotation Angle
	☐ Mating Gear Spec	No. of Tooth Outside Dia Center Distance
	☐ Root Radius	☐ Free ☐ Gear's Fillet Radius ☐ Hob's Nose Radius
☐	Semi-Topping	☐ Radius Direction Amount ☐ Amount on Oblique Edge ☐ Semi-Topping Dia ☐ Others
☐	Gear Shape	☐Open Gear(Face Width:) ☐ Shoulder Gear (Shoulder Outside Dia : Space :)

B	Hob spec	
☐	Tool No	
☐	Accuracy	☐ Class 1 ☐ ( )
☐	Coolant	☐ Dry ☐ Wet
☐	Material	☐ KMC ( ) ☐ KHA ( ) ☐ KVC ( ) ☐ Other ( ) ☐Free
☐	Surface Treatment	☐ Ti Coating ☐ Violet Coating ☐ GV40 ☐ DP ☐ Nothing ☐ Other ( )
☐	Outside Dia	
☐	Overall Length / Length of Cut	/ ☐ Free
☐	Bore Dia	
☐	Key Way	☐ JIS Standard ☐ Special (Width: Depth: R:)
	Side Key	☐ JIS Standard ☐ Special (Width: Depth: R:) ☐ Left ☐ Right ☐ Both (Hub Length:)
		☐Reference Drawing( )
☐	No. of Starts	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
☐	Direction	☐ RH ☐ LH ☐ Free
☐	Rake Angle	☐0° ☐6° ☐8° ☐( )
☐	No. of Gash	☐ Free ☐ Specified( )
☐	Gash Lead	☐ ∞ ☐ Exist ( )
☐	Tooth Profile	☐ Finish ☐ P ☐ PG ☐ S-Top ☐ PS ☐ PGS ☐ PP ☐ PGP ☐ PSP ☐ PGSP
☐	Topping	☐ No ☐ Yes
☐	Tooth Profile Modification	☐Nothing ☐ Stug ☐BS(A2, B) Modification ☐BS(C, D) Modification ☐Special Modification( )

Gear Cutting Toools Section Date ' . .

☐ Hob for Rack ☐ Serration Cutter Design Specification	Order No.	Quantity	Standard Design Plan		Sales Dep.
	Customer		Date	Name	Name
Supplied Drawing	☐Nothing ☐Gear Drawing ☐Our Company Drawing ☐Another Company Drawing ☐ Customer Spec ☐ Others				
Gear Spec	☐ As In The Supplied Figure ☐ Add or Change the following A				
Cutter Spec	☐ As In The Supplied Figure ☐ Add or Change the following B				
Date of Delivery	☐ Ordinary ☐ Certain ☐ Advanced (Date of Delivery)				

☐Standard Design ☐Improvement Design ☐Comparison Article	Remarks	☐ The material has previously arranged.

A	Working Gear Spec		B	Hob Spec	
	Part Name	Drawing ☐ Need ☐ Unneeded	☐	Tool No	
			☐	Accuracy	☐ Class 1 ☐ ( )
			☐	Coolant	☐ Dry ☐ Wet
	Part No	Drawing ☐ Need ☐ Unneeded	☐	Material	☐ KMC ( ) ☐ KHA ( ) ☐ KVC ( ) ☐ Other ( ) ☐Free
☐	Material		☐	Surface Treatment	☐ Ti Coating ☐ Violet Coating ☐ GV40 ☐ DP ☐ Nothing ☐ Other ( )
☐	Hardness				
☐	M or DP				
☐	Pressure Angle		☐	Outside Dia	
☐	No. of Teeth		☐	Overall Length /Length of Cut	/ ☐ Free
☐	Helix Angle	☐ RH ☐ LH			
☐	☐ Addendum		☐	Bore Dia.	
	☐ After Finishing Tooth Thickness (Normal)		☐	Key Way	☐ JIS Standard ☐ Special (Width: Depth: R:)
	☐ Grinding Stock	☐ No ☐ Yes( )		Side Key Way	☐ JIS Standard ☐ Special (Width: Depth: R:) ☐ Left ☐ Right ☐ Both (Hub Length:) ☐Reference Drawing( )
☐	Inequality Tooth Thickness	☐ No ☐ Yes(Another Indication)	☐	No. of Cutter Teeth	
			☐	Rake Angle	☐0° ☐6° ☐8° ☐( )
			☐	No. of Gash	☐ Free ☐ Specified( )
☐	Root Radius	☐ Free ☐ Gear's Fillet Radius ☐ Hob's Nose Radius	☐	Gash Lead	☐ ∞ ☐ Exist ( )
			☐	Tooth Profile	☐ Finish ☐ PG ☐ S-Top ☐ PGS
			☐	Topping	☐ No ☐ Yes
☐	Semi-Topping	☐ No ☐ Yes( )			
☐	Machining with Both End Part	☐ No ☐ Yes(Another Indication)		Reference End Face and Length	☐ No ☐ Left ☐ Right ☐ Symmetry ( ) Tolerance( )

 Date ' . .

Hob for Spline Shaft Design Specification	Order No.	Quantity	Standard Design Plan		Sales Dep.
	Customer		Date	Name	Name

Supplied Drawing	☐Nothing ☐Gear Drawing ☐Our Company Drawing ☐Another Company Drawing ☐ Customer Spec ☐ Others			
Gear Spec	☐ As In The Supplied Figure ☐ Add or Change the following A			
Cutter Spec	☐ As In The Supplied Figure ☐ Add or Change the following B			
Date of Delivery	☐ Ordinary ☐ Certain ☐ Advanced (Date of Delivery)			

☐ Standard Design ☐ Improvement Design ☐ Comparison Article	Remarks	☐ The material has previously arranged.

A	Working gear spec		B	Hob spec	
	Part Name	Drawing ☐ Need ☐ Unneeded	☐	Tool No	
			☐	Accuracy	☐ Class 1 ☐ ( )
			☐	Coolant	☐ Dry ☐ Wet
	Part No	Drawing ☐ Need ☐ Unneeded	☐	Material	☐ KMC ( ) ☐ KHA ( ) ☐ KVC ( ) ☐ Other ( ) ☐Free
☐	Material		☐	Surface Treatment	☐ Ti Coating ☐ Violet Coating ☐ GV40 ☐ DP ☐ Nothing ☐ Other ( )
☐	Hardness				
☐	Number of Serrations				
☐	Outside Dia		☐	Outside Dia	
☐	Root Dia	Grinding Stock( ) ☐ Root Dia ☐ One Side	☐	Overall Length / Length of Cut	/ ☐ Free
			☐	Bore Dia.	
☐	Spline Width	Grinding Stock( )	☐	Key Way	☐ JIS Standard ☐ Special (Width: Depth: R:)
☐	Tooth Form Diameter	☐ Form Diameter ☐ Mating Internal Spline Gear's Inside Diameter		Side Key Way	☐ JIS Standard ☐ Special (Width: Depth: R:) ☐ Left ☐ Right ☐ Both (Hub Length:)
☐	Slot on Corner between Spline and Root	☐ No ☐ Yes(Another Indication) ☐ Determined by Form Diameter			☐ Reference Drawing( )
☐	Semi-Topping	☐ Radius Direction Amount ☐ Amount on Oblique Edge ☐ Semi-Topping Dia ☐ Others	☐	Lug (correspond to Slot on Corner)	☐ No ☐ Free(Computed with Base Diameter) ☐ Specified
				No. of Starts	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
			☐	Direction	☐ RH ☐ LH ☐ Free
			☐	Rake Angle	☐0° ☐6° ☐8° ☐( )
			☐	No. of Gash	☐ Free ☐ Specified( )
			☐	Gash Lead	☐ ∞ ☐ Exist ( )

 Date ‘ . .

Shaper Cutter Design Specification ☐ Disc ☐ Counterbore ☐ Shank	Order No	Quantity	Standard Design Plan		Sales Dept.
	Customer		Date	Name	Name
Supplied Drawing	☐ None ☐ Gear Drawing ☐ Our Company's Cutter Drawing ☐ Other Company's Cutter Drawing ☐ Customer Spec ☐ Others				
Gear Spec	☐ As in the Supplied Figure ☐ Add or Change the Following A				
Cutter Spec	☐ As in the Supplied Figure ☐ Add or Change the Following B				
Delivery	☐ Ordinary ☐ Certain ☐ Advanced (Date of Delivery)				

☐ Standard Design Item ☐ Improved Design Item ☐ Comparative Article	Remarks	☐The material has been previously arranged

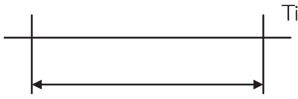
A	Working Gear Spec	
	Part Name	Add to Drawing ☐ Need ☐ Unneeded
	Part No.	Add to Drawing ☐ Need ☐ Unneeded
☐	Material	
☐	Hardness	
☐	M or DP	
☐	Pressure Angle	
☐	No. of Teeth	☐ EXT ☐ INT
☐	Helix Angle	☐ RH ☐ LH
☐	Outside Dia	
☐	Root Dia	☐ Root Dia ☐ Whole Depth ☐ Hob Addendum
☐	Tooth Thickness	☐ Circular Tooth Thickness ☐ Base Tangent Length No. of Teeth ( ) ☐ OBD Measurement Ball Dia (ϕ)
	☐ After Shaving	
	☐Before Shaving	
	☐SV Stock	☐ Circular ☐ Base Tangent L ☐ OBD
☐	☐ Tooth Profile Length	☐ Contact length ☐ TIF Dia ☐ Rotation Angle
	☐Mating Gear Spec	No. of Teeth Outside Dia Center Distance
☐	Root R	☐Free ☐Work root R ☐Cutter tip R
☐	Amount of Chamfering ☐After Cut ☐After Shv.GR	☐ Radial ; Circumferential ; ☐ Oblique Direction
☐	Face Width	
☐	Gear Shape	☐ Open gear ☐ Shoulder gear (Shoulder Outside Dia) (Space) ☐With side relief gear (With detail Spec)
	Note	☐ Non ☐ Special Index ☐ Irregular Pitch

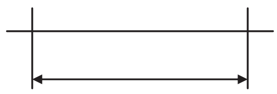
B	Cutter Spec		
☐	Tool No.		
☐	Accuracy	☐( ) ☐ (JIS Class)	
☐	Material	☐ SKH55 ☐ KMC3 ☐ KMCZ ☐ KHA( ) ☐ Other ( )	
☐	Surface Treatment	☐ TiN ☐ Violet ☐ DP ☐ Nothing ☐ Other ( )	
☐	No. of Teeth	☐ As demanded (T) ☐ Free ☐ 50type ☐ 75type ☐ 100type ☐125type ☐ 150 type ☐ 175type	
☐	Overall Width	☐ As demanded ( ) ☐ Free	
☐	Tooth Width	☐ Overall width ☐ As demanded ( ) ☐ Free ☐With Boss (Boss Dia)	
☐	Bore Dia	☐ 31.742 ☐ 44.45 ☐ 31.75 ☐ Other (Bore Dia Tolerance)	
☐	Keyway	☐ Nothing ☐ Bore Key (Width Height R) ☐ Side Key (Width Height R)	
☐	Rake angle	☐ 5° ☐ Other ( )	
☐	Helical rake Angle	☐ Free ☐ As demanded ( )	
☐	Helical Guide	☐ Free ☐ As demanded ( )	
☐	Tooth Profile ☐Standing Grinding ☐Through Grinding	☐ Standard ☐ P ☐ PG ☐ S-TOP ☐ PS ☐ PGS ☐ PP ☐ PGP ☐ PSP ☐ PGSP	
☐	Topping	☐ With ☐ Without	
☐	Shank size	Overall length	
		Tooth width	☐ As demanded( )☐ Free
		Neck Dia	☐ As demanded( )☐ Free
		Taper Shank	☐MT2 ☐MT3 ☐MT4 ☐F Type ☐Other( ) Shank length ☐ Standard ☐ Special( )
		Pull screw	☐With ☐ Without: Screw Dia ; Effective length ;
	Note		

Date ‘ . .

Shaving Cutter Design Specification	Order No.	Quantity	Standard Design Plan		Sales Dept.
	Customer		Date	Name	Name
Supplied Drawing	☐ None ☐ Gear Drawing ☐ Our Company's Cutter Drawing ☐ Other Company's Cutter Drawing ☐ Customer Spec ☐ Others				
Gear Spec	☐ As in the Supplied Figure ☐ Add or Change the Following A				
Cutter Spec	☐ As in the Supplied Figure ☐ Add or Change the Following B				
Delivery	☐ Ordinary ☐ Certain ☐ Advanced (Date of Delivery)				

☐ Standard Design Item ☐ Improved Design Item ☐ Comparative Article	Remarks	☐The material has been previously arranged.

A	Working Gear Spec	
	Part's Name	Add to Drawing ☐ Need ☐ Unneeded
	Part No.	Add to Drawing ☐ Need ☐ Unneeded
☐	Material	
☐	Hardness	
☐	M or DP	
☐	Pressure Angle	
☐	No. of Teeth	
☐	Helix Angle	☐ RH ☐ LH
☐	Outside Dia	
☐	Root Dia	☐ Root Dia ☐ Whole Depth ☐ Hob Addendum
☐	Tooth Thickness	☐ Circular Tooth Thickness ☐ Base Tangent Length No. of Teeth ( ) ☐ OBD Measurement Ball Dia (ϕ)
	☐ After Shaving	
	☐ Before Shaving	
☐	Add Modification Coef. or Amount	
☐	Face Width	
☐	☐ Tooth Profile Length	☐ Contact length
		☐ TIF Dia
		☐ Rotation Angle
	☐ Mating Gear Spec	No. of Teeth Outside Dia Center Distance
☐	Gear Shape	☐ Open Gear ☐ Shoulder Gear (Shoulder Outside Dia Space)
☐	Tooth Trace	Amount of Crowning lead  Helix ☐ True ☐ Higher ☐ Lower
☐	Tooth Profile ☐ True ☐ Standard ☐ Refer to Another Sheet ☐ According to the Right Figure	Tip  (Substance Side)

B	Cutter Spec	
☐	Tool No.	
☐	Accuracy	
☐	Material	☐ SKH51 ☐ KHV1 ☐ HSP ☐ KHVX ☐ Other ( )
☐	Surface Treatment	☐ Nothing ☐ Nitride Oxidation ☐ STH ☐ Other ( )
☐	Grind Method	☐ Un-Grind ☐ Semi-Grind ☐ Indicate Tooth Profile ☐ With Trial
☐	No. of Teeth	☐ As demanded (T) ☐ Free ☐ 175type ☐ 200 type ☐ 225 type ☐ 250 type ☐ 300 type
☐	Face Width	☐ As demanded ( ) ☐ Free
☐	Attaching Width	☐ As demanded ( ) ☐ The Same as Face Width
☐	Bore Dia , Keyway	☐ Standard ☐ Special(Bore Dia) (Tolerance)
☐	Helix angle	☐ As demanded (☐ RH ☐ LH) ☐ Free
☐	Weight Saving	☐ As demanded ☐ Free
☐	SV Method	☐ Conventional ☐ Diagonal ☐ Underpass ☐ Plunge
☐	Trial Condition ☐ As demanded ☐ Free	rotation min-1 Feed Speed mm/min Feed Length mm (Plunge) T1 T2 T3 BM Diagonal Angle
☐	SV Stock	☐ Base Tangent Length ( ) ☐ OBD ( )
☐	Pre-Shaving Tool ☐ Simultaneous Order ☐ As demanded ☐ Standard(2.35m)	☐ Hob ☐ Shaper Cutter Drawing No ( ) Protuberance ☐ with ☐ without
☐	SV Machine	Name Min-Distance
☐	Amount of Hollow Lead	☐ As demanded ( ) ☐ Free
☐	Tooth Profile ☐ True ☐ Response from Work ☐ Refer to Another Sheet ☐ According to the Right Figure	Tip  (Substance Side)

Gear Cutting Tools Section Date ‘ . .

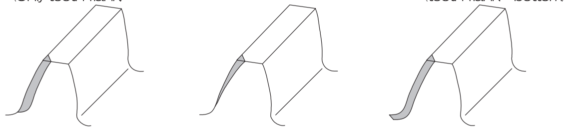
Deburring Cutter Design Specification	Order No.	Quantity	Standard Design Plan		Sales Dept.
	Customer		Date	Name	Name
Supplied Drawing	☐ None ☐ Gear Drawing ☐ Our Company's Cutter Drawing ☐ Other Company's Cutter Drawing ☐ Customer Spec ☐ Others				
Gear Spec	☐ As in the Supplied Figure ☐ Add or Change the Following A				
Cutter Spec	☐ As in the Supplied Figure ☐ Add or Change the Following B				
Delivery	☐ Ordinary ☐ Certain ☐ Advanced (Date of Delivery)				

☐ Standard Design Item ☐ Improved Design Item ☐ Comparative Article	Remarks	☐The material has been previously arranged.

