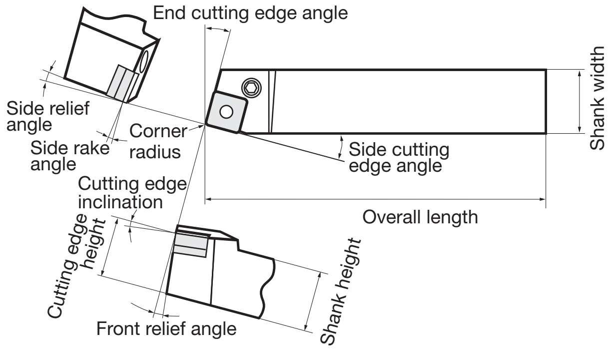
15 Technical reference

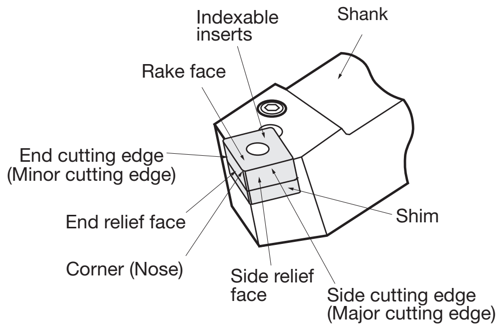
Cutting tools

Appendix

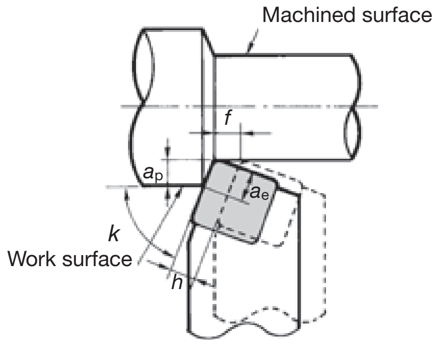
Turning Tools

Name of tools parts



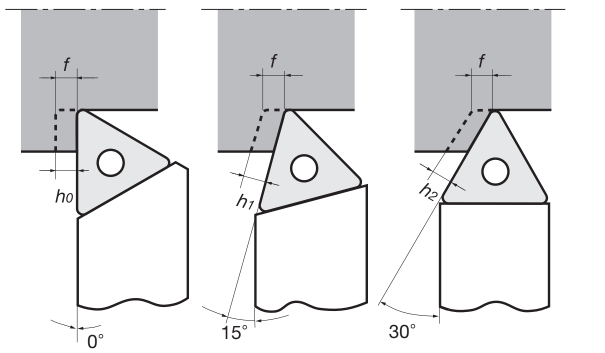


Relating angles between tool and workpiece



a_p … Depth of cut (Distance between work surface and machined surface)
a_e … Length of cutting edge engaging in cutting.
κ … Cutting edge angle (Angle to be made by cutting edge and work surface)
f … Feed per revolution
h … Thickness to be cut per revolution
Machined surface … Workpiece surface after having machined.
Work surface … Workpiece surface to be cut.

●Effect of side cutting edge angle



In the cutting of same feed, as the side cutting edge angle increases, the chip thickness decreases.

$h_0 > h_1 > h_2$

●Honing

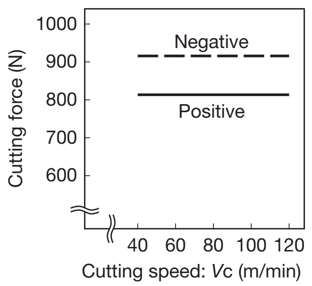
TAC indexable inserts of steel cutting grades are honed. Honing specifications are shown in the following table.

Edge condition	Shape
Sharp edge	
Round honing	
Chamfered honing	

●Effects of tool geometry on cutting phenomena

Phenomena / Increasing	Flank wear	Crater wear	Edge strength	Cutting force	Surface finish	Chattering	Cutting edge temperature	Chip shape and flow
Cutting edge inclination	–	Decrease	Lower	Radial force decrease	–	Less tendency	Lower	Effect on flow direction
Side rake angle	–	Decrease	Lower	Decrease	–	–	Lower	Effect on shape
Relief angle	Decrease	–	Lower	Decrease	–	Likely to occur	Lower	–
End cutting edge angle	Decrease	–	Lower	Radial force decrease	Roughen	Less tendency	Lower	–
Side cutting edge angle	Decrease	Decrease	Increase	Radial force decrease	–	Likely to occur	Increase	Decrease thickness
Nose radius	Decrease to some level		Increase	Increase	Improve	Likely to occur	Increase	Effect on flow direction
Honing width	Increase	–	Increase	Increase	–	Likely to occur	Increase	–