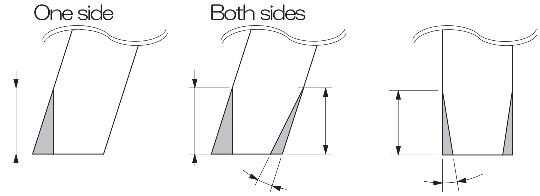
A	Working Gear Spec	
	Part's Name	Add to Drawing ☐ Need ☐ Unneeded
	Part No.	Add to Drawing ☐ Need ☐ Unneeded
☐	Material	
☐	Hardness	
☐	M or DP	
☐	Pressure Angle	
☐	No. of Teeth	
☐	Helix Angle	☐ RH ☐ LH
☐	Outside Dia	
☐	Root Dia	☐ Root Dia ☐ Whole Depth ☐ Hob Addendum
☐	Tooth Thickness (Before Shaving)	☐ Circular Tooth Thickness ☐ Base Tangent Length No. of Teeth ( ) ☐ OBD Measurement Ball Dia (ϕ)
☐	Add Modification Coef. or Amount	
☐	Face Width	
☐	☐ Tooth Profile Length	☐Contact Length
		☐TIF Dia
		☐Rotation Angle
	☐Mating Gear Spec	No. of Teeth Outside Dia Center Distance
☐	Gear Shape	☐ Open Gear ☐ Shoulder Gear (Shoulder Outside Dia Space)
		☐End (parallel) ☐End (taper)

B	Cutter Spec	
☐	Tool No.	
☐	Accuracy	☐Gear JIS 4 class ☐ Other ( )
☐	Material	☐ SKH51 ☐ Other ( )
☐	No. of Teeth	☐ As demanded (T)
		☐ Free ☐ 175type ☐ 200 type ☐ 225 type ☐ 250 type ☐ 300 type
		☐ Center Distance ( ) ☐Outside Dia ( )

☐ A parallel type (Only tooth flank) ☐ Taper type ☐ Parallel type (tooth flank + bottom)

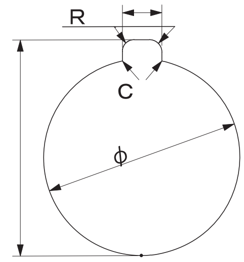


☐ Helical gear One side ☐ Helical gear Both sides ☐ Spur gear

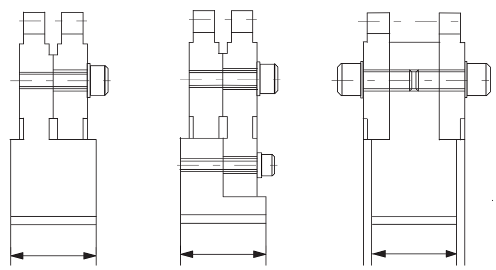


☐	Guide gear	☐ Unneeded ☐ Need
☐	Weight Saving	☐ Free ☐ As demanded
☐	Note	Reference Drawing ( )

☐ Bore Key way Shape



☐TYPE-1 ☐TYPE-2 ☐TYPE-3



☐ Other TYPE

 Date ‘ . .

Master Gear Design Specification	Order NO	Quantity	Standard Design Plan		Sales Dept.
	Customer		Date	Name	Name
Supplied Drawing	☐ None ☐ Gear Drawing ☐ Our Company's Cutter Drawing ☐ Other Company's Cutter Drawing ☐ Customer Spec ☐Others				
Gear Spec	☐ As in the Supplied Figure ☐ Add or Change the Following A				
Cutter Spec	☐ As in the Supplied Figure ☐ Add or Change the Following B				
Delivery	☐ Ordinary ☐ Certain ☐ Advanced (Date of Delivery)				

☐ Standard Design Item ☐ Improved Design Item ☐ Comparative Article	Remarks	☐The material has been previously arranged

A	Working Gear Spec	
☐	Part Name	Add to Drawing ☐ Need ☐ Unneeded
☐	Part No.	Add to Drawing ☐ Need ☐ Unneeded
☐	Material	
☐	Hardness	
☐	M or DP	
☐	Pressure Angle	
☐	No. of Teeth	☐ EXT ☐ INT
☐	Helix Angle	☐ RH ☐ LH
☐	Outside Diia	
☐	Root Dia	☐ Root Dia ☐ Whole Depth ☐ Hob Addendum
☐	Tooth Thickness	☐ Circular Tooth Thickness ☐ Base Tangent Length No. of Teeth ( ) ☐ OBD Measurement Ball Dia (φ)
☐	Add Modification Coef. or Amount	
☐	Face Width	
	☐ Tooth Profile Length	☐ Contact length
		☐ TIF Dia
		☐ Rotation Angle
	☐Mating Gear Spec	No. of Teeth Outside Dia Center Distance

B	Master Gear Spec	
☐	Tool No.	
☐	Accuracy	☐ M( )Class ☐ Gear JIS ( )Class ☐ Other ( )
☐	Material	☐ DC53 ☐ SKH51 ☐ Free ☐ Other ( )
☐ ☐	Surface Treatment	☐ TiN ☐ Violet ☐ Nothing ☐ Oxygen ☐ Other ( )
	No. of Teeth	☐ As demanded (T)
		☐ Free ☐ 175type ☐ 200type ☐ 225type ☐ 250type ☐ 300type
		☐ Center Distance ( )
	☐ Master Gear Tooth Profile	
	☐ True ☐ Refer to Another Sheet ☐Accoding to the Right Figure	Tip (Substance Side)
	☐Master Gear Tooth Trace	
	☐ True ☐ Refer to Another Sheet ☐ According to the Right Figure	Helix ☐True ☐Higher ☐Lower (Substance Side)

Master Gear Shape	Change of Others
To Attach the reference Drawing ☐Another Company's reference Drawing ☐Our Drawing NO. ( )	
☐Design as the Reference Drawing ☐Add or Change from the Reference Drawing (Entry the left column) ☐Change Bore Shape ☐Change Overall Width ☐Change Tooth Width ☐Change Hub Width ☐Change Hub Dia ☐Others	

Gear Cutting Tools Section

Date ' . .

Burnishing Gear Design Specification	
Customer	
☐ Standard ☐ Improved ☐ Comparative Article	

Supplied Drawing	☐ None ☐ With (sheets) ☐ Gear Drawing ☐ Our Company's Cutter Drawing ☐ Other Company's Cutter Drawing ☐ Customer Spec ☐ Others
Gear Spec	☐ As in the Supplied Figure ☐ Add or Change the Following
Cutter Spec	☐ As in the Supplied Figure ☐ Add or Change the Following
Delivery	☐ Ordinary ☐ Certain ☐ Advanced (Date of Delivery)

Remarks

Standard Design Plan		Sales Dep.
Date	Name	Name

A Working Gear Spec

	Part Name	Add to Drawing ☐ Need ☐ Unneeded
	Part No.	Add to Drawing ☐ Need ☐ Unneeded
☐	Material	
☐	Hardness	
☐	M or DP	
☐	Pressure Angle	
☐	No. of Teeth	
☐	Helix Angle	☐ RH ☐ LH
☐	Outside Dia	
☐	Root Dia	☐ Root Dia ☐ Whole Depth ☐ Hob Addendum
☐	Tooth Thickness	☐ Circular Tooth Thickness ☐ Base Tangent Length No. of Teeth ( ) ☐ OBD Measurement Ball Dia (ϕ)
☐	Add Modification Coef. or Amount	
☐	Face Width	
☐	☐ Tooth Profile Length	☐ Contact length ☐ TIF Dia ☐ Rotation Angle
	☐Mating Gear Spec	No. of Teeth Outside Dia Center Distance
☐	Root R	☐Free ☐Work Root R ☐Cutter Tip R

Remarks

Order No.	Quantity

B Burnishing Gear Spec (Difference to Pressure Angle)

☐	Tool No.	
☐	Pressure Angle	☐ As demanded ( ) ☐ Free
☐	Helix Angle	☐ As demanded (☐ RH ☐ LH) ☐ Free
☐	No. of Teeth	☐ As demanded (T)
		☐ Free ☐ 50 type ☐ 75 type ☐ 100 type ☐ 125 type ☐ 150 type
		☐ Center Distance
☐	Material ☐arranged	☐ DC53 ☐ SKH51 ☐ KHA ( ) ☐ Others ( ) ☐ Free
☐	Hardness	☐ As demanded ( ) ☐ Free
☐	Surface Treatment	☐ TiN ☐ Violet ☐ Nothing ☐ Oxygen ☐ Others ( )
☐	Overall Width	☐ As demanded ( ) ☐ Free
☐	Face Width	☐ As demanded ( ) ☐ The Same as Face Width
☐	Accuracy	☐ JIS ( ) Class ☐ Others ( )

☐ Burnishing Gear Tooth Profile

☐True
☐ Refer to the Another Sheet
☐ According to the Right Figure

Tip

(Substance Side)

☐ Burnishing Gear Tooth Trace

☐True
☐ Refer to Another Sheet
☐ According to the Right Figure

Helix ☐True ☐Higher ☐Lower

(Substance Side)

Order No.	Quantity

C Burnishing Gear Spec (Higher Helix)

☐	Tool No.	
☐	Pressure Angle	☐ As demanded ( ) ☐ Free
☐	Helix Angle	☐ As demanded (☐ RH ☐ LH) ☐ Free
☐	No. of Teeth	☐ As demanded (T)
		☐ Free ☐ 50 type ☐ 75 type ☐ 100 type ☐ 125 type ☐ 150 type
		☐ Center Distance
☐	Material ☐arranged	☐ DC53 ☐ SKH51 ☐ KHA ( ) ☐ Others ( ) ☐ Free
☐	Hardness	☐ As demanded ( ) ☐ Free
☐	Surface Treatment	☐ TiN ☐ Violet ☐ Nothing ☐ Oxygen ☐ Others ( )
☐	Overall Width	☐ As demanded ( ) ☐ Free
☐	Face Width	☐ As demanded ( ) ☐ The Same as Face Width
☐	Accuracy	☐ JIS ( ) Class ☐ Others ( )

☐Burnishing Gear Tooth Profile

☐True
☐ Refer to the Another Sheet
☐ According to the Right Figure

Tip

(Substance Side)

☐Burnishing Gear Tooth Trace

☐True
☐ Refer to Another Sheet
☐ According to the Right Figure

Helix ☐True ☐Higher ☐Lower

(Substance Side)

Order No.	Quantity

D Burnishing Gear Spec (Lower Helix)

☐	Tool No.	
☐	Pressure Angle	☐ As demanded ( ) ☐ Free
☐	Helix Angle	☐ As demanded (☐ RH ☐ LH) ☐ Free
☐	No. of Teeth	☐ As demanded (T)
		☐ Free ☐ 50 type ☐ 75 type ☐ 100 type ☐ 125 type ☐ 150 type
		☐ Center Distance
☐	Material ☐arranged	☐ DC53 ☐ SKH51 ☐ KHA ( ) ☐ Others ( ) ☐ Free
☐	Hardness	☐ As demanded ( ) ☐ Free
☐	Surface Treatment	☐ TiN ☐ Violet ☐ ☐ Nothing ☐ Oxygen ☐ Others ( )
☐	Overall Width	☐ As demanded ( ) ☐ Free
☐	Face Width	☐ As demanded ( ) ☐ The Same as Face Width
☐	Accuracy	☐ JIS ( ) Class ☐ Others ( )

☐ Burnishing Gear Tooth Profile

☐True
☐ Refer to Another Sheet
☐ According to the Right Figure

Tip

(Substance Side)

☐ Burnishing Gear Tooth Trace

☐True
☐ Refer to Another Sheet
☐ According to the Right Figure

Helix ☐True ☐Higher ☐Lower

(Substance Side)

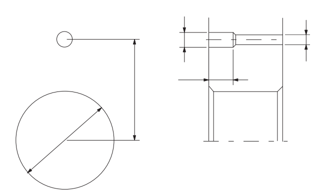
Burnishing Gear Shape

To Attach the reference Drawing
☐Another Company's reference Drawing
☐Our Drawing NO. ( )

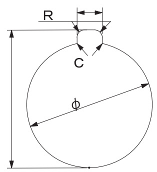
☐Design as the Reference Drawing
☐ Add or Change from the Reference Drawing
(Entry the left column)
☐Change Bore Shape
☐Change Overall Width
☐Change Tooth Width
☐Change Hub Width
☐ Change Hub Dia
☐Others

Change Bore Shape

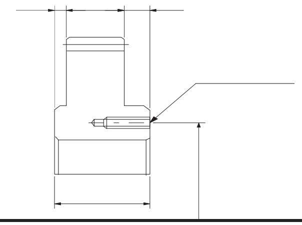
☐Pin Bore Type



☐Bore Key Type



Change Burnishing Gear Shape



Change of Others

Date ‘ . .

Customer	

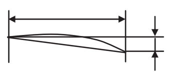
Set order (HOB, Shaving Cutter, Deburring Cutter) Design Specification	☐ HOB ☐ Shaving Cutter ☐ Deburring Cutter
Remarks	

Order No.	Quantity

Order No.	Quantity

Order No.	Quantity

A Working Gear Spec

	Part's Name	Add to Drawing ☐ Need ☐ Unneeded
	Part No.	Add to Drawing ☐ Need ☐ Unneeded
☐	Material	
☐	Hardness	
☐	m or DP	
☐	Pressure Angle	
☐	No. of Teeth	
☐	Helix Angle	☐RH ☐LH
☐	Outside Dia	
☐	Root Dia	☐ Root Dia ☐ Whole Depth ☐ Hob Addendum
☐	Tooth Thickness	☐ Circular Tooth Thickness ☐ Base Tangent Length No. of Teeth ( ) ☐ OBD Measurement Ball Dia (ϕ)
	☐ After Shaving	
	☐ Before Shaving	
☐	Add Modification Coef or Amount	
☐	Face Width	
☐	☐ Tooth Profile Length	☐ Contact length ☐ Rotation Angle ☐TIF Dia
	☐ Mating Gear Spec	No. of Teeth Outside Dia Center Distance
☐	Gear Shape	☐ Open Gear ☐ Shoulder Gear (Shoulder Outside Dia,Space)
☐	Tooth Trace	Amount of Crowning lead  Helix ☐True ☐ Higher ☐ Lower
☐	Tooth Profile ☐ True ☐ Standard ☐ Refer to Another Sheet ☐ According to The Right Figure	Tip (Substance Side)

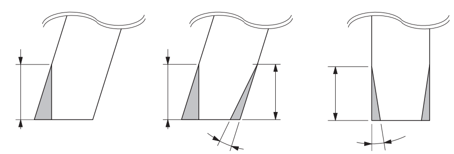
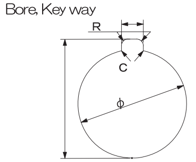
B ☐ Solid ☐ Inserted Blade ☐ Carbide Hob Spec

☐	Tool No.	
☐	Accuracy	☐( ) ☐ (JIS Class)
☐	Material	☐ KMC ( ) ☐ KHA ( ) ☐ KVC ( ) ☐ Other ( ) ☐Free
☐	Surface Treatment	☐ Ti Coating ☐ Violet Coating ☐GV40 ☐ DP ☐Nothing ☐Other ( )
☐	Outside Dia	
☐	Overall Length /Lengthof Cut	/ ☐ Free Inserted Blade type( )
☐	Key Way	☐ JIS Standard ☐ Special (Width: Depth: R:)
	Side Key	☐ JIS Standard ☐ Special (Width: Depth: R:) ☐ Left ☐ Right ☐ Both (Hub Length:)
		☐Reference Drawing( )
☐	No. of Starts	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
☐	Direction	☐ RH ☐ LH ☐ Free
☐	Rake Angle	☐ 0° ☐ 6° ☐ 8° ☐( )
☐	No. of Gash	☐ Free ☐ Specified( )
☐	Gash Lead	☐ ∞ ☐ Exist ( )
		☐ Finish ☐ P ☐ PG
		☐ S-Top ☐ PS ☐ PGS
		☐ PP ☐ PGP
		☐ PSP ☐ PGSP
☐	Topping	☐ No ☐ Yes
☐	Tooth Profile Modification	☐ Nothing ☐ Stug ☐ BS(A2, B) Modification ☐ BS(C, D) Modification ☐ Special Modification( )
☐	Coolant	☐ Dry ☐ Wet

C Shaving Cutter Spec

☐	Tool No.	
☐	Accuracy	☐J I S ☐Other ( )
☐	Material	☐ SKH51 ☐ KHV1 ☐ HSP ☐ KHVX ☐ Other ( )
☐	Surface Treatment	☐ Nothing ☐ Nitride Oxidation ☐ STH ☐ Other ( )
☐	Grind Method	☐ Un-Grind ☐ Semi-Grind ☐ Indicate Tooth Profile ☐ With Trial
☐	No. of Teeth	☐ As demanded (T) ☐ Free ☐ 175type ☐ 200 type ☐ 225 type ☐ 250 type ☐ 300 type
☐	Overall Width	☐ As demanded ( ) ☐ Free
☐	Tooth Width	☐ Overall width ☐ As demanded ( ) ☐ Free
☐	Bore Dia , Keyway	☐ Standard ☐ Special(Bore Dia) (Tolerance)
☐	Helix angle	☐ As demanded (☐ RH ☐ LH)
☐	Weight Saving	☐ As demanded ☐ Free
☐	SV Method	☐ Conventional ☐ Diagonal ☐ Underpass ☐ Plunge
☐	Trial Condition ☐As demanded ☐ Free	rotation min-1 Feed Speed mm/min Feed Length mm (Plunge) Diagonal Angle
☐	SV Machine	Name Min-Distance
☐	Amount of Hollow Lead	☐ As demanded ( ) ☐ Free
	Tooth Profile ☐ True ☐ Response from Work ☐ Refer to Another Sheet ☐ According to the Right Figure	Tip (Substance Side)

D Deburring Cutter Spec

☐	Tool No.	
☐	Accuracy	☐Gear JIS 4 class ☐ Other ( )
☐	Material	☐ SKH51 ☐ Other ( )
☐	No. of Teeth	☐ As demanded (T) ☐ Free ☐ 175type ☐ 200 type ☐ 225 type ☐ 250 type ☐ 300 type ☐ Center Distance ( ) ☐Outside Dia ( )
☐	Chamfering Shape	☐ A parallel type (Only tooth Flank) ☐ Taper type ☐ Parallel type (tooth flank + bottom)
	☐ Helical gear One side ☐ Helical gear Both sides ☐ Spur gear	
☐	Guide gear	☐ Unneeded ☐ Need
☐	Weight Saving	☐ Free ☐ As demanded
	Bore, Key way 	Shape Standard ☐ 2 peaces type ☐ 3 peaces type ☐ Another type (refer to another Sheet) Cutter Width ( )
☐	Note	Reference Drawing( )

Gear Cutting Tools Section

Date ' . .