Relations between cutting force and cutting conditions or cutting phenomena

<table>
<tr><th>Conditions</th><th>Grey cast iron (HB130)</th><th>Stainless steel (HB145)</th><th>Carbon steel (HB230)</th></tr>
<tr><td>Cutting speed and cutting force
f = 0.2 mm/rev
a_p = 2 mm
Side cutting edge angle 0°
Corner radius r_ε 0.4</td>
<td>
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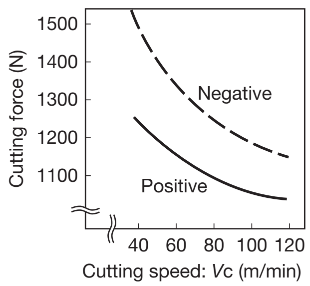
<td>
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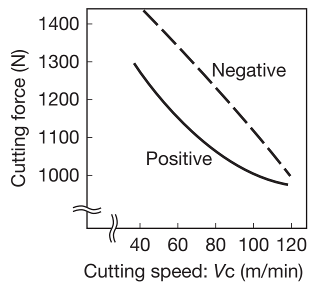
<td>
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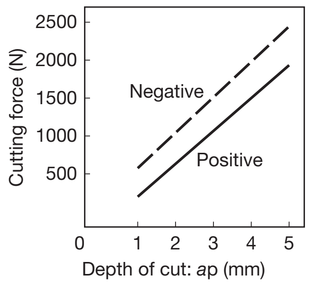
<tr><td>Depth of cut and cutting force
V_c = 100 m/min
f = 0.2 mm/rev
Side cutting edge angle 0°
Corner radius r_ε 0.4</td>
<td>
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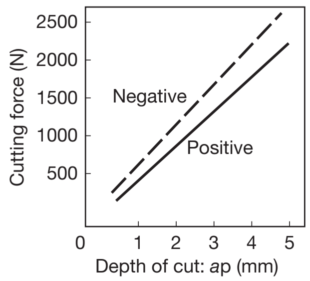
<td>
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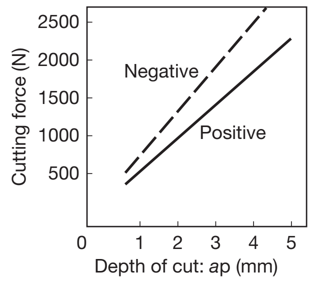
<td>
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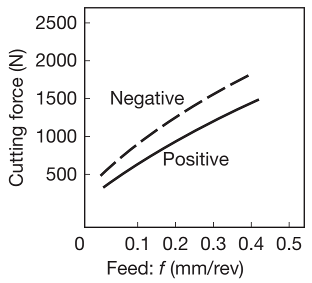
a_p = 2 mm
Side cutting edge angle 0°
Corner radius r_ε 0.4</td>
<td>
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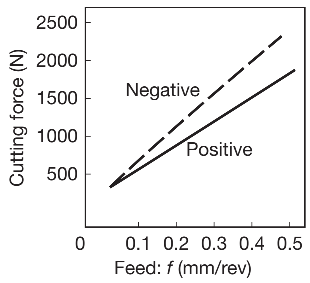
<td>
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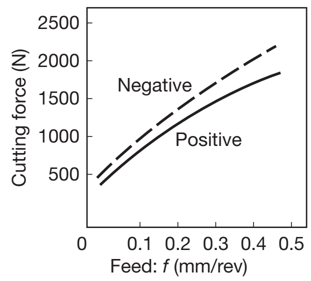
<td>
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<tr><td>Corner radius and cutting force
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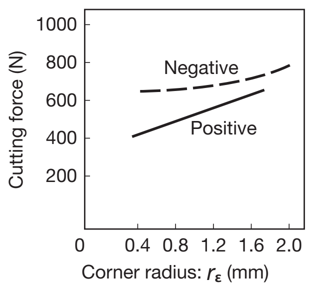
f = 0.2 mm/rev
a_p = 1.2 mm
Side cutting edge angle 0°</td>
<td>
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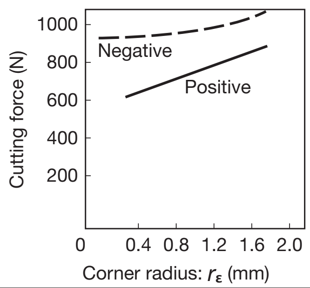
<td>
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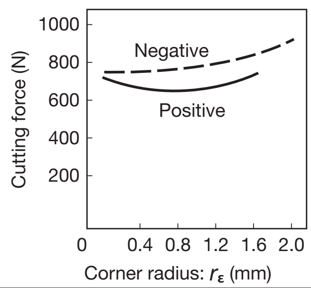
<td>
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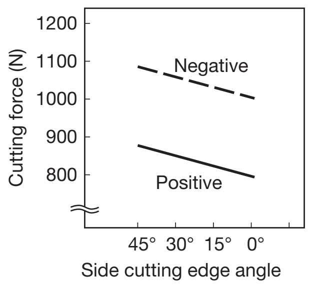
f = 0.2 mm/rev
a_p = 2 mm
Corner radius r_ε 0.4</td>
<td>
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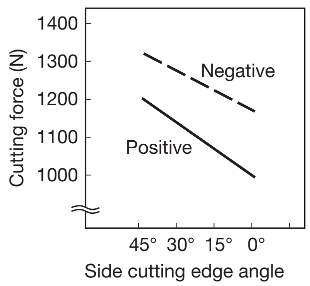
<td>
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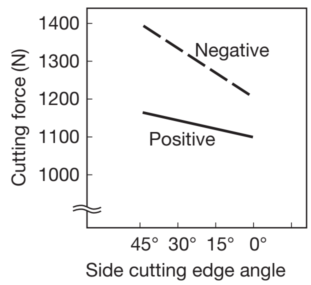
<td>
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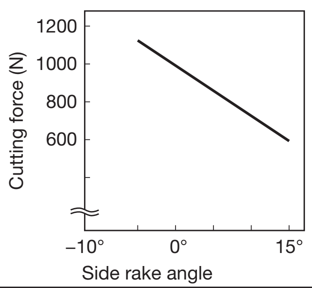
<tr><td>Side rake angle and cutting force
V_c = 100 m/min
f = 0.2 mm/rev
a_p = 2 mm
Side cutting edge angle 0°
Corner radius r_ε 0.2</td>
<td>
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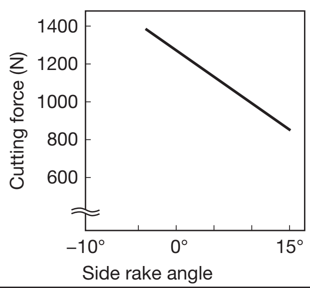
<td>
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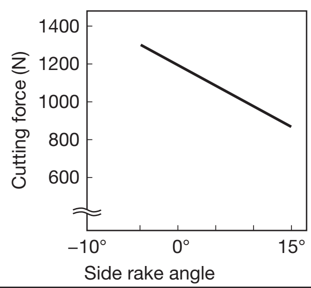
<td>
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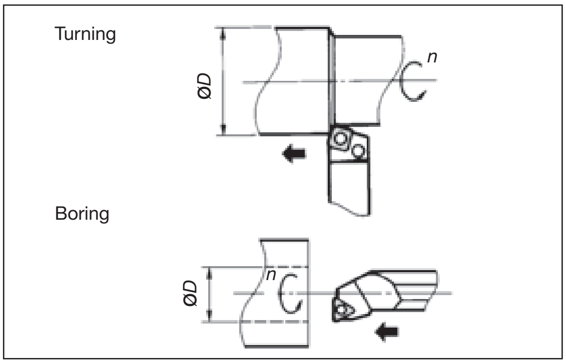
</table>

* 9.8N = 1kgf

Turning Tools

Calculation formulas for turning

●Cutting speed



When calculating cutting speed from number of revolutions:

$$Vc = \frac{\pi \times øD \times n}{1000}$$

V_c : Cutting speed (m/min)
n : Number of revolution (min^{-1})
$øD$: Diameter of workpiece (mm)
$\pi \approx 3.14$