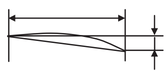
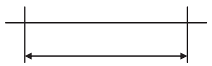
Customer

Set order (Shaper Cutter, Shaving Cutter, Deburring Cutter) Design Specification	☐ Shaper cutter ☐ Shaving Cutter ☐ Deburring Cutter
Remarks	

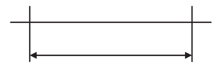
Order No.	Quantity

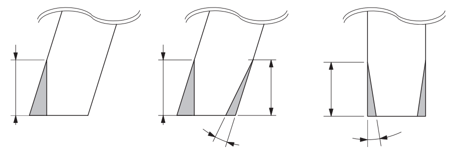
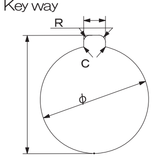
Order No.	Quantity

Order No.	Quantity

A	Working Gear Spec	
	Part's Name	Add to Drawing ☐ Need ☐ Unneeded
	Part No.	Add to Drawing ☐ Need ☐ Unneeded
☐	Material	
☐	Hardness	
☐	m or DP	
☐	Pressure Angle	
☐	No. of Teeth	
☐	Helix Angle	☐RH ☐LH
☐	Outside Dia	
☐	Root Dia	☐ Root Dia ☐ Whole Depth ☐ Hob Addendum
☐	Tooth Thickness	☐ Circular Tooth Thickness ☐ Base Tangent Length No. of Teeth ( ) ☐ OBD Measurement Ball Dia (φ)
	☐ After Shaving	
	☐ Before Shaving	
☐	Add Modification Coef or Amount	
☐	Face Width	
☐	☐ Tooth Profile Length	☐ Contact length ☐ Rotation Angle ☐TIF Dia
	☐ Mating Gear Spec	No. of Teeth Outside Dia Center Distance
☐	Gear Shape	☐ Open Gear ☐ Shoulder Gear (Shoulder Outside Dia.Space)
☐	Tooth Trace	Amount of Crowning lead  Helix ☐True ☐ Higher ☐ Lower
☐	Tooth Profile ☐ True ☐ Standard ☐ Refer to Another Sheet ☐ According to The Right Figure	Tip  (Substance Side)

B	☐ Disc ☐ Counterbore Shaper Cutter Spec	
☐	Tool No.	
☐	Accuracy	☐( ) ☐ (JIS Class)
☐	Material	☐ SKH55 ☐ KMC3 ☐ KMCZ ☐ KHA( ) ☐ Other ( )
☐	Surface Treatment	☐ TiN ☐ Violet ☐ DP ☐ Nothing ☐ Other ( )
☐	No. of Teeth	☐ As demanded (T) ☐ Free ☐ 50type ☐ 75type ☐ 100type ☐125type ☐ 150 type ☐ 175type
☐	Overall Width	☐ As demanded ( ) ☐ Free
☐	Tooth Width	☐ Overall width ☐ As demanded ( ) ☐ Free ☐With Boss (Boss Dia)
☐	Bore Dia	☐ 31.742 ☐ 44.45 ☐ 31.75 ☐ Other (Bore Dia Tolerance)
☐	Keyway	☐ Nothing ☐ Bore Key (Width Height R) ☐ Side Key (Width Height R)
☐	Rake angle	☐ 5° ☐ Other ( )
☐	Helical rake Angle	☐ Free ☐ As demanded ( )
☐	Helical Guide	☐ Free ☐ As demanded ( )
☐	Tooth Profile ☐Standing Grinding ☐Through Grinding	☐ Standard ☐ P ☐ PG ☐ S-TOP ☐ PS ☐ PGS ☐ PP ☐ PGP ☐ PSP ☐ PGSP
☐	Topping	☐With ☐Without
☐	Note	

C	Shaving Cutter Spec	
☐	Tool No.	
☐	Accuracy	☐J I S ☐Other ( )
☐	Material	☐ SKH51 ☐ KHV1 ☐ HSP ☐ KHVX ☐ Other ( )
☐	Surface Treatment	☐ Nothing ☐ Nitride Oxidation ☐ STH ☐ Other ( )
☐	Grind Method	☐ Un-Grind ☐ Semi-Grind ☐ Indicate Tooth Profile ☐ With Trial
☐	No. of Teeth	☐ As demanded (T) ☐ Free ☐ 175type ☐ 200 type ☐ 225 type ☐ 250 type ☐ 300 type
☐	Overall Width	☐ As demanded ( ) ☐ Free
☐	Tooth Width	☐ Overall width ☐ As demanded ( ) ☐ Free
☐	Bore Dia , Keyway	☐ Standard ☐ Special(Bore Dia) (Tolerance)
☐	Helix angle	☐ As demanded (☐ RH ☐ LH)
☐	Weight Saving	☐ As demanded ☐ Free
☐	SV Method	☐ Conventional ☐ Diagonal ☐ Underpass ☐ Plunge
☐	Trial Condition ☐As demanded ☐ Free	rotation min-1 Feed Speed mm/min Feed Length mm (Plunge) Diagonal Angle
☐	SV Machine	Name Min-Distance
☐	Amount of Hollow Lead	☐ As demanded ( )☐ Free
	Tooth Profile ☐ True ☐ Response from Work ☐ Refer to Another Sheet ☐ According to the Right Figure	Tip  (Substance Side)

D	Deburring Cutter Spec	
☐	Tool No.	
☐	Accuracy	☐Gear JIS 4 class ☐ Other ( )
☐	Material	☐ SKH51 ☐ Other ( )
☐	No. of Teeth	☐ As demanded (T) ☐ Free ☐ 175type ☐ 200 type ☐ 225 type ☐ 250 type ☐ 300 type ☐ Center Distance ( )☐Outside Dia ( )
☐	Chamfering Shape	☐ A parallel type (Only tooth Flank) ☐ Taper type ☐ Parallel type (tooth flank + bottom)
	☐ Helical gear One side ☐ Helical gear Both sides ☐ Spur gear 	
☐	Guide gear	☐ Unneeded ☐ Need
☐	Weight Saving	☐ Free ☐ As demanded
	Bore, Key way 	Shape Standard ☐ 2 peaces type ☐ 3 peaces type ☐ Another type (refer to another Sheet) Cutter Width ( )
☐	Note	Reference Drawing( )

Date ‘ . .

☐Dressing Gear ☐Dressing Ring Design Specification	Order NO	Quantity	Standard Design Plan		Sales Dept.
	Customer		Date	Name	Name

Supplied Drawing	☐ None ☐ Gear Drawing ☐ Our Company's Cutter Drawing ☐ Other Company's Cutter Drawing ☐ Customer Spec ☐Others
Gear Spec	☐ As in the Supplied Figure ☐ Add or Change the Following A
Cutter Spec	☐ As in the Supplied Figure ☐ Add or Change the Following B
Delivery	☐ Ordinary ☐ Certain ☐ Advanced (Date of Delivery)

☐ Standard Design Item ☐ Improved Design Item ☐ Comparative Article	Remarks	☐The material has been previously arranged ☐Design of Honing Wheel (☐ϕ300 ☐ϕ350☐ϕ400)

A	Working Gear Spec	
☐	Part's Name	Add to Drawing ☐Need ☐Unneeded
☐	Part No.	Add to Drawing ☐Need ☐Unneeded
☐	Material	
☐	Hardness	
☐	M or DP	
☐	Pressure Angle	
☐	No. of Teeth	
☐	Helix Angle	☐RH ☐LH
☐	Outside Dia	
☐	Root Dia	☐Root Dia ☐Whole Depth ☐Hob Addendum
☐	Tooth Thickness After Honig	☐Circular Tooth Thickness ☐Base Tangent Length No. of Teeth( ) ☐OBD Measurement Ball Dia(ϕ)
☐	Tooth Thickness Before Honing (Heat Treatment)	☐Circular Tooth Thickness ☐Base Tangent Length No. of Teeth ☐OBD Measurement Ball Dia
☐	Add Modification Coef. or Amount	
☐	Face Width	
☐	☐Tooth Profile Length	☐Contact Length ☐TIF Dia ☐Rotation Angle
	☐Mating Gear Spec	No. of Teeth Outside Dia Center Distance

B	Dressing Gear and Dressing Ring Spec	
☐	Tool No.	
☐	Accuracy	☐Gear JIS ( ) Class ☐Other ( )
☐	Diamond Grain	☐#120 ☐#100 ☐#80 ☐Free ☐Other ( )
☐	Truing	☐Need ☐Unneeded
☐	No. of Teeth	☐As Demanded (T)
☐	Face Width	☐As Demanded ( ) ☐Free
☐	☐Arbor Production	☐Need ☐Unneeded
	☐Construction	☐Shrink Type ☐Amounting Type
	☐Arbor Sharing	for Gear and Ring ☐Yes ☐No
☐	Dressing Ring	Order No. ( )
	Diamond Grain	☐#80 ☐Free ☐Other (#)
☐	Profile·Lead	☐True ☐As Demanded (Note Under Colum)

☐Dressing Gear (Work piece) Tooth Profile

☐True
☐Refer to Another Sheet
☐According to the Right Figure

Tip

(Substance side)

☐Dressing Gear (Work) Lead

☐True
☐Refer to Another Sheet
☐According to the Right figure

Bottom Upper

(Substance side)

Dressing Gear Shape	Change of Others
To Attach the reference Drawing ☐Another Company's reference Drawing ☐Our Drawing NO. ( )	
☐Design as the Reference Drawing ☐Add or Change from the Reference Drawing (Entry the left column) ☐Change Bore Shape ☐Change Overall Width ☐Change Tooth Width ☐Change Hub Width ☐Change Hub Dia ☐Others	

Broach

Introduction

Broaches handle mass-production with high accuracy and high efficiency. It is very significant that complex shapes can be steadily produced without requiring special skills. Broaches are widely used for small lot production of wide variety of products as well.

Our company has promptly introduced CNC grinders, and made the best use of CAD·CAM functions. We manufacture products with more complex tooth profiles with high accuracy and integrate them with original materials, heat treatment and coating technology. Thus we respond to the various customer needs such as thinning and difficult machining by means of high accuracy and long tool life.

Features

Broaching has features shown below. It is a method to cut inside or outside (surface) of the work material with numbers of cutting edges that are roughing teeth and finishing teeth arranged in order of the size.

◇ Extremely short machining time with high accuracy.

◇ Easy machining of the same complex shapes in the axis direction.

◇ No special skills required, since machining conditions such as depth of cut per tooth or the total amount of cuttings are decided when designed and manufactured.

◇ Fine finish surface, accurate in size.

◇ Work piece is fixed by pressure when machining.

Part names

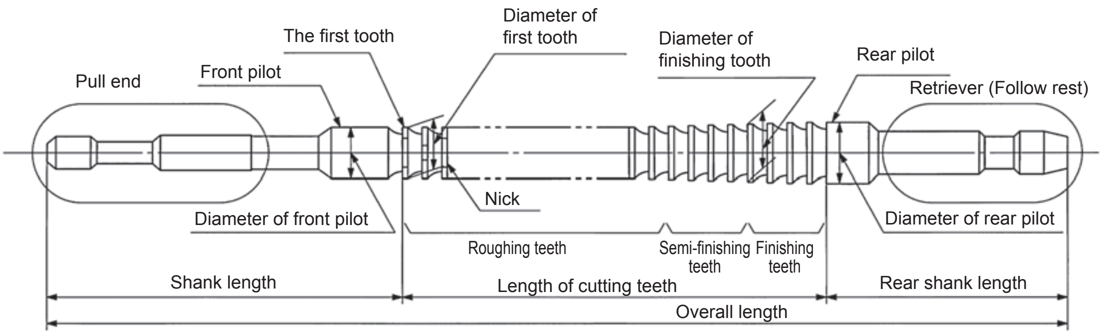


Fig.1 Parts names of pulling broach

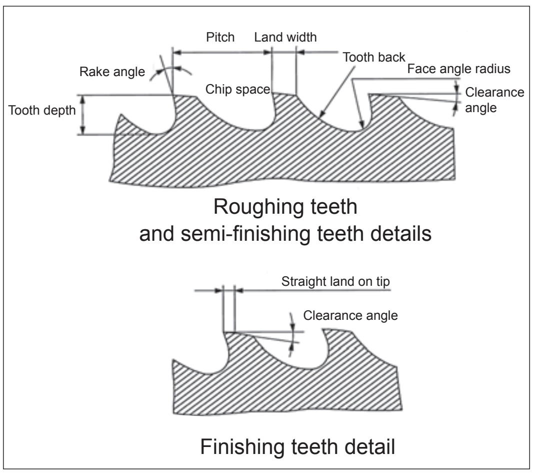


Fig.2 Teeth details

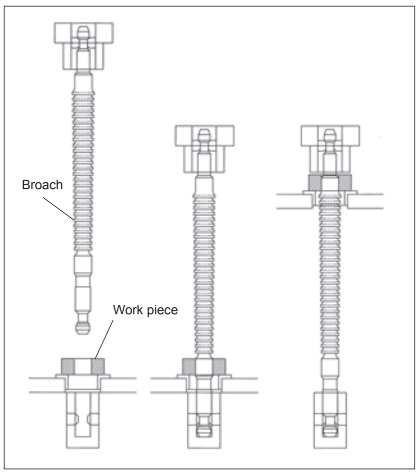


Fig.3 Broaching (work transfer type)

1. Classification and features of our broaches

Material of cutting tooth		Surface treatment	Structure
High-speed steel	SKH51(AISI M2)	Nitride oxidation·STH	Solid
	KMC3 (SKH55)		Assembly
	Powder metallurgy HSS	TiN·GV21	

Cutting method	Operating method	Cutting part
Normal (outside diameter up)	Pulling	Internal
Outline (form · tooth thickness up)	Pushing	

Finishing shape and usage	
Round broach	Round type · flatted round · obal type · D type
Spline broach	Parallel spline · Involute
Serration broach	Straight-sided · Involute
Special bore broach	Straight-sided serration · Involute · Ball groove
Helical broach	For helix flute bore machining
	For helical internal gear (Shell assembly type · Integrated type)

Function
For roughing and finishing
With chamfering tooth
With burnishing tooth
With round tooth (Front round tooth / rear round tooth / alternate round tooth)

2. Broach selection standard (Tool material, surface treatment) according to work materials and recommended standard cutting conditions

Table 1

Small items \ Work material		Cemented steel/tough steel/carbon steel (tensile strength: 600 N/mm² or more)	Stainless steel	Free-cutting steel /carbon steel (tensile strength: 600 N/mm² or less)	Cast steel
Tool material	SKH51 (AISI M2)			○	○
	KMC3（SKH55）	◎	◎		
	Powder HSS (KHA)	○	○		
Surface treatment	Non-treated				
	Nitride oxidation・STH	○		○	
	TiN・GV21	※1 ○			
Cutting speed (m/min)	Work material Brinell hardness – 150HB or below	—	9	12—9	8
	150～250	8—5	8—6	10—8	6—4
	250～350	5	5—3	—	4—3
	350～450	3	3—2	—	—

Small items \ Work material		Cast iron	Aluminium alloy	Copper alloy	Titanium alloy Nickel alloy
Tool material	SKH51 (AISI M2)	○	○	○	
	KMC3（SKH55）				○
	Powder HSS (KHA)				◎
Surface treatment	Non-treated				
	Nitride oxidation・STH	○			○
	TiN・GV21	※1 ○			
Cutting speed (m/min)	Work material Brinell hardness – 150HB or below	9—6	15—10	12—8	8
	150～250	5—3	—	9—6	
	250～350	3	—	—	6—4
	350～450	—	—	—	3—2

◎Most applicable　○Applicable　xNot applicable　*1 No TiN coating is recommended for round broach.

(1) High accuracy and long tool life owing to powder metallurgy HSS (KHA)

Rich alloy powder metallurgy HSS, whose carbides are minute and even in construction, is superior to ordinary HSS in toughness and wear resistance. As for the sharpness of the cutting edge, the powder metallurgy HSS with minute construction maintains the sharp edge steady for a long time, whereas ordinary HSS allows its big carbide to drop off. In broaching, an interrupted cutting method, such material characteristics of powder metallurgy HSS are taken advantage of improvement of finish surface accuracy and control of size changes. Especially for high hardness difficult-to-cut materials, its tool life can be more than twice as long as that of ordinary HSS.

Table 2 Machining example of powder metallurgy HSS broach

Type of broach	Work piece		Cutting length (mm)	Cutting speed (m/min)	Evaluation		Longevity judgment
	Work material	Hardness (HB)			Powder metallurgy HSS	Ordinary high speed steel (HSS)	
Round broach	S48C	250	40	5	1500 pieces	800 pieces	Processing accuracy
Spline broach	SCr420	200	20.5	7	7200 pieces	3600 pieces	Processing accuracy
	FCD700	280	24	7	1200 pieces	800 pieces	Processing accuracy
	SCr420	180	23	7	4500 pieces	3000 pieces	Tool wear

(2) STH&GV21 broach

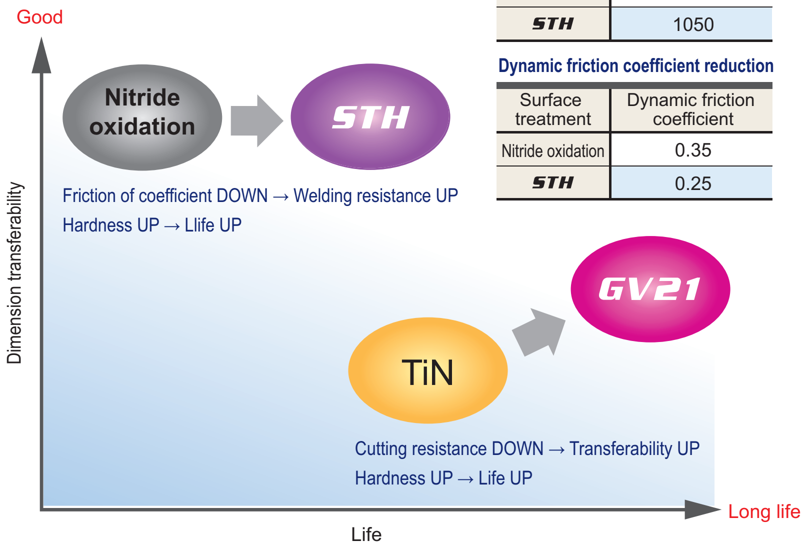
Nitride oxidation treatment can extend the tool life by means of reduction of the friction coefficient and adhesion prevention of the work material to the cutting edge. After giving nitride treatment to improve the hardness of the tip of the teeth, oxidation treatment is conducted to generate film of porous oxidation iron, which keeps cutting oil. This process enhances the internal diffusion within the nitride layer. Then, a layer with gradual hardness inclination is formed and wear resistance improves. Moreover, we improved the performance of this diffusion infiltration layer and developed STH treatment that has enabled sharpness and size accuracy to be maintained for a long time.
Coating technology, that physically and densely deposit (PVD) TiN film and (Al,Ti)N film both with high hardness and excellent oxidation resistance. It is a special treatment technology which makes films stick with each other, under the HSS tempering temperature (550°C) or below, overcoming the hardness difference between the coating film and the base material. In its developing process, the interfacial control technology demonstrated with Miracle 40 was applied. As a result, GV21 we have developed has achieved long tool life and high efficiency. Moreover, the membrane system gives the excellent performance and promising synergistic effect with base material.
We respond to the customer needs such as long tool life and high efficiency, by combining these surface treatments with basic performance of tools such as high accuracy and sharpness.