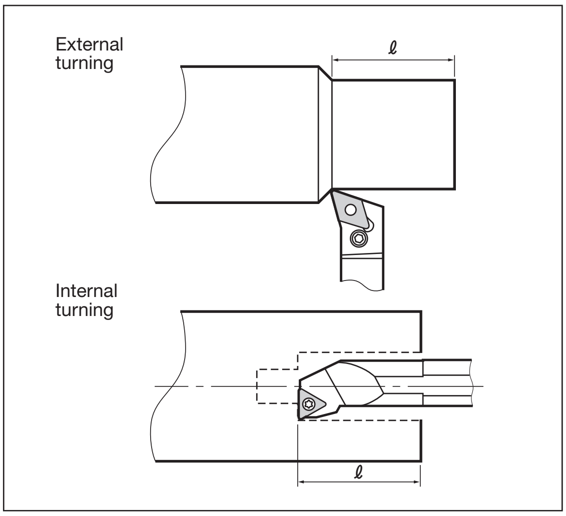
When calculating required number of revolutions from cutting speed:

$$n = \frac{Vc \times 1000}{\pi \times øD}$$

Example : Calculating the cutting speed when turning a ø150 mm-diameter workpiece at 250 min^{-1}

$$V_c = \frac{3.14 \times 150 \times 250}{1000} = 117 \text{ m/min}$$

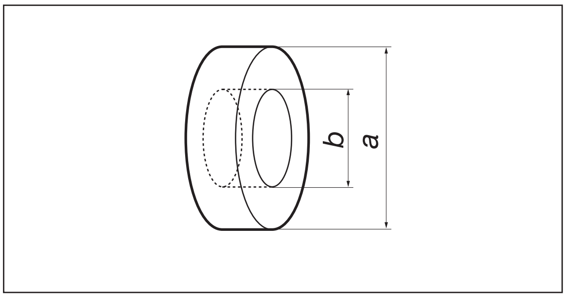
●Cutting time on external and internal turning



$$\underset{\text{(min)}}{T} = \frac{\ell}{f \times n}$$

T : Cutting time (min)
ℓ : Cutting length (mm)
f : Feed (mm/rev)
n : Number of revolution (min^{-1})

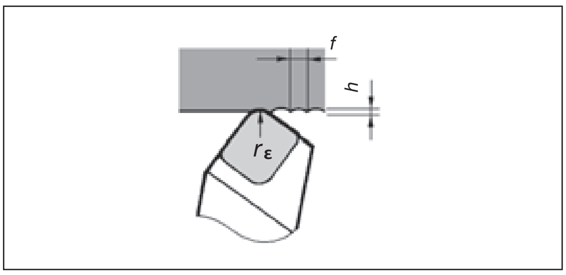
●Cutting time on face turning



$$\underset{\text{(min)}}{T} = \frac{\pi \times (a^2 - b^2)}{4000 \times v_c \times f}$$

V_c : Cutting speed (m/min)
f : Feed (mm/rev)
T : Cutting Time (min)

●Theoretical surface finish



$$\underset{(\mu m)}{h} = \frac{f^2}{8 r_\varepsilon} \times 1000$$

h : Surface finish (μm)
f : Feed (mm/rev)
r_ε : Nose radius (mm)

●Calculation of power consumption (kW)

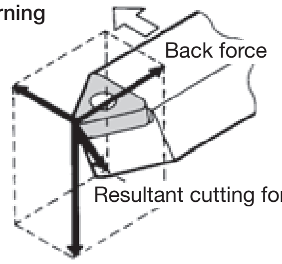
$$\underset{\text{(kW)}}{P_c} = \frac{F \times v_c}{60000}$$

P_c : Power requirement (kW)
F : Cutting force (N)
V_c : Cutting speed (m/min)

●Cutting forces

(1) Finding from the diagram based on experimental data.
(2) In case determining by simplified equation:

Cutting force in turning



$$F = k_c \times a_p \times f \quad \text{(N)}$$

F : Cutting force (N)
k_c : Specific cutting force (N/mm^2) [Refer to the Table below]
a_p : Depth of cut (mm)
f : Feed (mm/rev)

Example :
Calculating the cutting force when cutting a high carbon steel (JIS S55C) at f = 0.2 mm/rev and ap = 3 mm.
$F = 3430 \times 3 \times 0.2 = 2058\text{N}$

●Calculating power requirement

$$P_c \text{ (kw)} = \frac{k_c \times a_p \times v_c \times f}{60 \times 1000}$$

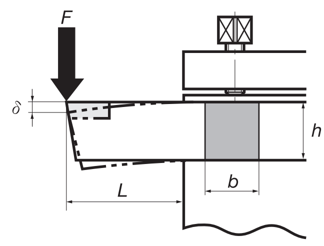
P_c : Net power requirement (kW)
k_c : Specific cutting force (N/mm^2) [Refer to the Table below]
v_c : Cutting speed (m/min)
a_p : Depth of cutting (mm)
f : Feed (mm/rev)

Value of specific cutting force (k_c)

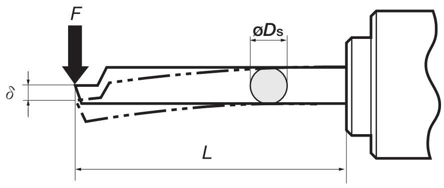
Work material	Tensile strength (Mpa)	Hardness (HB)	Value of specific cutting force on feed k_c (N/mm²)				
			0.04 (mm/rev)	0.1 (mm/rev)	0.2 (mm/rev)	0.4 (mm/rev)	1.0 (mm/rev)
SS400, S15C	390	100	3430	2840	2450	2080	1700
S35C, S40C	590	170	4220	3490	2940	2500	2080
S50C, SCr430	785	230	4900	4020	3430	2940	2400
SCM440, SNCM439	980	300	5390	4410	3780	3240	2650
SDK	1765 (56HRC)	56HRC	8390	6870	5880	5000	4120
FC200	(160HB)	160	2550	1960	1630	1340	1030
FCD600	(200HB)	200	3330	2550	2110	1750	1340
Aluminium alloy	(89HB)	89	1350	1130	950	810	670
Aluminium			1050	870	740	640	520
Magnesium alloy			390	390	390	390	390
Brass			1080	1080	1080	1080	1080

●Bending stress and tool deflection

Square shank



Round shank



Bending stress

(1) Square shank

$$S \text{ (MPa)} = \frac{6 \times F \times L}{b \times h^2}$$

(2) Round shank

$$S \text{ (MPa)} = \frac{32 \times F \times L}{\pi \times øD_s^3}$$

S : Bending stress in shank (MPa)
F : Cutting force (N)
L : Overhang length of tool (mm)
b : Shank width (mm)
h : Shank height (mm)
$øD_s$: Shank diameter (mm)
E : Modulus of elasticity of shank material (MPa)

Tool defection (mm)

(1) Square shank

$$\delta \text{ (mm)} = \frac{4 \times F \times L^3}{E \times b \times h^3}$$

(2) Round shank

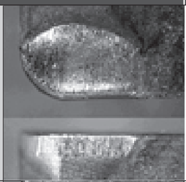
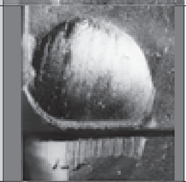
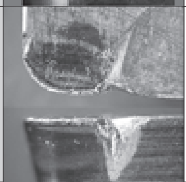
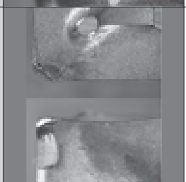
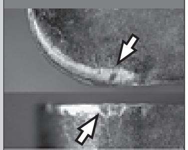
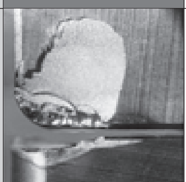
$$\delta \text{ (mm)} = \frac{64 \times F \times L^3}{3 \times \pi \times E \times øD_s^4}$$