• STH

Tooth surface characteristics are improved and longer life is realized by increasing welding resistance by oxidation.

• GV21

Offers longer life than TiN and realizes better dimension transferability.



Hardness UP

Surface treatment	Hardness(HV)
Nitride oxidation	1000
STH	1050

Dynamic friction coefficient reduction

Surface treatment	Dynamic friction coefficient
Nitride oxidation	0.35
STH	0.25

Hardness UP

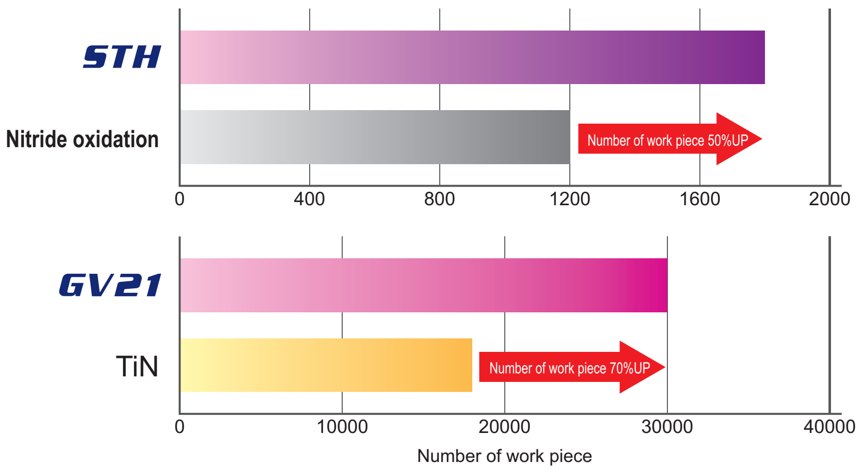
Surface treatment	Hardness(HV)
TiN	2000
GV21	2800

Reducing cutting resistance

Surface treatment	Cutting resistance*
TiN	1
GV21	0.8

*TiN=1

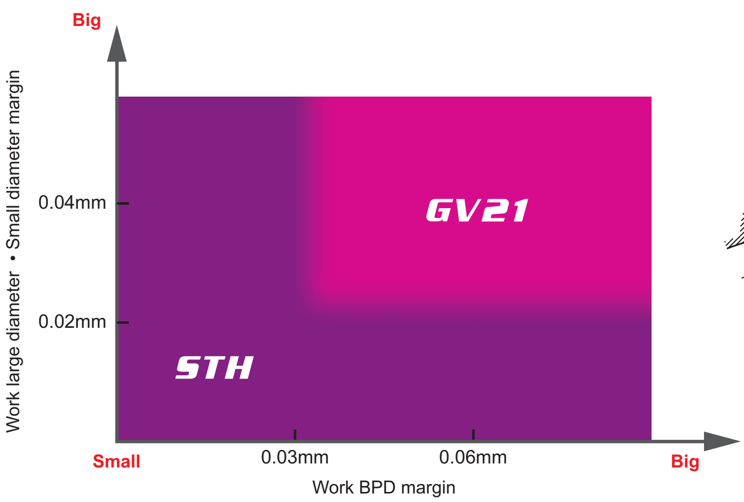
• Cutting result

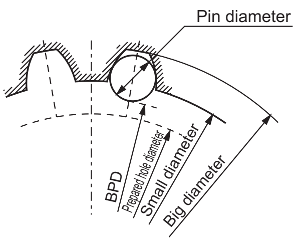


Module	1.2
Pressure angle	20
Number of teeth	75
Cutting length	25
Torsion angle	25° (Right)
Work material	SCM material

United teeth	–
Number of teeth	27
Cutting length	8mm
Work material	Boron steel

New material broach promotion area

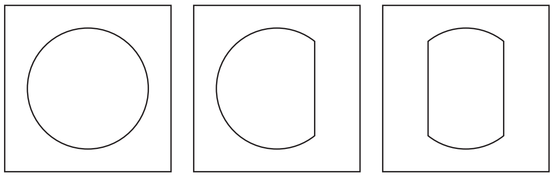




3. Features of each broach

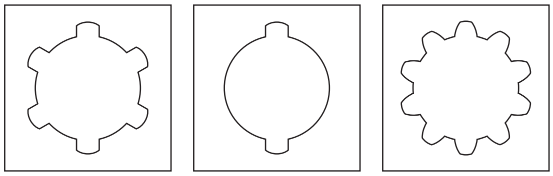
(1) Round broach

A highly accurate round bore can be completed without precise pre-cutting like reaming. There are burnishing tooth types and two step finishing types in order to make a fine finishing surface.



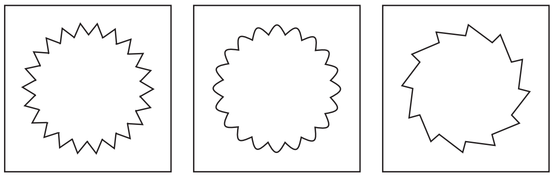
(2) Spline broach

As for spline shapes there are parallel spline with square sections mutually paralleled, and involute spline used for connection of axes and bore for power supply of automobiles. (JIS B1601 square type spline, JIS B1603 involute spline, JIS B4239 involute spline broach)



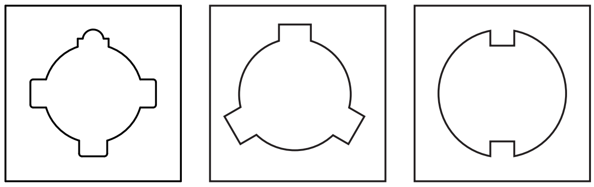
(3) Serration broach

It is used to unite axes and bores almost permanently. Generally, straight-sided serration and involute serration types are used.



(4) Special broach

Cutting complex shapes that was impossible before is now possible without any special skills, achieving high accuracy and high efficiency.



(5) Round tooth broach

Round tooth position is the front spline tooth, rear, or alternately arranged, so 1 broach can machine bore and spline simultaneously.

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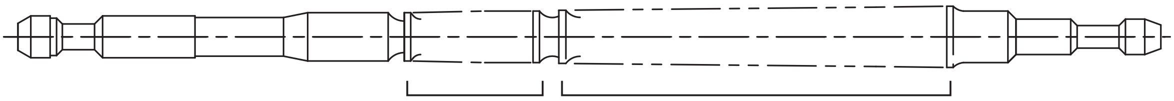
<tr><th></th><th></th></tr>
<tr><td>Before</td><td>
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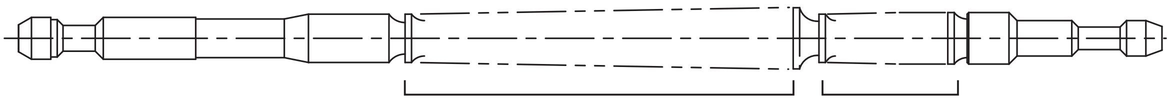
<tr><td>After</td><td>
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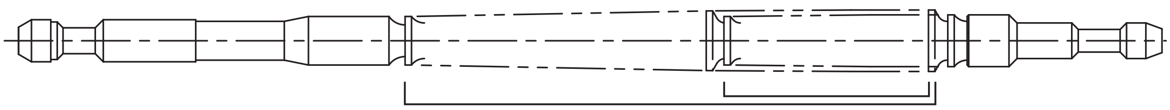
<tr><td>Alternate</td><td>
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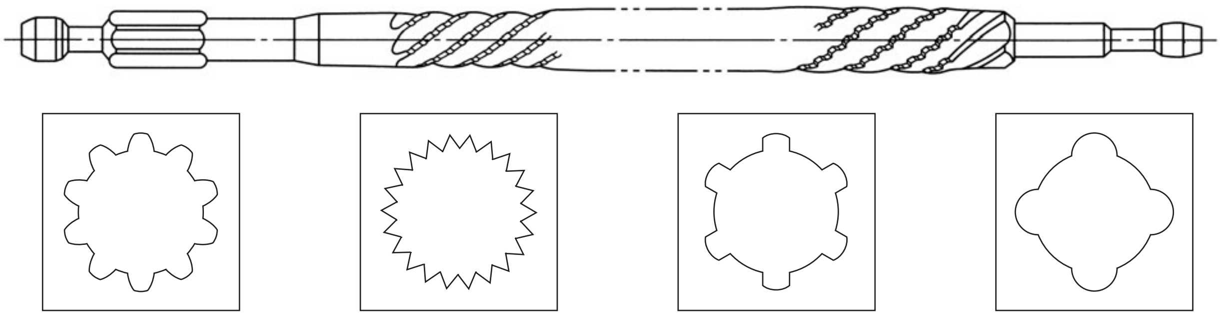
(6) Helical broach

■ For helix flute bore machining

It is used for helix bore cutting for automobiles and spare parts for electric appliances, etc. It is remarkably superior in cost,machining accuracy and productivity compared with electric discharge machining (EDM), etc. It is widely used especially for cutting small diameter bores.



■ Large-diameter helical broach

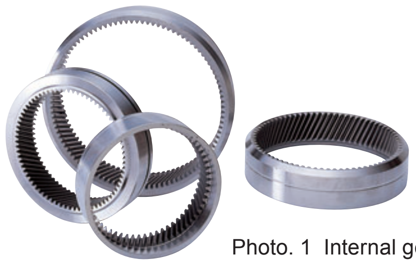


Photo. 1 Internal gear

The former is used for machining helical bores of general automobile parts and electrical components. The latter is used for internal gear cutting of ring gears inside automatic transmission for automobile. This ring gear-intended type of helical broach is generally called "Large-diameter helical broach". Because this Large-diameter helical broach requires extremely high precision and its size makes machining and tooth profile precision measurement difficult, it has normally been made into an assembly type, in which the roughing teeth part (body) and finishing teeth part (shell) are composed of cutting edge for radial part and cutting edge for tooth thickness, respectively. Our company has developed high precision tooth grinder with onboard measuring instrument to manufacture an integrated type of Large-diameter helical broach integrating the body and shell parts, making it possible to meet higher precision requirements.

1. Cutting Method

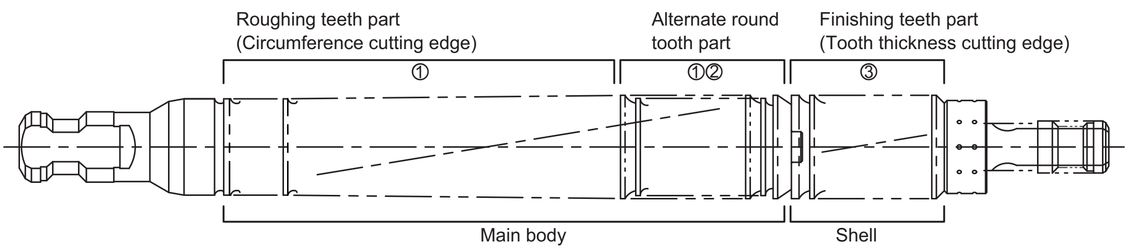


Fig.4 Helical broach

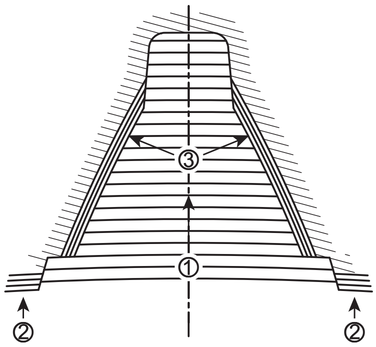
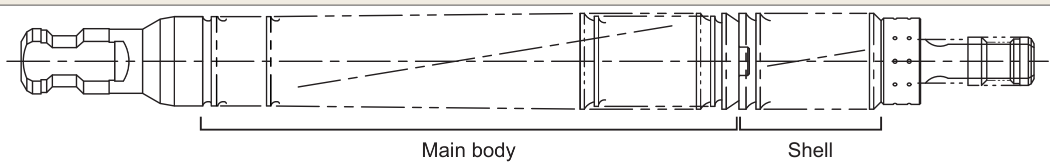
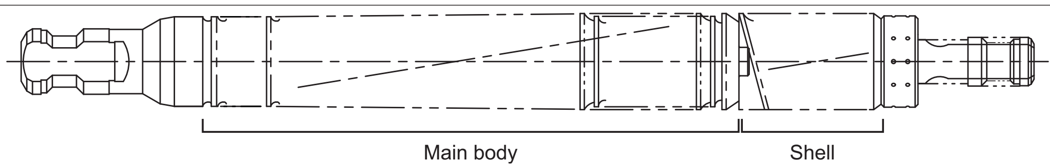
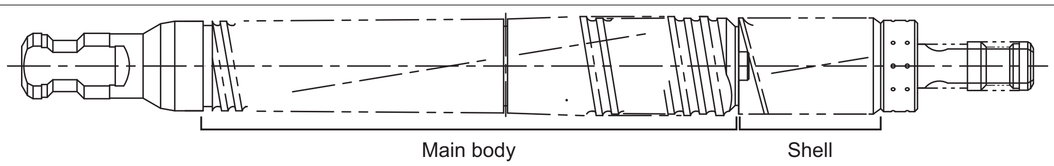
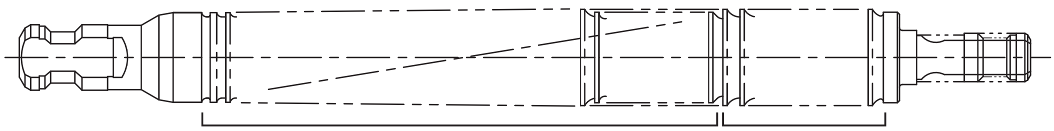
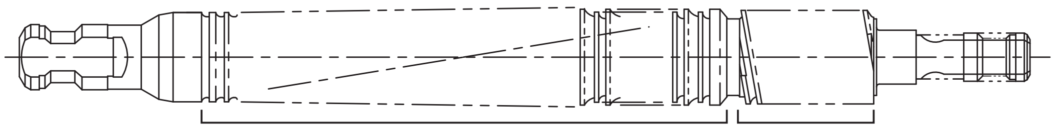
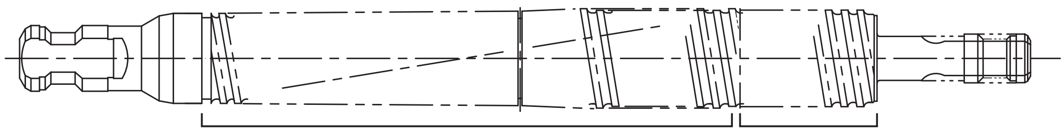


Fig.5 Cutting method

2. Types of construction and blade

	Assembly type
Main Body Normal Shell Normal	
Main Body Off-normal Shell Normal	
Main Body Off-normal Shell Off-normal	

	Integrated type
Main Body Normal Shell Normal	
Main Body Off-normal Shell Normal	
Main Body Off-normal Shell Off-normal	

3 Off-normal gullet

There are two types of Large-diameter helical broach gullets (chip-receiving spaces): normal (straight gullet) and off-normal (helical gullet) ones. The normal type more varies in broaching load than the off-normal one. Therefore, it is disadvantageous due to shorter life. On the other hand, the off-normal type less varies in broaching load, improving the tooth profile precision and tool life. However, it requires exclusive regrinding equipment. Recently, a demand for off-normal type has been increased.

Photo 1-1 Off-normal type

Photo 1-2 Normal type

Comparison in broaching load between normal and off-normal types

A comparison between both types using their respective broaching load diagrams indicates that the normal type more varies in broaching load. This is a result of variation in number of edges related with cutting. This load variation-caused vibration accelerates cutting edge wear or damage. The off-normal type is stable due to slight variation in broaching load because number of edges related with cutting is nearly constant at all times. Therefore, its wear or damage is minimized, realizing longer tool life and stable tooth profile precision.

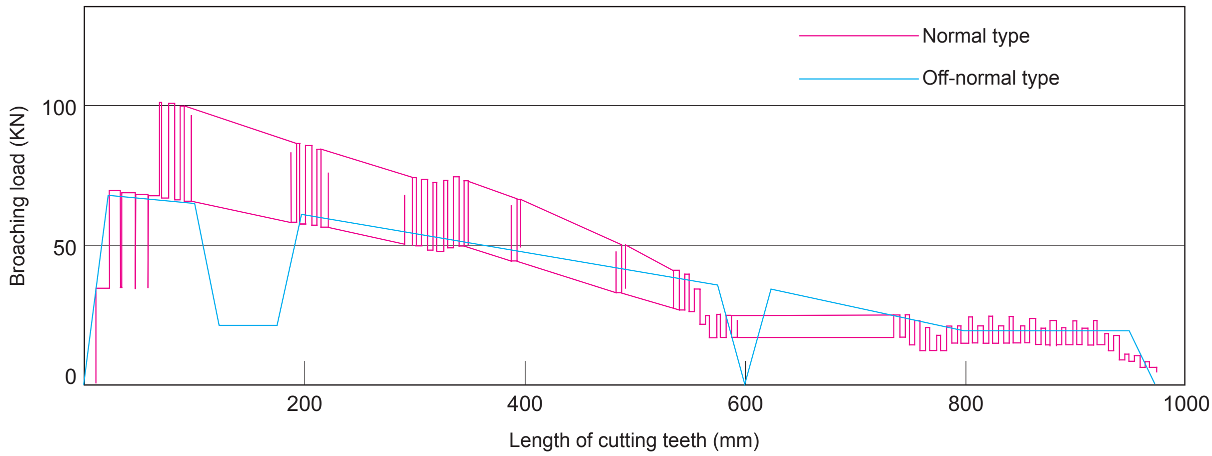


Fig.6 Comparison in broaching load

4. Integrated type

The tooth thickness finishing stock is reduced and cutting accuracy of gears improves since this broach is manufactured with a main body and a shell integrated. Load per cutting edge can be reduced, therefore total wear also decreases and larger number of gears can be produced per re-grinding. In addition, complex works such as decomposition and assembly of the shell, or a minor adjustment of the phase have become unnecessary, and running cost is reduced.

Machining allowance of integrated helical broach and tooth profile accuracy

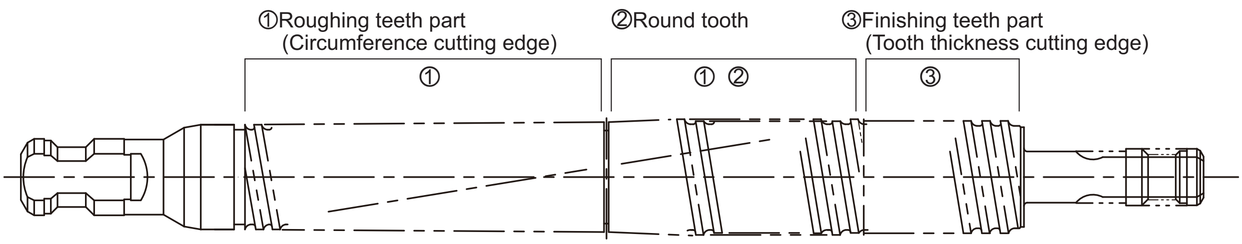


Fig.7 Integrated helical broach

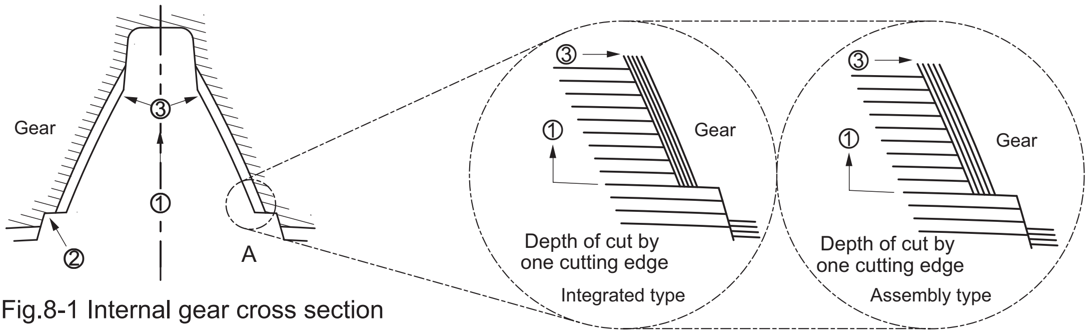


Fig.8-1 Internal gear cross section

Fig.8-2 Comparison of machining allowance between integrated and assembly types (Enlargement of part A in Fig.8-1)

● Machining examples/gear spec.: Module 1.25; Pressure angle 20°; Number of teeth 77; Helix angle 23°30'LH

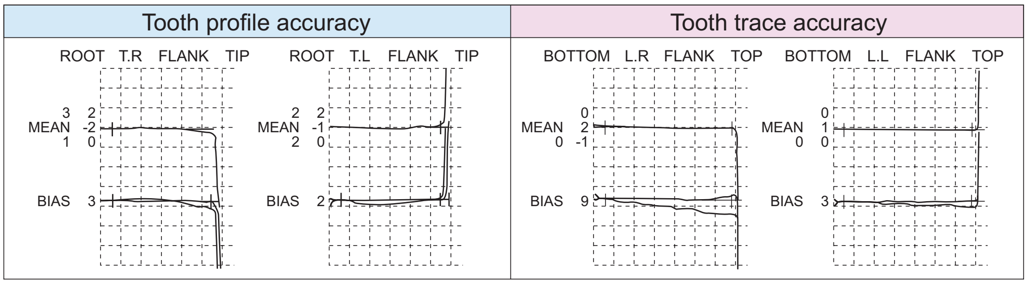
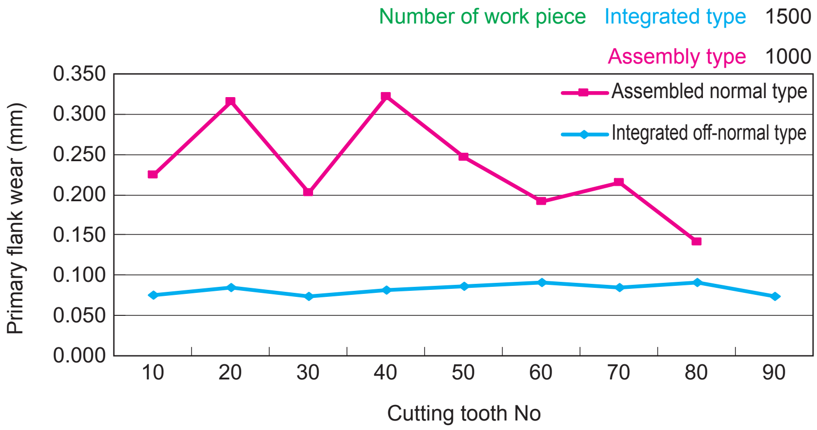


Fig.9 Tooth profile accuracy of machined gear



Work dimension mn1.13 PAn20° NT82 HA25° RH Work material : S45C

Fig.10 Comparison in cutting edge wear between integrated off-normal type and assembled normal type

Table 3 Cutting example of integrated type helical broaches

mn	PAn	NT	HA	Type of broach	Work material	Hardness	Cutting length(mm)	Number of work piece	Re-grinding allowance	Number of Re-grinding
1.25	17	75	23.664L	Off-normal type	SCr420H	HB207-229	26.75	6,000	0.10	30
1.36	20	62	20.725L	Off-normal type	SCr420H1	HB220-258	19.25	5,000	0.06	25
1.13	20	82	25R	Off-normal type	S45C	Hv250-290	31	1,600	0.10	25
1.3	20	83	25.05R	Normal type	S45C	Hv230-275	21	1,300	0.11	22
1.3	20	69	24.687L	Normal type	S45C	Hv230-275	18	2,000	0.10	25
1.3	20	77	24.7099L	Normal type	S45C	Hv230-275	22	2,000	0.10	25

Inline measurement and grinding technology ensuring high machining accuracy

A large-diameter helical broach, which has a required high-precision rating of JIS level 4 or higher, is common for dividing, separating, and producing while measuring using a special tooth-shaped examination device shell parts (tooth surface finish) that require a high-precision tooth shape based on an outside diameter of ø100-ø180 x a total length of 1,500-2,500mm.

We developed a state of the art tooth profile grinder with a gear measurement device and manufacture integrated type helical broaches while measuring inline. CAD·CAM functions of CNC grinders are fully used for accurate positioning, so that any tool shapes are made precisely.

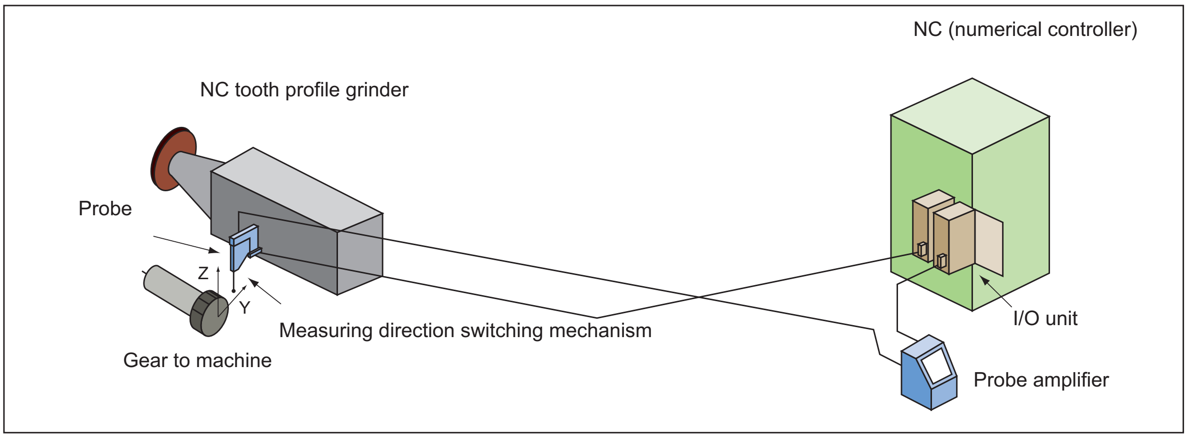
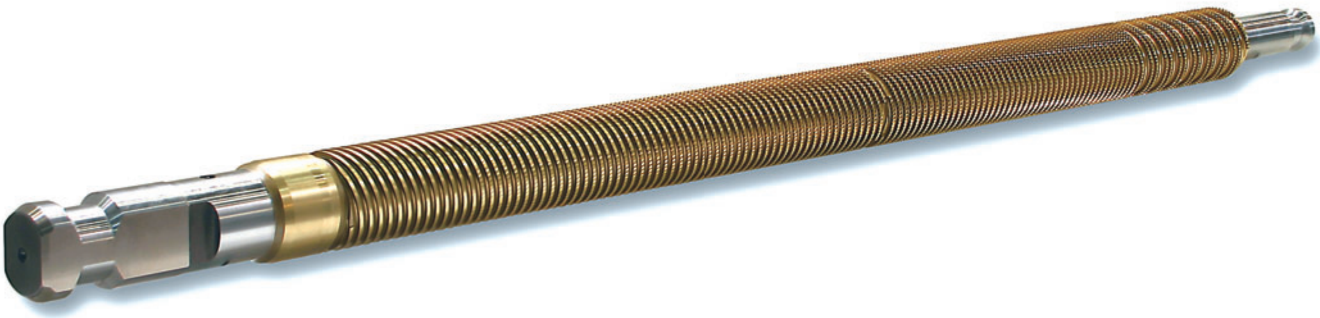


Fig.11 Sketch drawing of gear tester



4. Selection of major dimensions

Broaches should be designed small and accurate as much as possible. Unnecessarily long broaches make manufacturing process difficult, cause deterioration of accuracy and raise cost. Also in use, they cause accuracy deterioration of work piece to be broached, and inconveniences when handling.

Therefore, it is important to correctly report dimensions necessary for design when ordering broaches. Especially cutting length and prepared hole diameter greatly influence overall length of broach, so that one should not include anything extra.

Internal broach

Design of an internal broach is determined by the specification of the broaching machine (shape and size of pull end, pulling out capacity stroke length, maximum length that can manage the stroke length), the shape and size of work piece.

The relation between the design and the dimension of a broach is shown on fig.17. One has to understand each item without fail because many of these items are independently used.

(1) Pull end & retriever

A pulling broach is used as shown in Fig.12, and the model of broaching machine used decides the size of pull end. A pull end has to be designed to easily go into work piece, pull head and retrieving head, and be strong enough to endure cutting resistance, and be easily operated without fail.

(2) Front pilot

The length of the front pilot must be longer than that of work piece in order to always correctly guide the tooth that first cuts into the work piece. This is to be added to the cutting length when there is a recess in the middle or on the machining standard surface of the work piece. (Refer to Fig.13)

Standard width allowance of prepared hole diameter is 0.05mm, and fit tolerance g7 is applied to diameter of front pilot.

(3) Shank length (Length to first tooth)

First tooth must not touch work piece when the broach is clamped to the broaching machine and ready to cut (Fig. 12). We usually ask for user's direction regarding length to table from pull head of the broaching machine and the thickness of the jig although it is also possible to calculate it by adding the length of front pilot to pull end length (for instance, DIN type, userstandard).

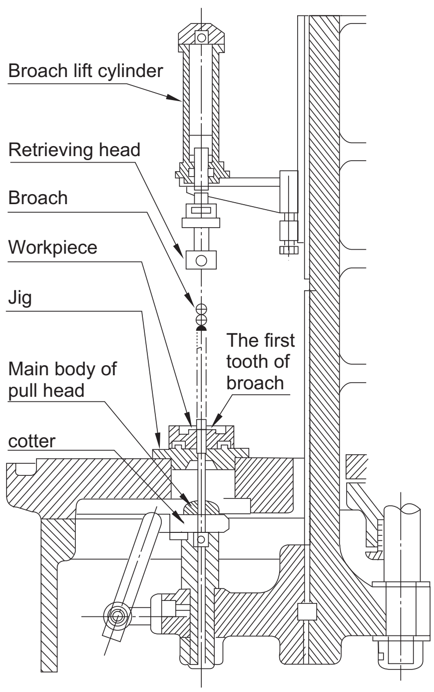


Fig.12 State of broach pulled out

(4) Cutting length

It is the length that a broach cuts a work piece, and the length obtained by deducting recess length from the overall length of the work piece (Fig.13).
When cutting length is short (8mm or below), we recommend that some work pieces are pulled at once according to machining stability (longevity and accuracy, etc.) and cost performance of broaches.
The end face chamfering of machining portion is not usually considered, however, it should be considered in selecting pitches, when cutting length is short, and the number of cutting teeth changes simultaneously.

Cutting length=l_1+l_2
When the length of the handle is examined, the material to be processed length(L) is used.

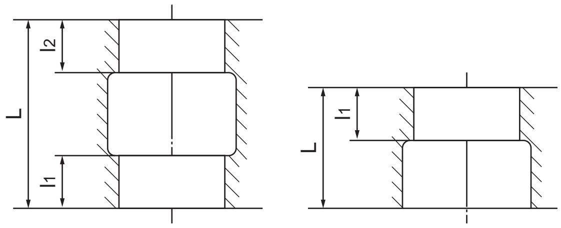


Fig.13 How to decidde cutting length

(5) Total amount of cutting (Depth of cut)

Total amount of cutting = finishing size-minimum diameter of prepared hole
When asked by a user for cutting amount of round tooth of broach, select the prepared hole diameter at 0.3 to 0.35mm and the allowance +0.05.

(6) Depth of cut by one tooth

Depth of cut by one roughing tooth (depth of cut per tooth in diameter) is decided in consideration of quality and hardness of work piece, kind and size of a broach, capacity of broaching machine and so on. Selection standard of general depth of cut by one tooth is shown in Fig.14.
When length of cutting teeth changes greatly, the depth of cut by one roughing tooth may be adjusted by 2 to 3 steps according to the change of length of cutting teeth.
Several semi-finishing teeth should be set following the roughing tooth. To improve finishing surface, depth of cut by one tooth should be decreased gradually. Several finishing (generally 4) teeth should be installed with depth of cut 0.

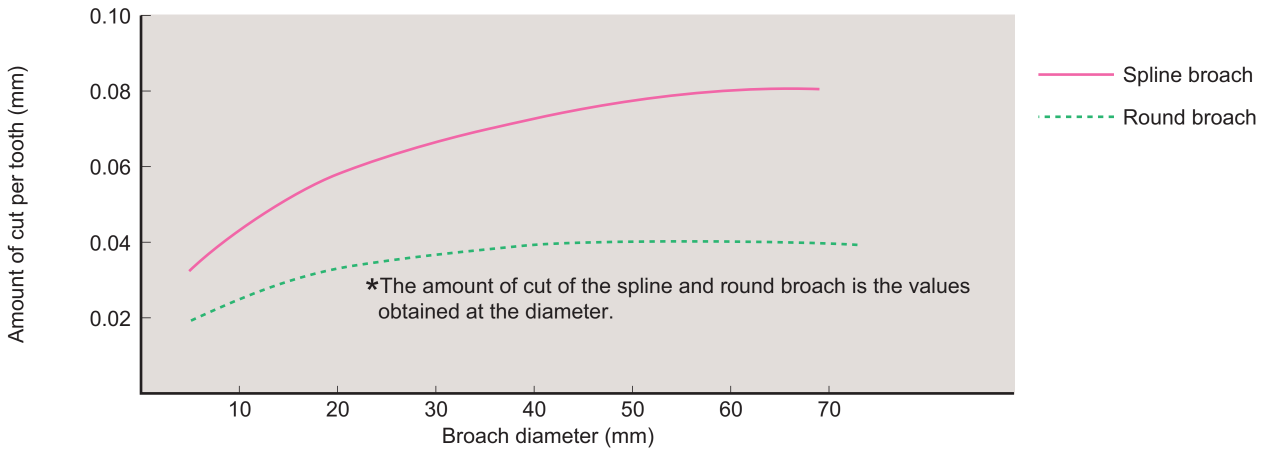


Fig.14 Standard amount of cut per tooth in machining of steel

(7) Pitch

Pitch of cutting edge is usually calculated by the following expression.

$P=k \cdot Lw^{1/2}$

P; Pitch, k; Coefficient Lw; Cutting length

k is about 1.2 to 1.6, and the more depth of cut by one tooth is, the larger it grows.

Numerical values obtained through calculation should be sorted out every 0.5mm. (1) Lw/P must not become an integer. (2) Lw/P should be larger than 2.