(Ref.) Values of E

Material	MPa (N/mm^2)	{kgf/mm^2}
Steel	210,000	21,000
Cemented Carbide	560,000~620,000	56,000~62,000

Turning Tools

Troubleshooting in turning

Typical tool failure		Countermeasures		
		Tool grade	Cutting conditions	Tool geometry
Flank wear		• Change to more wear resistant grades. **P, M, K30 → 20 → 10**	• Reduce cutting speed. • Change to appropriate feed. • Change to wet cutting.	• Decrease honing width. • Increase relief angle. • Increase end cutting edge angle. • Increase corner radius. • Select free-cutting chipbreaker. • Increase rake angle.
Crater wear		• Change to more wear resistant grades. **P, M, K30 → 20 → 10**	• Reduce cutting speed. • Reduce feed. • Reduce depth of cut. • Change to wet cutting.	• Increase rake angle. • Select an appropriate chipbreaker. • Increase side cutting edge angle. • Increase corner radius.
Notch wear		• Change to more wear resistant grades. **P, M, K30 → 20 → 10**	• Reduce cutting speed. • Reduce feed.	• Increase rake angle. • Increase side cutting edge angle.
Fracture		• Change to tougher grades. • Change to thermal-shock resistant grades. **P, M, K10 → 20 → 30**	• Reduce feed. • Reduce depth of cut • Improve holding rigidity of work and tool. • Reduce overhang length of toolholder. • Improve looseness in machine.	• Reduce rake angle • Select a chipbreaker with high edge strength. • Increase honing width. • Increase side cutting edge angle. • Select larger shank size • Increase corner radius.
Chipping		• Change to tougher grades. **P, M, K10 → 20 → 30**	• Reduce cutting speed • Reduce feed. • Reduce depth of cut. • Improve holding rigidity of work and tool. • Reduce overhang length of toolholder. • Improve looseness in machine.	• Reduce rake angle • Select a chipbreaker with high edge strength. • Increase honing width. • Increase side cutting edge angle. • Select larger shank size
Flaking		• Change to tougher grades. **P, M, K10 → 20 → 30**	• Reduce cutting speed • Reduce feed.	• Reduce rake angle • Increase corner radius • Increase honing width.
Plastic deformation		• Change to more wear resistant grade. **P, M, K30 → 20 → 10**	• Reduce cutting speed. • Change to appropriate feed. • Reduce depth of cut. • Supply cutting fluid in adequate volume.	• Increase relief angle. • Increase rake angle. • Reduce corner radius. • Reduce side cutting edge angle. • Select a free-cutting chipbreaker.
Chip welding		• Use a grade which has a low tendency to adhere to work material. **Cemented carbide → Coated carbide or cermet**	• Increase cutting speed. • Increase feed • Change to water-insoluble cutting fluid. • Change to wet cutting.	• Increase rake angle • Select a free-cutting chipbreaker. • Decrease honing width.
Built-up edge				
Thermal cracking		• Change to tougher grades. • Change to thermal-shock resistant grades. **P, M, K10→20→30**	• Reduce cutting speed. • Reduce feed. • Change to dry cutting. • Supply cutting fluid in adequate volume. • Reduce depth of cut. • Change to water-insoluble cutting fluid.	• Increase rake angle • Select a free-cutting chipbreaker. • Decrease honing width.

Technical Reference

15

Problem	Cause	Countermeasures: Tool	Countermeasures: Cutting conditions and others
Deteriorated surface roughness	• Increased tool wear	• Select a more wear resistant grade. • Use an insert with a larger rake angle. • Use an insert with a larger nose radius. • Use a more lightly honed insert. • Use an insert of closer tolerance. (from M class to G class)	• Select a proper feed. • Decrease the cutting speed. • Select a freer-cutting chipbreaker type. • Use a cutting fluid.
	• Edge chipping	• Use a tougher grade. • Select a chipbreaker with strong cutting edges. • Use a largely honed insert. • Increase the side cutting edge angle. • Use a larger shank size.	• Decrease the depth of cut. • Decrease the feed. • Use a more rigid machine. • Improve the holding rigidity of the tool and workpiece. • Shorten the overhang of the toolholder. • Improve the machine looseness.
	• Chip welding • Built-up-edge	• Select a grade with less affinity with the work material. • Use an insert with a larger rake angle. • Select a freer-cutting chipbreaker type. • Use a more lightly honed insert. • Use an insert of closer tolerance. (from M class to G class)	• Increase the cutting speed. • Increase the feed. • Use a water-insoluble cutting fluid. • Use a cutting fluid.
	• Vibration and chatter	• Use a tougher grade. • Use an insert with a larger rake angle. • Select a freer-cutting chipbreaker type. • Use an insert with a smaller nose radius. • Decrease the side cutting edge angle. • Use a more lightly honed insert. • Use a larger shank size.	• Use a proper cutting speed. • Decrease the feed. • Decrease the depth of cut. • Improve the holding rigidity of the tool and workpiece. • Shorten the overhang of the toolholder. • Improve the machine looseness.
Deteriorated dimensional accuracy	• Improper insert accuracy	• Use an insert of closer tolerance. (from M class to G class)	
	• Incomplete engagement of tool and workpiece	• Use an insert with a larger rake angle. • Select a freer-cutting chipbreaker type. • Use an insert with a smaller nose radius. • Use a more lightly honed insert.	• Improve the holding rigidity of the tool and workpiece. • Shorten the overhang of the toolholder. • Improve the machine looseness.
Burr occurrence	• Unsuitable cutting speed		• Decrease the cutting speed. • Increase the feed. • Use a cutting fluid.
	• Worn tool or improper cutting edge geometry	• Use a harder grade. • Use an insert with a larger rake angle. • Select a freer-cutting chipbreaker type. • Increase the relief angle. • Use an insert with a smaller nose radius. • Decrease the side cutting edge angle. • Use a more lightly honed insert.	
Edge breakout	• Improper cutting speed		• Decrease the feed. • Decrease the depth of cut.
	• Worn tool or improper cutting edge geometry	• Use a harder grade. • Use an insert with a larger rake angle. • Select a freer-cutting chipbreaker type. • Increase the side cutting edge angle. • Use an insert with a larger nose radius. • Use a more lightly honed insert. • Use a larger shank size.	• Improve the holding rigidity of the tool and workpiece. • Shorten the overhang of the toolholder. • Improve the machine looseness.
Fuzzy surface finish	• Improper cutting conditions		• Increase the cutting speed. • Select a proper feed. • Use a water-insoluble cutting fluid. • Use a cutting fluid.
	• Worn tool or improper cutting edge geometry	• Use a harder grade. • Select a grade with less affinity with the work material. • Use an insert with a larger rake angle. • Select a freer-cutting chipbreaker type. • Use a more lightly honed insert.	