Irregular pitch;It is applied to avoid resonating of cutting vibration. Especially in round broach, it is effective for undulation and accuracy on the finishing surface. For irregular pitch, add or take 0.5 to 1mm to/ from the standard pitch.

(8) Chip space shape

Chip space shape is composed of pitch, land width and depth of gullet. It is a key item of design to demonstrate the best of broach's function since it influences capacity of chip space volume, cutting edge strength, and the number of re-grindings, etc. Each setting value in Fig.15 has the following relation with pitch.

$L=0.25\text{-}0.3P$, $H=0.3\text{-}0.5P$, $R_1=0.4\text{-}0.6H$

The chip space shape is decided in this way and it is at least six times, usually about ten times the volume of chip generated while machining. This is a safety coefficient since chip shape changes due to wear of cutting edge. If an operator cannot observe machining at all times, it should be set large.

(9) Rake angle and clearance angle

They should be as Table 4, according to the work material.

Clearance angle should be smaller than that of other tools to keep minimum the decrease in diameter due to re-grinding, and the irregularity of depth of cut by each tooth due to different amount of re-grinding.

Table 4 Standard value of rake angle and clearance angle to various work materials

Work Material	Rake angle	Clearance angle	
		Roughing teeth	Finishing teeth
High-tension steel	10～15°	2°	1°
Mid-tension steel	13～18°	2°	1°
Cast steel	8～15°	2°	1°
Cast iron	8～10°	2°	1°
Malleable cast iron	8～10°	2°	1°
Copper Alloy	5～8°	1°	30´
Aluminium alloy	15～20°	3°	1°30´

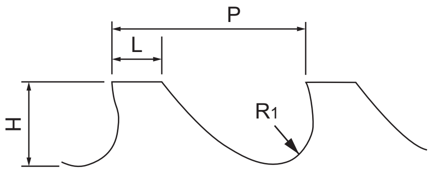


Fig.15 Tooth shape of broach

(10) Side relief

When contact area of work piece and tooth flank broadens, adhesion on tooth flank and tear on finishing surface easily occur. To reduce friction, a relief is applied to tooth side. As for side relief, there are land leaving method and back taper method. Three methods including no side relief are used depending on tooth profile, tooth length and work piece (heat treated or non-heat treated), etc.

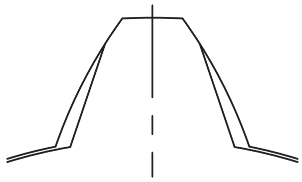


Fig 16-1 Land leaving method

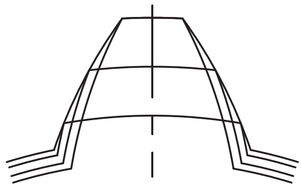


Fig 16-2 Back taper method

(11) Rear pilot

Work piece is supported by a rear pilot set behind the last tooth, until the last finishing tooth is completed machining. The diameter should be a minimum limit of the diameter of finishing round tooth, and the length should be about the same as the diameter.

(12) Retriever

It is prepared on a vertical-type broaching machine to lift up the broach. Just like pull end it is decided by the retrieving head of the machine, so that it is necessary to get user's direction.

(13) Nick

It prevents chip interference and facilitates outflow of chip when tooth is round or cutting edge is long. Generated chip damages the finished face when machining groove such as spline. Because width of chip becomes larger than that of cutting edge due to resistance at generating. This can be prevented by preparing nicks as they divide chip into pieces. Nicks should be arranged in zigzag so as not to overlapped by adjoining teeth. (Photo. 3)

(14) Length of cutting teeth and overall length

Length of cutting teeth is calculated as "Length of cutting teeth = Number of cutting teeth × Pitch." However, the value of length of cutting teeth plus cutting length, and if necessary length of rear shank, must be shorter than a stroke of broaching machine. Overall length is calculated as "Overall length = Shank length + Length of cutting teeth + Length of rear pilot + Length of retriever." However it has to be shorter than the length that can accommodate the broaching machine.

Too long and slender broaches occasionally cause problems while being manufactured or operating. Therefore, it is preferable to use set broaches by dividing into two or more.

(15) Calculated broaching load

It is necessary to confirm in advance whether the broach will perform well enough with the broaching machine. Calculated broaching load multiplied by safety rate 1.8 is safety load, and it has to be less than pulling out capacity of the broaching machine.

$F = L \times \Delta R \times C$

F : Calculated broaching load

L : Maximum cutting tooth length at simultaneous cutting

C : Specific cutting resistance (Table 7)

ΔR : Depth of cut in radius direction

$FS = 1.8F < \text{pulling out capacity}$

Photo. 2 Chips divided by nicks

Calculation of maximum cutting tooth length at simultaneous cutting of various broaches, l :

(a)Round broach $l=N \times \pi \times D$

(b)Spline or Serration broach $l=N \times Z \times W$

N : Number of simultaneously cutting teeth

D : Maximum diameter

Z : Number of teeth

W : Spline width(Maximum face width)

Table 5 Amount of cut per tooth and ratio cutting resistance (kN/mm^2)

Work material \ Amount cut per tooth (mm)	0.02	0.04	0.06	0.08	0.10	0.15
High-tensile steel	4.5	3.6	3.2	2.9	2.7	—
Mid-tensile steel	3.6	2.7	2.5	2.3	2.2	2.0
Cast steel	—	2.4	2.1	1.9	1.8	1.6
Cast iron	—	1.9	1.7	1.6	1.5	1.4
Malleable cast iron	—	2.2	1.9	1.7	1.6	1.6
Copper Alloy	—	—	1.5	1.3	1.2	1.1
Aluminum alloy	—	—	1.3	1.1	1.0	0.9

(16) Broach strength

It is possible to confirm by the following expression that broach will not be damaged by broaching load that is caused in normal broaching.

$FP = \sigma B \times A/S > FS$

S : Safety rate =3

σB : Tensile-strength, kN/mm^2

A : Minimum sectional area

σB is different at grip part and cutting part, so it should be calculated simply by the following expressions.

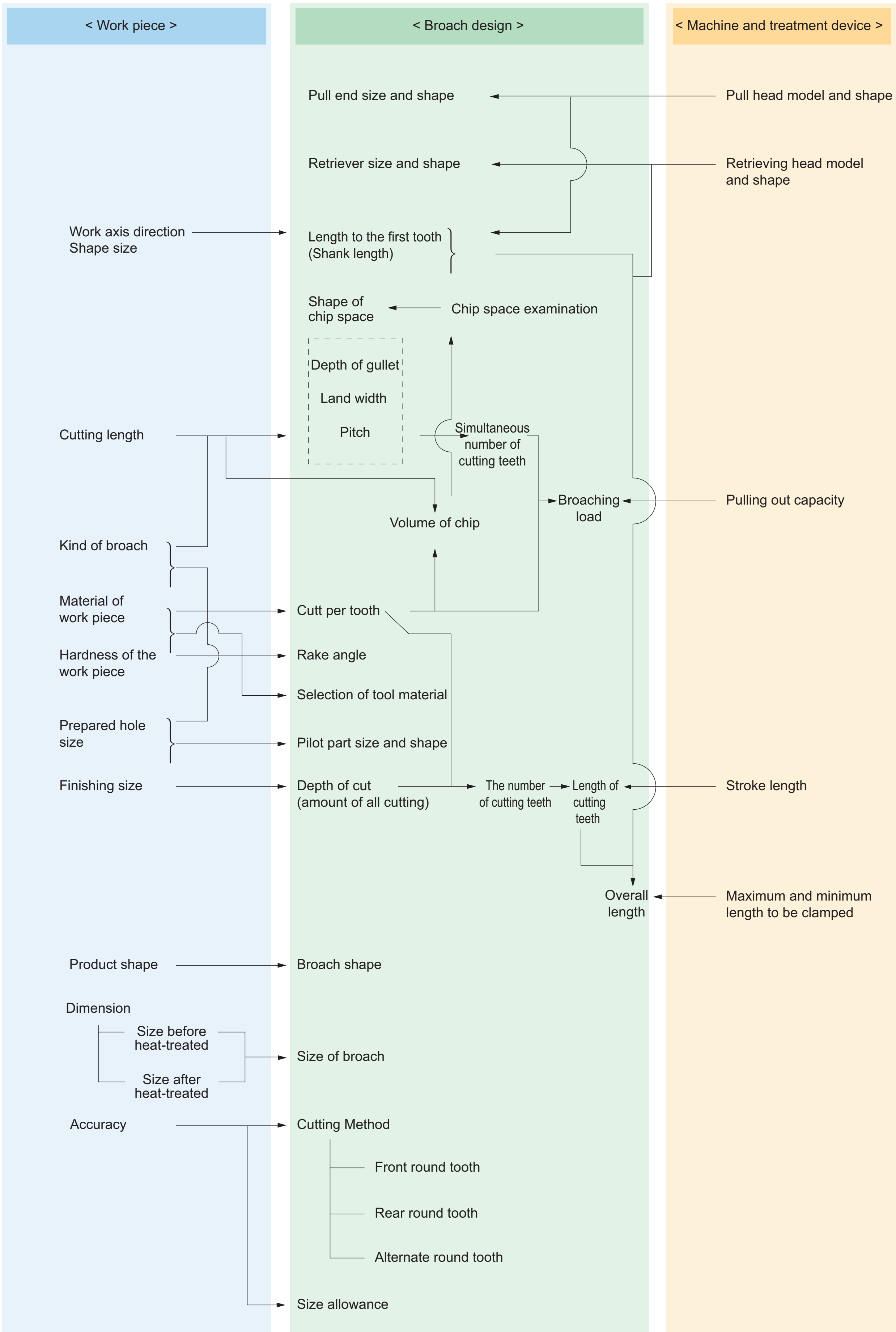
Cutting part $Ft=0.6 \times At$

Grip part $Fc=0.4 \times Ac$

At and Ac are minimum sectional areas of cutting part and grip part. The smallest value of these becomes permissible load FP, and it has to be larger than safety load FS.

Fig.17 describes the outline of relations among broaching machine, specification of work piece and broach dimensions.

Fig.17 Figure for selecting dimensions from specifications



5. Cutting action

An operator can freely select depth of cut and feed rate in boring or turning, however, in case of broaching, the amount of cut per tooth, equivalent for these is decided when designing. All that an operator can change is cutting speed. Chip in turning and milling is removed as soon as it is generated, whereas in broaching, chip from all cutting length must be accommodated in the chip space.
Therefore, the size of chip space is an important point. When designing, a suitable chip space for cutting length is adopted. Therefore, if work piece, which is longer than designated length on the drawing, is to be cut, chip gets stuck in the chip space. It may end up in remarkably bad finishing surface and cause cutting tooth chipping or breakage.
Length of chip that broach generates is always shorter than cutting length, and it is about 1/2-1/4 of cutting length. Oppositely thickness of chip increases by 2 to 4 fold. Thickness of chip varies due to rake angle, material of work piece, state of cutting edge, cutting speed, and the cutting oil, etc.
Fig.18 shows how chip is generated. When cutting edge meshes with work material and starts shearing, removed chip slips up along the cutting face, just like other cutting tools. Then when cutting edge further progresses, shorn chip will weld to front chip and will make a layer of parallelogram. These chips overlap one after another, and create a single bound chip.
Rake angle applied for a broach ranges from 5° to 25° depending on condition. When chip is generated, an angle is formed with the direction of progress and the shearing surface where chip slips. This is called a shear angle.
This angle plays an important role in cutting resistance and cutting mechanism.
As shown in Fig.19, the smaller shear angle is, the longer shearing surface becomes and the thicker chip becomes. Ultimately cutting resistance grows.
On the contrary, the larger shear angle is, the shorter shearing surface becomes and the thinner the chip becomes, then cutting resistance decreases.
The best shape of chip is a swirl rolling well, and chips from work piece with toughness forms this shape.

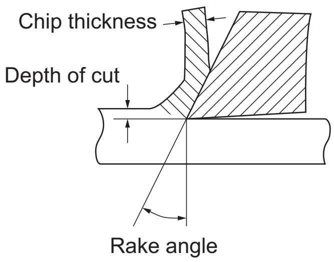


Fig.18 State of chip generation

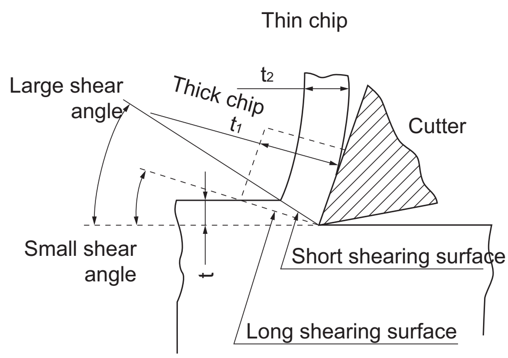


Fig.19 Shear angle and chip thickness

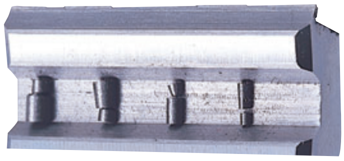


Photo. 3

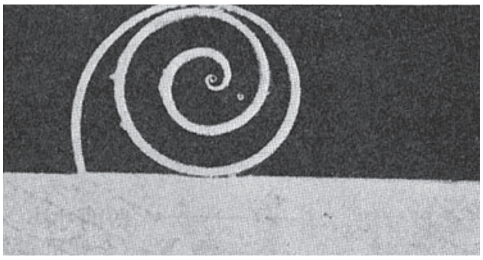


Photo. 4

Photo. 5

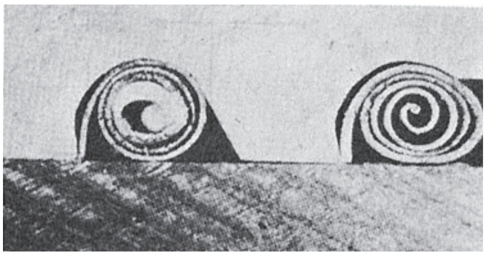


Photo. 6

Rolling state of chip varies according to amount of cut per tooth, cutting length, cutting oil, hardness, chemical elements and formation of work material etc.

Generally soft material creates larger rolling diameter than hard material. Since chip from a fragile material like cast iron does not curl and is not bulky, even if the chip space capacity is small any problem will not occur.

Photograph 3 shows generation of chip during cutting, and Photograph 4 shows chip freely curling. Photograph 5 shows chip in insufficient chip space, and the left one in Photograph 6 shows normal chip in sufficient chip space. The right one of Photograph 6 shows a deformed chip due to defective re-grinding.

6. Point to notice at broaching

(1) Hardness of work material

Generally, it is said that suitable hardness of steel for broaching is approximately between 200 HB and 240HB. Finishing surface of hard material can be better than that of soft material. Because extremely soft steel easily causes adhesion on land part of broach, then, causes scuffing and tears, and deteriorates finishing surface occasionally. Oppositely, steel with too high hardness quickens wear of broach and shortens tool life.

(2) Prepared hole

Prepared hole must be bored accurately since it gives a big influence on roughness on finishing surface, longevity, machining accuracy and so on when internal broaching. Inaccurate prepared hole often comes with troubles below.

① Prepared hole should be right-angled to datum clamp face. If it is not, broach bends during machining, and precise size and desirable finishing surface cannot be obtained.

② If prepared hole is too small or bent, a front pilot cannot enter. On the other hand, if too large, the broach inclines toward one side and an eccentricity grows.

③ If there is a falling piece of a build-up edge or a hard alien substance, etc. in prepared hole, they can cause extremely short tool life for broach.

(3) Cutting speed

Because cutting speed influences finishing roughness, tool life, and machining accuracy etc. of broach, it must be carefully selected well considering machinability etc. of work piece material. Cutting speed of broach is usually about 2-8 m/min although high-speed broaching at 15-40 m/min or higher has been done recently.

(4) Cutting oil

The cutting oil greatly influences longevity of broach. The following is its main purpose of use.

① To improve finishing surface.

② To improve size accuracy.

③ To control wear of cutting edge.

④ To make removal of chip easy.

Broaching is a low-speed cutting and rise of cutting temperature remains little, compared with other machining methods. Cutting oil does not easily infiltrate tooth tip in machining because relief angle is smallened from the viewpoint of re-grinding. It gets even more difficult for oil to come in as machining progresses. So that generation of chip, roughness of finishing surface, and machining accuracy, etc., present a complex aspect. To solve these various problems, selecting the most appropriate cutting oil is an important point.

One has to be very careful since there is some unsuitable oil for broaching sold in the market. One should not forget that if cutting oil is mixed with water, lubricant and light oil, etc., finishing surface may be extremely bad and abnormal wear may be caused.

(5) Wall thickness of work piece

In internal broaching, wall thickness of work piece slightly influences machining accuracy of bore diameter and roundness, etc. While broaching, work piece expands due to back force, causing elastic and plastic deformation. However, after broaching, it recovers to almost original by elastic recovery (spring back). (Refer to Fig.20)

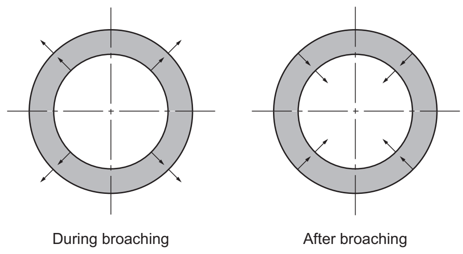


Fig.20 Spring back

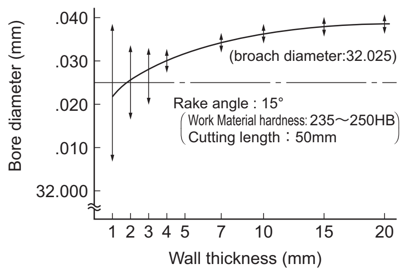


Fig.21-1 Relation between hole diameter and wall thickness

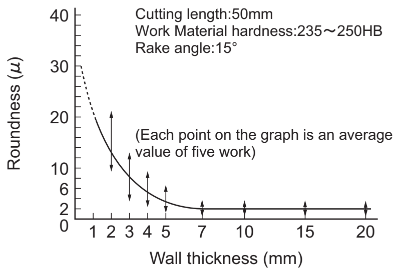


Fig.21-2 Relation between roundness and wall thickness

When deformation is too serious, in some case it may remain as plastic deformation. And degree of this recovery greatly depends on wall thickness of work piece. For instance, even when same broach are used for machining, thinner work piece will have small bore diameter compared with thicker work piece after broaching. As an example, Fig.21-1, 1 shows relation among wall thickness, bore diameter size and roundness when work piece with various wall thickness is machined by round broach. As one can see from the figure, when wall thickness is thin, size becomes small, roundness worsens, and irregularity grows, compared with thick work piece, Therefore, in broaching it is better to thicken wall of work piece and widen the datum clamp surface as much as possible.
In addition, when wall thickness of work piece changes along into the direction of circumference or cutting, Fig.22(a), (b), and (c) can be refereed to. Since this phenomenon cannot be avoided with tools, it is necessary to closely examine and study machining accuracy and work piece shape.

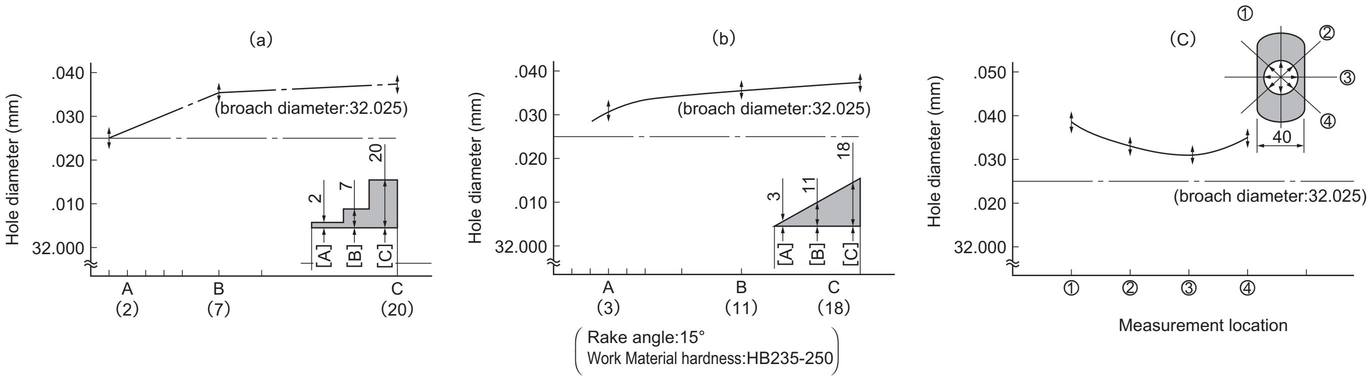


Fig.22 Bore diameter and the special shape wall thickness (Each point in the graph is an average value of five works)

7. Re-grinding of round and spline broach

It is necessary to set grinding wheel diameter and inclination angle (grinding wheel inclination) correctly in order to re-grind correct rake angle.

Expression

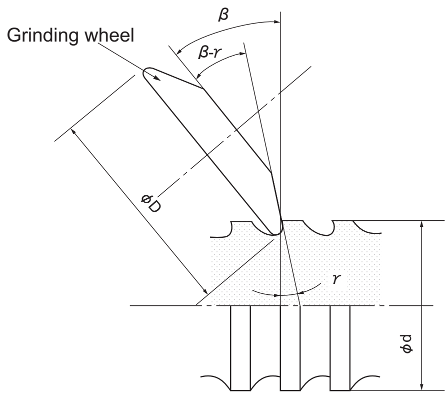
$D=0.85 \cdot d \cdot \mathrm{Sin}(\beta-\gamma)/\sin\gamma$

D :Grinding wheel diameter

d :Diameter of broach

β :Grinding wheel inclination

γ :Rake angle



Values of D obtained from above expression are indicated in the table below.

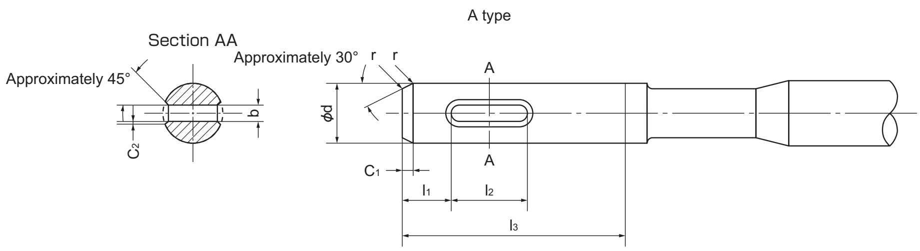
Table 6 Diameter of grinding wheel when re-grinding

Diameter of broach d	β=30°							β=40°							β=50°							β=60°						
	Rake angle γ°																											
	7	9	12	14	16	18	20	7	9	12	14	16	18	20	7	9	12	14	16	18	20	7	9	12	14	16	18	20
		Diameter of grinding wheel D																										
8	21	15	10	—	—	—	—	27	19	13	10	-	-	-	38	28	20	15	13	11	-	44	33	23	19	17	14	12
10	27	19	12	—	—	—	—	39	28	19	15	12	10	-	47	35	25	20	17	14	12	55	42	29	24	21	18	16
12	32	23	15	11	—	—	—	46	33	23	18	15	12	10	57	42	30	25	20	17	14	69	50	35	29	25	22	19
14	38	27	17	13	10	—	—	54	39	27	21	17	14	11	66	50	35	29	24	20	17	78	59	41	34	29	25	22
15	41	29	19	14	11	—	—	58	42	28	23	18	15	12	71	53	37	31	26	21	18	83	63	44	36	32	27	24
16	43	31	20	15	12	—	—	62	45	30	24	20	16	13	76	57	40	33	27	23	19	89	68	47	39	34	29	25
18	49	35	22	17	13	10	—	70	50	34	27	22	18	15	85	64	45	37	31	26	22	100	76	53	44	38	33	28
20	54	39	25	19	14	11	—	78	56	38	31	25	20	17	95	71	50	41	34	29	24	111	84	59	49	43	36	32
22	60	43	27	21	16	12	—	85	61	42	34	27	22	18	105	78	55	45	38	32	27	123	93	65	53	47	40	35
24	66	46	30	23	17	13	10	93	69	46	37	30	24	20	114	86	60	49	41	35	29	134	101	70	58	51	44	38
25	68	48	31	24	18	14	11	97	70	48	38	31	25	21	119	89	62	50	43	36	31	139	105	73	61	53	46	40
28	77	56	36	27	21	16	12	106	79	53	43	35	29	24	137	100	72	58	50	41	35	156	118	84	71	60	51	45
30	82	60	38	29	22	17	13	114	84	57	46	38	31	26	147	108	77	62	54	44	37	167	126	90	76	64	55	48
32	88	64	41	31	24	18	14	121	90	61	49	40	33	27	158	115	82	66	57	47	40	178	135	96	81	69	59	51
35	96	70	44	34	26	20	15	132	98	67	54	44	36	30	172	125	89	72	63	51	43	195	147	105	88	75	64	56
36	99	72	46	35	27	21	16	136	101	69	55	45	37	31	176	129	92	74	64	53	45	200	151	107	91	77	66	58
38	104	76	48	37	28	22	17	144	107	72	58	48	39	32	186	136	97	78	68	55	47	212	160	114	96	81	70	61
40	109	80	50	40	30	23	18	151	112	76	61	50	41	34	195	143	102	82	71	58	50	222	168	120	101	86	74	64
42	115	84	53	41	31	24	19	159	118	80	64	53	43	36	205	150	107	87	75	61	52	234	177	125	105	90	77	67
45	123	90	57	44	34	26	20	170	126	86	69	57	47	38	220	160	115	93	80	66	56	250	190	135	113	96	83	72
48	131	95	61	46	36	28	21	182	135	91	73	60	50	41	234	172	122	99	86	70	60	268	202	143	121	103	88	77
50	137	99	63	48	37	29	22	189	140	95	76	63	52	42	244	178	127	103	89	73	62	278	210	150	126	107	92	80
55	150	109	70	53	41	32	24	208	154	105	84	69	57	47	268	197	140	113	98	80	68	311	232	164	138	118	101	88

8. Pull end shape

There are three kinds of pull ends, namely cotter type, round type and thread type.

(1) Cotter type shank (JIS B4237)



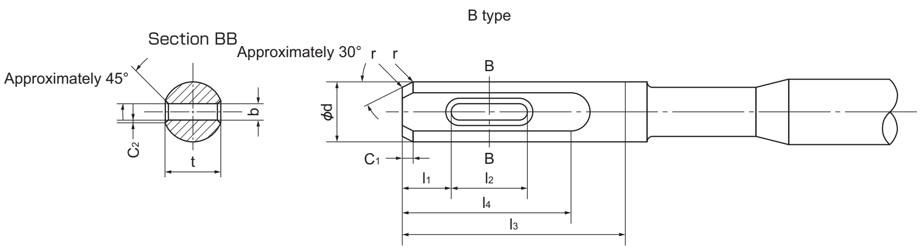


Table 7 Size of cotter type shank

(Unit: mm)

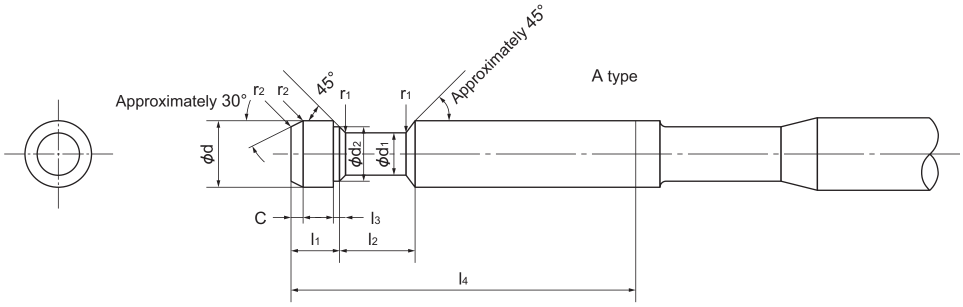
Nominal size	Shank diameter (ϕd)		Width of cotter slot (b)		Distance from end to cotter slot l_1	Length of cotter slot l_2	Effective shank length l_3 (minimum)	Reference				
	Standard size	Allowance	Standard size	Allowance				l_4	t	c_1	c_2	r
10	10	−0.013 −0.035	3	+0.4 0	16	20	70	50	9	3	0.4	1
(11)	11	−0.016 −0.043	3						10			
12	12		3			25			11			
(14)	14		3.5	+0.5 0	18		80	60	12	4		
16	16		4						14			
(18)	18		4.5						16			
20	20	−0.020 −0.053	5						18			
(22)	22		5.5		20	32	90	70	20	5	0.6	1.6
25	25		6						22			
(28)	28		7	+0.6 0					25			
32	32	−0.025 −0.064	8						28			
(36)	36		9		22	40	100	80	32	6	1	2.5
40	40		10						36			
(45)	45		11	+0.7 0					40			
50	50		12						45			
(56)	56	−0.030 −0.076	14		25	50	120	100	50	8	1.6	4
63	63		16						56			
(70)	70		18		32	56	140	120	63	10		
80	80		20	+0.8 0					70			
(90)	90	−0.036 −0.090	22		40	63	160	140	80	12	2.5	6
100	100		25						90			

• Note
1. Do not use ones with ( ).
2. The allowance of d is from f8 of JIS B0401.
3. The allowance of l_1 l_2 is from the rough class of JIS B0405.
4. l_3 means the part where d satisfies the range of the allowance.

Pull end shape

(2) Round type shank

(2) - ① JIS type shank (JIS B4237)



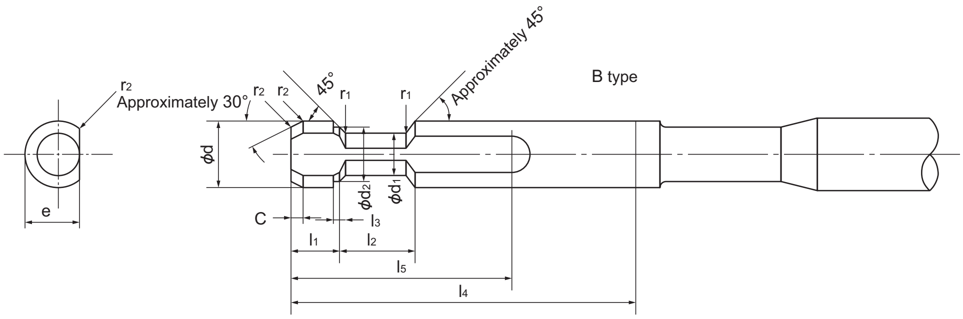


Table 8 Size of JIS type shank

(Unit: mm)

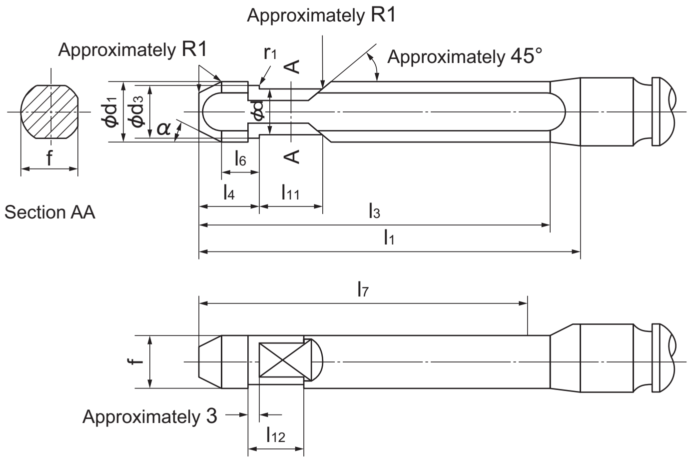
Nominal size	Shank diameter (ϕd)		Neck diameter (ϕd_1)		Height of flat (e)		Head length l_1	Neck length l_2	Effective shank length l_4 (minimum)	Length of flat face l_5 (minimum)	Reference				
	Standard size	Allowance	Standard size	Allowance	Standard size	Allowance					d_2	l_3	c	r_1	r_2
8	8	−0.013 −0.035	6	−0.080 −0.170	6.5	−0.025 −0.047	12	20	90	60	7.8	1	2	0.4	1
(9)	9		6.8		7.4						8.8				
10	10		7.5		8.25		14	22	100	65	9.8		3		
(11)	11	−0.016 −0.043	8.2		9.1						10.8				
12	12		9		10						11.8				
(14)	14		10.5	−0.095 −0.205	11.75	−0.032 −0.059	16	25	110	75	13.7	2	4	0.6	
16	16		12		13.5						15.7				
(18)	18		13.5		15.25						17.7				
20	20	−0.020 −0.053	15		17		18	28	125	85	19.7		5		
(22)	22		16.5		18.75	−0.040 −0.073					21.7				
25	25		19	−0.110 −0.240	21.5						24.7				
(28)	28		21		24		20	32	140	95	27.6	3	6	1	1.6
32	32	−0.025 −0.064	24		27.5						31.6				
(36)	36		27		31	−0.050 −0.089					35.6				
40	40		30		34.5		25	40	160	110	39.5		8		2.5
(45)	45		34	−0.120 −0.280	39						44.5				
50	50		38		43.5						49.5				
(56)	56	−0.030 −0.076	42	−0.130 −0.290	48.5		32	50	180	130	55.4		10	1.6	4
63	63		48		55	−0.060 −0.106					62.4				
(70)	70		53	−0.140 −0.330	61						69.4				
80	80		60		69.5		40	63	200	150	79.2		12		6
(90)	90	−0.036 −0.090	68	−0.150 −0.340	78.5						89.2				
100	100		75		87	−0.072 −0.126					99.2				

• Note
1. Do not use ones with ( ).
2. The allowance of d, d1, and e is from f8, c11 and e8 of JIS B 0401.
3. The allowance of l_1 and l_2 is from the rough class of JIS B 0405.
4. l_4 and l mean the part which satisfies d and e each.