Chipbreaker

Chip controllability

Necessity of chip control

①Why is chip control needed?
②Effect of improper chip control

Necessity of chip control (Problems and effects)

Problems	Effects
1. Scattering of chips and coolant. 2. Wrapping around the workpiece and the tool. 3. Accumulation on the tool, jig, and machining facilities.	1. Disturbs unmanned and automated machining. 2. Disturbs high-speed and high-efficiency machining. 3. Degrades finished surface. 4. Threatens operator's safety. 5. Reduced operation rate.

Additional problems when chips are not properly controlled

①Why is chip control needed?

What is chip?

For making a product from a workpiece, removed objects produced by a tool which is set to cut to a specified depth with the relative motion of the tool and the workpiece.

Problems when chips are not properly controlled

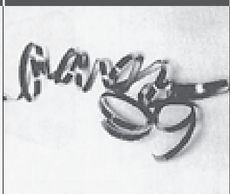
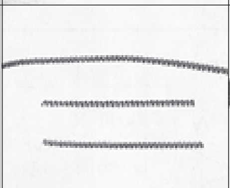
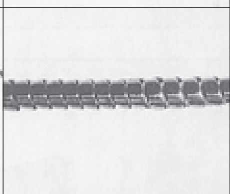
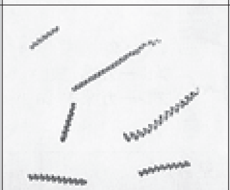
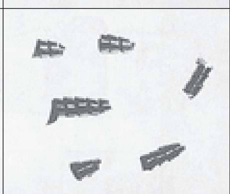
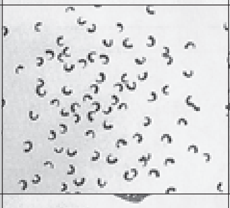
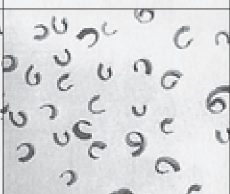
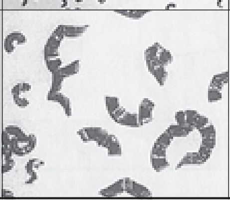
②Effect of improper chip control

Effects on quality
- Defective work.
- Defective surface finish
- Chip entangling

Effects on operation
- Increased number of man-hours for handling.
- Increased tool costs.
- Troublesome chip handling.
- Machine stoppage and reduced operation rate.

Effect on safety and health.
- Stain and damage on machine caused from improper carrying-out of chips.
- Dangerous effects on the human body. (Injury and burns on hand, etc.)

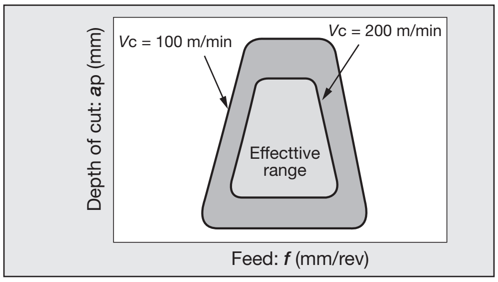
Effective measures → **"Chipbreaker"**

Classi-fication	Chip shape		Description of chip shape	Acceptability	Effect
	Depth of cut: small	Depth of cut: large			
Shape A			Chips irregularly entangled	Not acceptable	• Wrapping around the tool or workpiece or accumulation around the cutting point, hindering cutting • Possible damage to the machined surface
Shape B			Long continuous spiral chips $\ell > 50$ mm		• Bulky during transport in the automatic line • May be preferred when one operator handles one machine
Shape C			Short spiral chips $\ell < 50$ mm	Acceptable	• Smooth chip flow • Difficult to scatter • Favorable shape
Shape D			"C" or "9" shaped chips (Around one coiling)		• Favorable shape if not scattering • Not bulky and easy to transport
Shape E			Excessively broken chips. Thin pieces or connected in a form of wave as shown in the figure left	Not acceptable	• Readily scattering. If scattering is the only trouble, it may be acceptable because the chip cover, etc. may be used. • Tend to cause chatter, causing harm on the finished surface roughness or tool life.

Factors affecting chip control

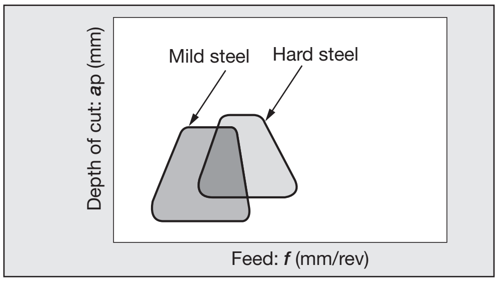
(1) Cutting conditions
1 Feed
2 Depth of cut
3 Cutting speed

- Of these, feed has the greatest effect followed by depth of cut and cutting speed in order listed.
- Feed is proportionate to the thickness of chips.
- Depth of cut is proportionate to the width of chips.
- There are optimum values (effective range) in feed and depth of cut.
- Cutting speed is in inverse proportion to chip thickness. Effective range becomes narrow at high speed.



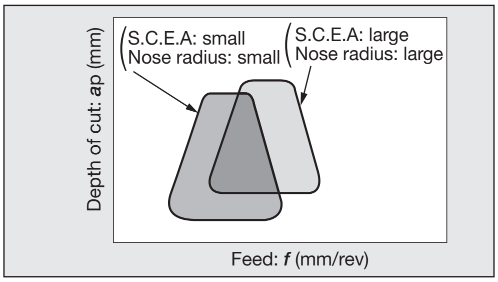
(2) Work material
1 Alloy element
2 Hardness
3 Heat treatment condition

- These are related to thickness of chips and ease of curling.
- Mild steel chips are thicker than those of hard steel.
- Hard steel chips are liable to curl more than those of mild steel.
- Chips that do not curl are thin. As an exception, in case of mild steel even if thick, may not curl.



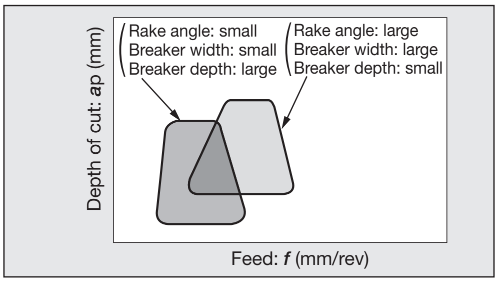
(3) Tool geometry
1 Side cutting edge angle
2 Nose radius

- Side cutting edge angle is relative to chip thickness and width
- Side cutting edge angle is preferably small.
- Nose radius is relative to thickness and width and the direction of flowing out.
- In finishing, small nose radius, whilst for rough cutting, large nose radius is better.



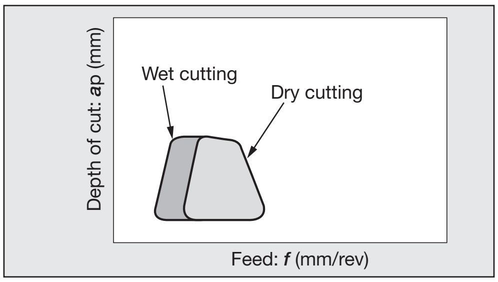
(4) Shape of chipbreaker
1 Rake angle
2 Chipbreaker width
3 Chipbreaker depth

- Rake angle is in inverse proportion to chip thickness.
- Depending on the work material, there is an optimum value.
- Chipbreaker width is selected proportionately to feed.
- Narrow at low feed and wide at high feed.
- Chipbreaker depth is to be selected so as to be inversely proportionate to feed.
- Deep at low feed and shallow at high feed.



(5) Cutting fluid

- Effective range is wider with wet cutting.
- Especially at low feed range is liable to curl.

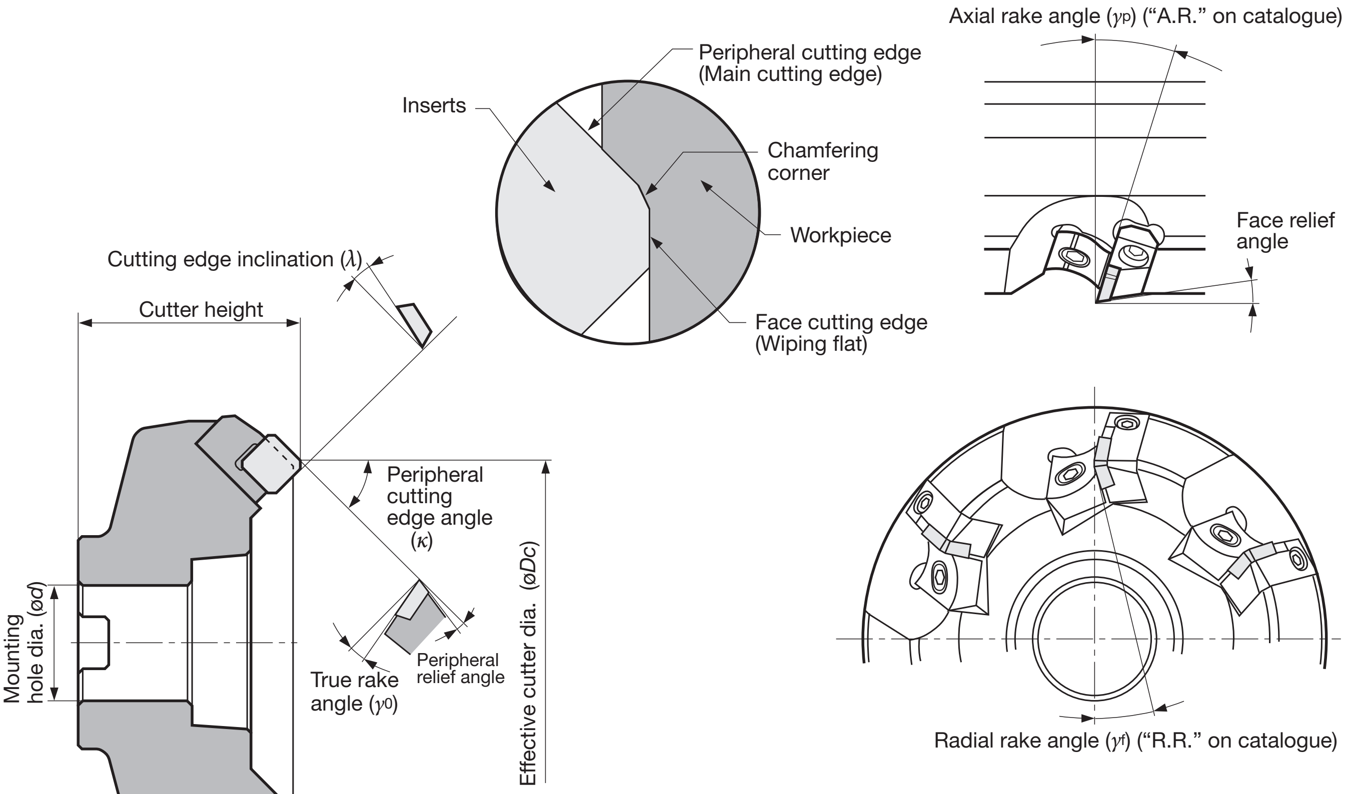


(6) Machine
1 Strength
2 Power limit

- The machine has enough power and mechanical strength.
- Select the machine consistent with the size of work material to be used.

Milling Tools

Nomenclature for face milling cutter



- Relations of various rake angles are according to the following equations.

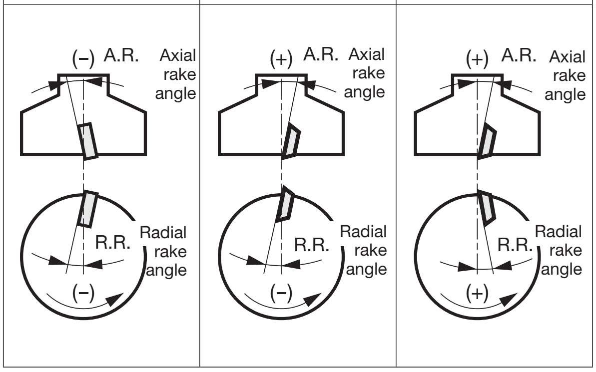
$\tan\gamma_0 = \tan\gamma_f \cos\kappa + \tan\gamma_p \sin\kappa$