Pull end shape

(2) Round type shank

(2) - ② DIN type shank (DIN 1415)



(Nominal size 4–18)

Table 9 Size of DIN type shank

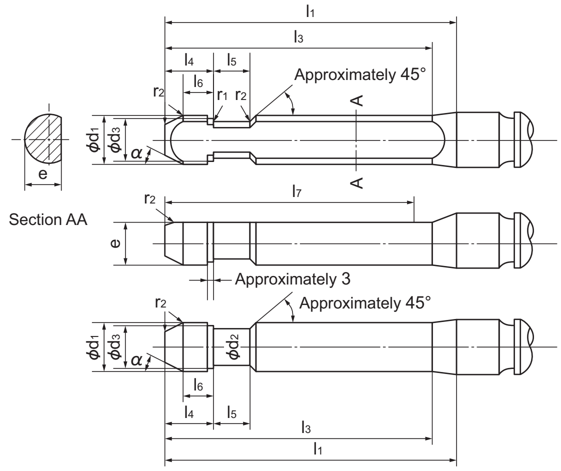
(Unit: mm)

Nominal size	φd1		φd		r		l4	l11	Reference							
	Standard size	Allowance	Standard size	Allowance	Standard size	Allowance			φd3	l1	l3	l6	l7	l12	r1	α
4	4	−0.030 −0.048	2.3	−0.060 −0.120	3.7	−0.030 −0.048	16	16	3.8	160	120		90	15	0.2	
4.5	4.5		2.6		4.2		16	16	4.3	160	120		90	15	0.2	
5	5		3		4.6		16	16	4.8	160	120		90	15	0.2	
5.5	5.5		3.3	−0.070 −0.145	5.1		16	16	5.3	160	120		90	15	0.2	
6	6		3.6		5.6		16	16	5.8	160	120		90	15	0.2	
7	7	−0.040 −0.062	4.2		6.5	−0.040 −0.062	16	16	6.8	160	120		90	15	0.2	
8	8		4.8		7.5		16	16	7.8	160	120		90	15	0.2	
9	9		5.4		8.5		16	16	8.8	160	120		90	15	0.2	
10	10		6		9.5		20	16	9.8	180	140	12	120	15	0.2	10°
11	11	−0.050 −0.077	6.6	−0.080 −0.170	10.5	−0.050 −0.077	20	16	10.8	180	140	12	120	15	0.2	10°
12	12		7.2		11.5		20	16	11.8	180	140	12	120	15	0.2	10°
14	14		8.5		13.5		20	16	13.7	180	140	12	120	15	0.3	20°
16	16		10		15.5		20	16	15.7	180	140	12	120	15	0.3	20°
18	18		11.5	−0.095 −0.205	17.5		20	16	17.7	180	140	12	120	15	0.3	20°

Pull end shape

(2) Round type shank

(2) - ② Continued from of DIN type shank (DIN 1415)



(Nominal size 20–100)

Table 10 Size of DIN type shank

(Unit: mm)

Nominal size	ϕd1		ϕd2		e		l_4	l_5	Reference							
	Standard size	Allowance	Standard size	Allowance	Standard size	Allowance			ϕd3	l_1	l_3	l_6	l_7	r_1	r_2	α
20	20	−0.065 −0.098	15	−0.095 −0.205	17	−0.032 −0.059	25	16	19.7	210	170	12	160	0.3	1	20°
22	22		16.5		18.75	−0.040 −0.073	25	16	21.7	210	170	12	160	0.3	1	20°
25	25		19	−0.110 −0.240	21.5		25	16	24.7	210	170	12	160	0.3	1	20°
28	28		21		24		32	20	27.6	220	180	16	170	0.4	1.6	20°
32	32	−0.080 −0.119	24		27.5		32	20	31.6	220	180	16	170	0.4	1.6	20°
36	36		27		31	−0.050 −0.089	32	20	35.6	220	180	16	170	0.4	1.6	30°
40	40		30		34.5		40	25	39.5	230	190	20	180	0.5	2.5	30°
45	45		34	−0.120 −0.280	39		40	25	44.5	230	190	20	180	0.5	2.5	30°
50	50		38		43.5		40	25	49.5	230	190	20	180	0.5	2.5	30°
56	56	−0.100 −0.146	42	−0.130 −0.290	48.5		50	32	55.5	270	230	25	220	0.6	4	30°
63	63		48		55	−0.060 −0.106	50	32	62.4	270	230	25	220	0.6	4	30°
70	70		53	−0.140 −0.330	61		50	32	69.4	270	230	25	220	0.6	4	30°
80	80		60		69.5		63	40	79.2	315	275	32	265	0.8	6	30°
90	90	−0.120 −0.174	68	−0.150 −0.340	78.5		63	40	89.2	315	275	32	265	0.8	6	30°
100	100		75		87	−0.072 −0.126	63	40	99.2	315	275	32	265	0.8	6	30°

(3) Thread type shank (JIS B4237)

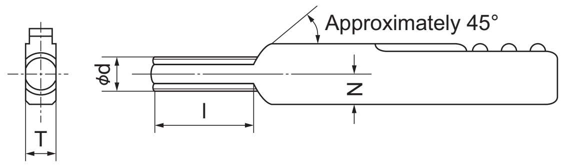


Table 11 Size of thread type shank

(Unit: mm)

Nominal size	Nominal of thread screw (d)	Thread length l	Reference	
			T	N
6	M6	20	5	3.5
8	M8	25	6	4.5
			7	4.5
10	M10	30	8	5.5
			9	6
12	M12	35	10	6.5
			11	7
14	M14	40	12	8
16	M16	40	15	11
18	M18	50	17	13
20	M20	50	19	15

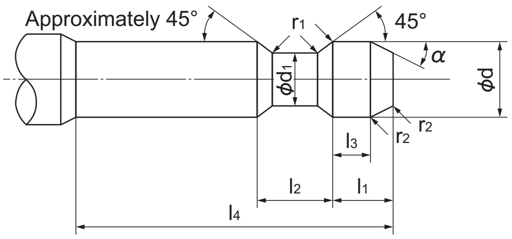
• Note

1. The screw of the installation screw is from JIS B0205.
   The accuracy is from 8g of JIS B0209.

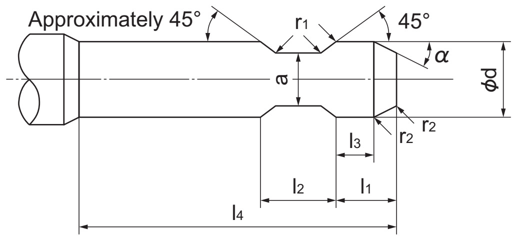
9. Retriever shape

Please select retriever according to lifter of broaching machine.

(1) Round type retriever and retriever with trapezoid groove (JIS B4237)



(round type)



(Trapezoid type)

Table 12 Size of round type retriever and retriever with trapezoid groove

(Unit: mm)

Nominal size	Shank diameter ϕd		Neck diameter or width across flat face ϕd_1 or a		Head length to installation ditch (l_1)	Neck length Installation ditch length (l_2)	Effective shank length l_4 (minimum)	Reference			
	Standard size	Allowance	Standard size	Allowance				l_3	r_1	r_2	α
12	12	−0.016 −0.043	9	−0.080 −0.170	16	16	60	8	0.4	1	10°
16	16		12	−0.095 −0.205							20°
20	20	−0.020 −0.053	15		20	20	70	10	0.6	1.6	
25	25		18								
32	32	−0.025 −0.064	24	−0.110 −0.240	25	25	80	12	0.8	2.5	
40	40		30								30°
50	50		38	−0.120 −0.280	28	32	90	16	1	4	
63	63	−0.030 −0.076	49	−0.130 −0.290							
80	80		66	−0.140 −0.330	32	40	110	20	1.6	6	
100	100	−0.036 −0.090	86	−0.170 −0.390							

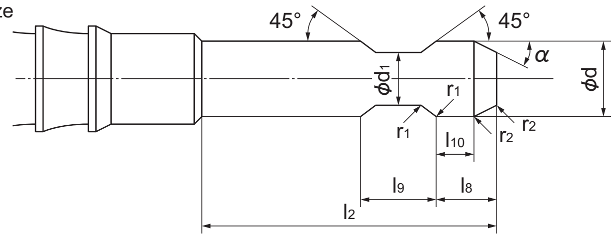
• Note

1. The allowance of d, d_1, and α are from f8 and c11 of JIS B 0401 each.
2. The allowance of l_1 and l_2 are from a rough class of JIS B 0405.

Retriever shape

(2) DIN type retriever (DIN 1415)

Nominal size 12-100



Nominal size 20-100

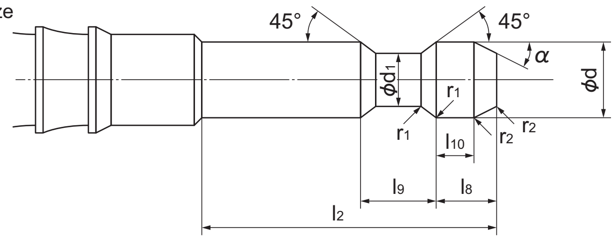


Table 13 Size of DIN type retriever

(Unit: mm)

Nominal size	d		d_1		l_8	l_9	Reference				
	Standard size	Allowance	Standard size	Allowance			l_2	l_{10}	r_1	r_2	α
12	12	−0.050 −0.077	9	−0.080 −0.170	16	16	70	8	0.2	1	10°
14	14		10		16	16	70	8	0.3	1	20°
16	16		12	−0.095 −0.205	16	16	70	8	0.3	1	20°
18	18		14		16	16	70	8	0.3	1	20°
20	20	−0.065 −0.098	15		20	20	90	10	0.3	1	20°
22	22		17		20	20	90	10	0.3	1	20°
25	25		20	−0.110 −0.240	20	20	90	10	0.3	1	20°
28	28		22		25	25	125	12	0.4	1.6	20°
32	32	−0.080 −0.119	26		25	25	125	12	0.4	1.6	20°
36	36		30		25	25	125	12	0.4	1.6	30°
40	40		34	−0.120 −0.280	25	25	125	12	0.5	2.5	30°
50	50		42	−0.130 −0.290	25	25	125	12	0.5	2.5	30°
63	63	−0.100 −0.146	53	−0.140 −0.330	28	32	160	16	0.6	4	30°
80	80		68	−0.150 −0.340	32	40	200	20	0.8	6	30°
100	100	−0.120 −0.174	86	−0.170 −0.390	32	40	200	20	0.8	6	30°

10. Troubles and solutions

Trouble	Cause	Solution
The broach stops during machining	Power shortage of broaching machine	Use broaching machine with enough power.
	Increase of cutting resistance due to adhesion, cutting edge chipping, and abnormal wear	Remove adhesion, cutting edge chipping, and abnormal wear by re-grinding. Change cutting oil.
	Deterioration of machinability because of quality change of work material	Check the composition, the structure, and the hardness of the work material. Change cutting oil.
	Chip stuck	Check whether the work piece of a specified cutting length or more is machined. Remove chip completely.
Generation of Chattering vibration	Number of cutting teeth being too small, that can work simultaneously	Check whether the cutting length is not longer than it should be. If so, cut some piled work pieces at once.
	Spring back phenomenon of work material	The wall thickness of the work piece should be thickened.
	Resonance due to pitch and cutting length	Support the retriever.
	Rigidity shortage of machine and jig	Repair the machine and the jig. Increase rigidity.
Tear of finishing face	Adhesion on the cutting edge side face	Remove the adhesion part by re-grinding. Change cutting oil.
A big burr generates	Deterioration of machinability because of quality change of work material	Check the composition, the structure, and the hardness of the work material. Change cutting oil.
	Deterioration of sharpness	Re-grind to improve sharpness.
Tear of contour	Due to wear of the tip of the cutting edge, finishing surface wears off	Re-grind to improve sharpness.
	Adhesion on the cutting edge	Remove the adhesion part by re-grinding. Change cutting oil.
	Cutting edge chipping is caused on	Remove chipping part by re-grinding.
	Dent on the cutting edge	Remove the dent by re-grinding.
	Chip and the work piece surface rub each other	Re-grind to improved sharpness. Remove chip completely. Change cutting oil.

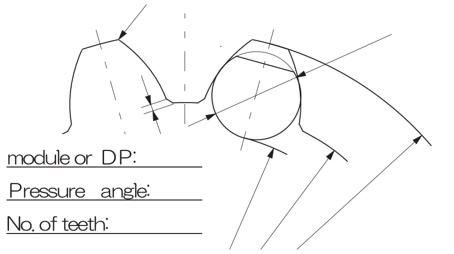
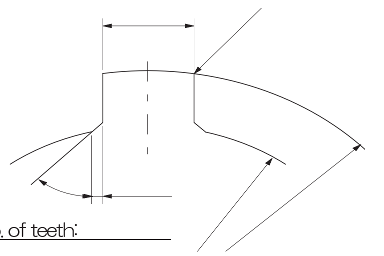
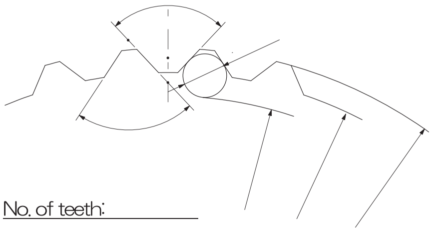
Trouble	Cause	Solution
Thread streak	Cutting edge chipping	Remove chipping part by re-grinding.
	Dent on the cutting edge	Remove the dent by re-grinding.
	Adhesion on the cutting edge	Remove the adhesion part by re-grinding. Change cutting oil.
Minute chip at broach exit of work piece	Broaching load increases	Re-grind to improve sharpness. Change cutting oil.
	No back metal in the work piece	Change the shape of the work piece, or examine the machining method.
Breakage and tooth lack	Broach installation is not good	Improve the clamping.
	Chip stuck	Check whether the cutting length is not longer than it should be. Remove chip completely. Change cutting oil.
The through gauge does not enter	Eccentricity of machining bore	Remove chipping part and dent on the broach cutting edge if there is any. The datum clamp surface an prepared hole should be correctly machined.
	The corner part of the cutting edge wears out abnormally	Remove the wear part by re-grinding.
	The finishing size is smaller than the allowance lower bound	Re-grind to improve sharpness. The wall thickness of the work piece should be enlarged.
The stop gauge passes	Large burr when the cutting face is ground	Remove burr.

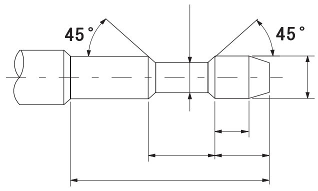
11. Broach order specifications

When ordering, please specify necessary dimensions for designing and manufacturing of broaches, referring to the specifications below.

Gear Cutting Tools Section　　　　　　　　　　　　　　Date ‘　.　.

☐Involute ☐Parallel spline ☐Seration ☐Trapizoid Broach Specification	Order NO	Quantity	Standard design Plan		Sales Dep.
	Customer		Completion Day	Name	Name
☐Standard Design ☐Improvement Design ☐Comparison Article	Remarks				
Delivery time	☐Ordinary ☐Certain ☐ Advanced (Date of Delivery)				

A	Work spec	
☐	Work drawings	☐respected spring back ☐Not respected spring back
☐	Applicable standard	☐with (standard) ☐without
☐	Parts name ,Parts number	Add to Drawing ☐need ☐unneed
☐	Material / Hardness / Length of cut	
☐	Finished size	
	☐Involute spline  module or DP: Pressure angle: No. of teeth:	
	☐Parallel spline  No. of teeth:	
	☐Seration ☐Trapizoid Need direction of uniting or lacking teeth type  No. of teeth:	
☐	Prepared hole size	ϕ

B	Broach spec		
☐	Broach Drawings ☐with ☐without	☐same as provided drawing	
		☐Improvement Design	
		☐with compensation ☐majour diameter ☐tooth thichness ☐other	
☐	Tool No		
☐	Marking		
☐	Material		
☐	Surface treatment	☐none ☐nitride oxidation ☐STH ☐TiN coat ☐GV21 ☐other ( )	
☐	Heart treatment after broaching ☐with ☐without	☐with compensation	
		work compensation value	Majour diameter： Minar diameter： B.P.D.：
		☐without compensation	
☐	Over size by burr	☐disapproval	☐only first work ☐ first work and after re-grind
		☐OK	
☐	Shank type	☐JIS ☐Nachi ☐other ( )	
		☐round ☐cotter ☐pin ☐other ( )	
		Flat faces	☐with positioning ☐without positioning
			☐without
		☐before No.1 teeth ☐before front pilot ϕ ( ) × ( )	
		☐reference drawing no ( )	
☐	Retriever type ☐with (Check right) ☐without	☐with reference drawing	
		☐without reference drawing(write below)  	
☐	Round teeth	☐none ☐front ☐rear ☐combination	
☐	Entire length	☐without direction (estimated length) ☐with direction (directed length)	

☐	Broach machine	Type：	Capacity： KN	Stroke： mm

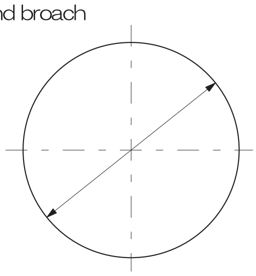
Drawing no	

Date ' . .

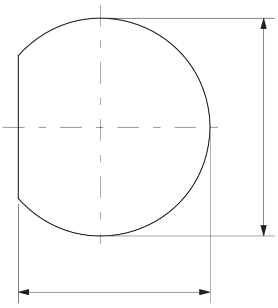
□round □half round □two chamferings Broach Specification	Order NO	Quantity	Standard design Plan	Sales Dep.
	Customer		Completion Day / Name	Name
□Standard Design □Improvement Design □Comparison Article	Remarks			
Delivery time	□Ordinary □Certain □ Advanced (Date of Delivery)			

A	Work spec	
□	Work drawings	□respected spring back □Not respected spring back
□	Applicable standard	□with (standard) □without
□	Parts name ,Parts number	Add to Drawings □need □unneed
□	Material / Hardness / Length of cut	
□	Finished size	

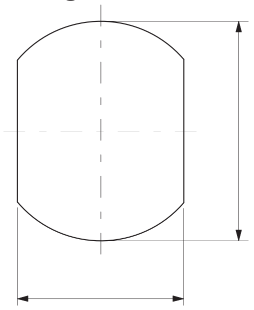
□Round broach



□Half round broach

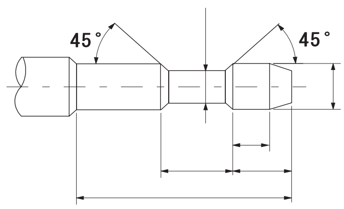


□two chamferings broach



□	Prepared hole size	ϕ

B	Broach spec	
□	Broach Drawings □with □without	□same as provided drawing □Improvement Design □with compensation □majour diameter □other
□	Tool No	
□	Marking	
□	Material	
□	Surface treatment	□none □nitride oxidation □STH □TiN coat □GV21 □other ( )
□	Heart treatment after broaching □with □without	□with compensation work compensation value: Majour diameter : / width : □without compensation
□	Over size by burr	□disapproval: □only first work □first work and after re-grind □OK
□	Shank type	□JIS □Nachi □other ( ) □round □cotter □pin □other ( ) Flat faces: □with positioning □without positioning / □without □before No.1 teeth □before front pilot ϕ ( ) × ( ) □reference drawing no ( )
□	Retriever type □with (Check right) □without	□with reference drawing □without reference drawing(write below)



□	Flat teeth	With flat teeth is impossible
□	Entire length	□without direction (estimated length) □with direction (directed length)

□	Broach machine	Type :	Capacity : KN	Stroke : mm

Drawing no	

Memo

Memo

GEAR CUTTER / BROACH

MITSUBISHI MATERIALS CORPORATION

MITSUBISHI MATERIALS CORPORATION

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(Tools specifications subject to change without notice.)

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