$\tan\lambda = \tan\gamma_p \cos\kappa - \tan\gamma_f \sin\kappa$

Cutter geometry and applications

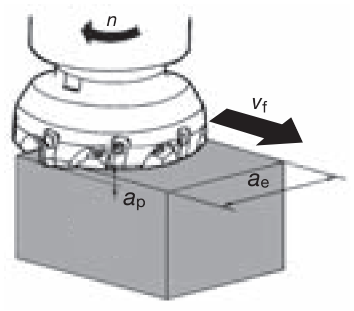
Conditions		Rake angle combination and applicability		
		Negative-Negative	Negative-Positive	Positive-Positive
Shapes of cutting edge	γp (A.R.)	-	+	+
	γf (R.R.)	-	-	+
	γo	-	+	+
Work material	Carbon steels, alloy steels (< 300HB)	△	◎	◎
	Stainless steels (< 300HB)	×	◎	○
	Die steels (< 300HB)	△	◎	○
	Cast irons Ductile cast irons	◎	○	○
	Aluminium alloys	×	○	◎
	Copper and its alloys	×	○	◎
	Titanium and its alloys	×	○	○
	Hardened steels (40 ~ 55HRC)	○	○	×
Features		· Higher cutting edge strength · Many usable corners of inserts	· Excellent chip removal · Higher cutting edge strength and Freer cutting action	· Most excellent cutting action
Typical examples of TAC mills		TGN4200 DoPent	TAW13 TME4400 TMD4400	THF4000 THE4000

Rake angle combination		
Negative type (Negative-Negative)	Negative-Positive type	Positive type (Positive-Positive)



Calculation formulas for milling

●Cutting speed



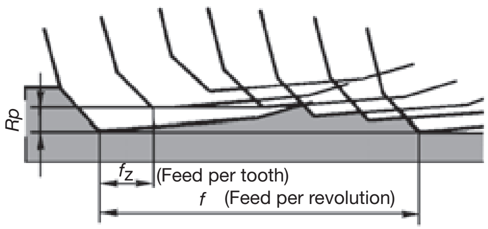
●Cutting speed (Calculated from number of revolutions)

$$v_c = \frac{\pi \times øD_c \times n}{1000} \quad \text{(m/min)}$$

v_c : Cutting speed (m/min)
$øD_c$: Effective diameter (mm)
n : Number of revolutions (min^{-1})
$\pi \approx 3.14$

●Number of revolution (Calculated from cutting speed)

$$n = \frac{1000 \times v_c}{\pi \times øD_c} \quad (min^{-1})$$



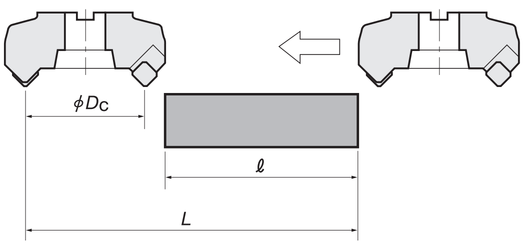
●Feed speed and feed per tooth

$$v_f = f_z \times z \times n \quad \text{(mm/min)}$$

v_f : Feed speed (mm/min)
f_z : Feed per tooth (mm/t)
z : No. of teeth of the cutter
n : Number of revolutions (min^{-1})

Feed speed is relative speed of cutter and work material and in the normal milling machine, it is the table speed.
In milling, the feed per tooth is very important. The recommended cutting condition is expressed by v_c and f_z and using the above equation calculate n and v_f and input in the machine.

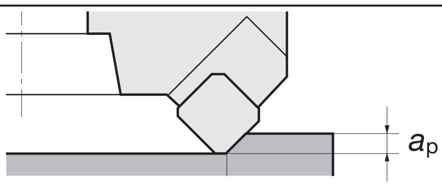
●Cutting time on face milling



$$T = \frac{L}{v_f} \quad \text{(min)}$$

T : Cutting time (min)
L : Total table feed length.
(ℓ: Workpieces length (mm) + $øD_c$: Effective cutter diameter (mm))
v_f : Feed speed (mm/min)

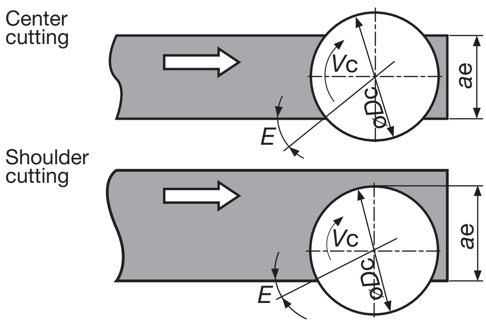
Depth of cut and width of cut



●Depth of cut

Determine by required allowance for machining and capacity of the machine. In case of TAC mill, there are cutting limits according to shape and size of the insert. Please see spec on the catalogue.

a_p : Depth of cut (mm)



●Width of cut and engagement angle

There is an appropriate engage angle depending on the cutter diameter, cutting position, work material, etc., and ordinarily the values in the table below are used as a guide.

$øD_c$: Cutter diameter (mm)
E: Engage angle
a_e: Width of cut (mm)

Center cutting

Work material	Appropriate E	Cutter dia. and a_e
Steel	~ 42°	$a_e \approx \frac{2}{3}\, øD_c$
Cast iron	~ 53°	$a_e \approx \frac{4}{5}\, øD_c$

Shoulder cutting

Work material	Appropriate E	Cutter dia. and a_e
Steel	~ 30°	$a_e \approx \frac{3}{5}\, øD_c$
Cast iron	~ 40°	$a_e \approx \frac{3}{4}\, øD_c$

Milling Tools

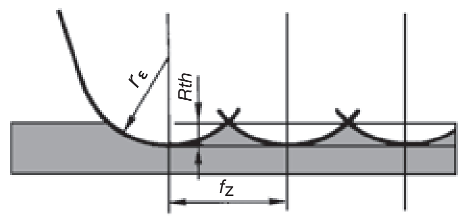
Roughness of finished surface

(1) Theoretical surface roughness

Theoretical roughness as shown below, is the same as for single point turning

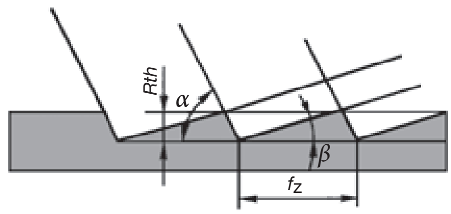
●With corner radius r_ε

$$Rth = \frac{fz^2}{8r_\varepsilon} \times 1000$$

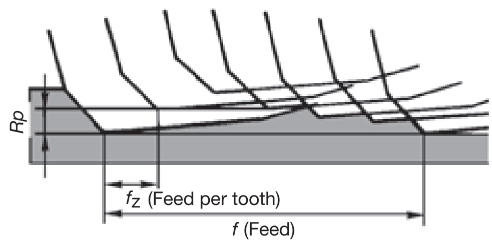


●Without corner radius r_ε

$$Rth = fz\left(\frac{\tan\alpha \cdot \tan\beta}{\tan\alpha + \tan\beta}\right) \times 1000$$



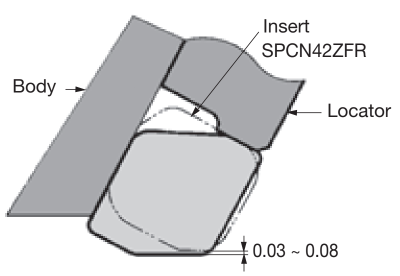
Rth: Theoretical roughness (μm)
fz: Feed per tooth (mm/t)
r_ε: Corner radius (mm)
α: Corner angle
β: Face cutting edge angle



(2) Practical surface roughness

In case of practical milling, there are many teeth and natural differences in levels of edges occur. The maximum difference is called "run out". (*Rp*)
In the actual face milling, finished surface roughness, as shown left, is worse than the single point cutting. If only one tooth is projecting, it will be similar to the single point shown above but of a large value substituting *f* (mm/rev) for *fz* (mm/t).

Improving surface roughness



Face run out must be minimized and a low feed and high speed should be used. Also, in order to attain good finished surface at high efficiency, there are the following methods:

(1) In case of ordinary TAC mill
Use wiper insert as shown in the figure at left.
(2) Use of TAC super finish mill for finishing.
- Use of combination TAC mills with finishing insert such as TFD4400-A and TFP4000ⅠA (a_p < 1.0 mm).
- Use of TAC supe finish mill for finishing such as NMS cutters and SFP4000 etc.

Calculating power requirement

$$P_c = \frac{k_c \times a_p \times a_e \times v_f}{60 \times 1000 \times 1000}$$
(kW)

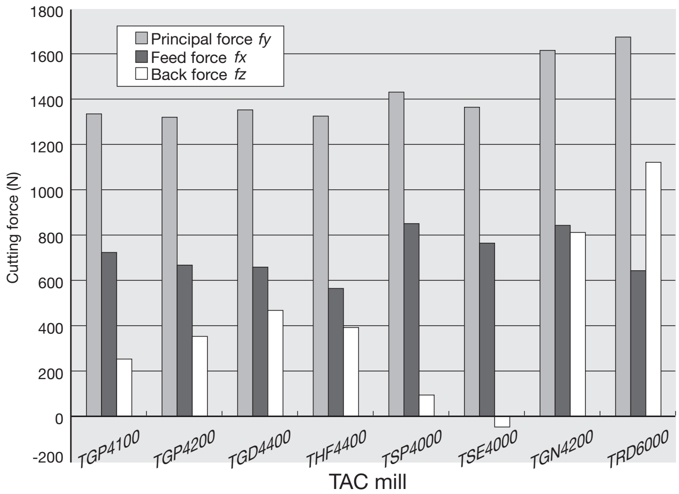
P_c : Net power requirement (kW)
k_c : Specific cutting force (N/mm²)
[Refer to the Table below]
a_p : Depth of cut (mm)
a_e : Width of cut (mm)
v_f : Feed speed (mm/min)

Because practical power requirements depend on the type of TAC mill (proportional to the true rake angle) and the motor efficiency of the machine used, the result calculated from the above formula should be considered as a rough guide.

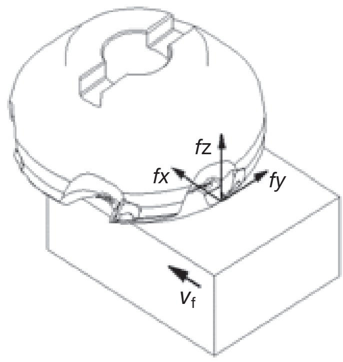
●Values of specific cutting force (**k_c**)

Work material	Tensile strength	Value of specific cutting force on feed per tooth k_c (N/mm²)				
	MPa	0.1 (mm/t)	0.15 (mm/t)	0.2 (mm/t)	0.3 (mm/t)	0.4 (mm/t)
SS400	520	2150	2000	1900	1750	1650
S55C	770	1970	1860	1800	1760	1620
SCM3	730	2450	2350	2200	1980	1710
SKT4	(HB352)	2030	2010	1810	1680	1590
SC450	520	2710	2530	2410	2240	2120
FC250	(HB200)	1660	1450	1320	1150	1030
Aℓ (Si)	200	660	580	522	460	410
Brass	500	1090	960	877	760	680

●Values of cutting force (**k_c**)



Work material : S50C (210HB), Diameter of TAC mill : ø160 mm
Cutting speed : V_c = 150 m/min, Feed per tooth: f_z = 0.20 mm/t
Depth of cut: a_p = 3 mm, Cutting by a single edge, dry



●Conversion from cutting speed to number of revolutions

(unit : min⁻¹)

Cutter diameter ØDc (mm)	Cutting speed (v_c) m/min												
	10	30	50	100	125	150	200	300	500	800	1,000	2,000	4,000
10	318	955	1,592	3,184	3,980	4,777	6,369	9,554	15,923	25,477	31,847	63,694	127,388
12	265	796	1,326	2,653	3,317	3,980	5,307	7,961	13,269	21,231	26,539	53,078	106,157
16	199	597	995	1,990	2,488	2,985	3,980	5,971	9,952	15,923	19,904	39,808	79,617
20	159	477	796	1,592	1,990	2,388	3,184	4,777	7,961	12,738	15,923	31,847	63,694
25	127	382	636	1,273	1,592	1,910	2,547	3,821	6,369	10,191	12,738	25,477	50,955
30	106	318	530	1,061	1,326	1,592	2,123	3,184	5,307	8,492	10,615	21,231	42,462
32	99	298	497	995	1,244	1,492	1,990	2,985	4,976	7,961	9,952	19,904	39,808
35	90	272	454	909	1,137	1,364	1,819	2,729	4,549	7,279	9,099	18,198	36,396
40	79	238	398	796	995	1,194	1,592	2,388	3,980	6,369	7,961	15,923	31,847
50	63	191	318	636	796	955	1,273	1,910	3,184	5,095	6,369	12,738	25,477
63	50	151	252	505	631	758	1,011	1,516	2,527	4,044	5,055	10,110	20,220
80	39	119	199	398	497	597	796	1,194	1,990	3,184	3,980	7,961	15,923
100	31	95	159	318	398	477	636	955	1,592	2,547	3,184	6,369	12,738
125	25	76	127	254	318	382	509	764	1,273	2,038	2,547	5,095	10,191
160	19	59	99	199	248	298	398	597	995	1,592	1,990	3,980	7,961
200	15	47	79	159	199	238	318	477	796	1,273	1,592	3,184	6,369
250	12	38	63	127	159	191	254	382	636	1,019	1,273	2,547	5,095
315	10	30	50	101	126	151	202	303	505	808	1,011	2,022	4,044

Note: In this table, the effects of centrifugal force on the rotating balance of the tool and the toolholder, flying risk of cutter parts, and limited value of toolholder destruction are not considered. Therefore, when using the tool at high speeds, be sure to observe the specified condition range.

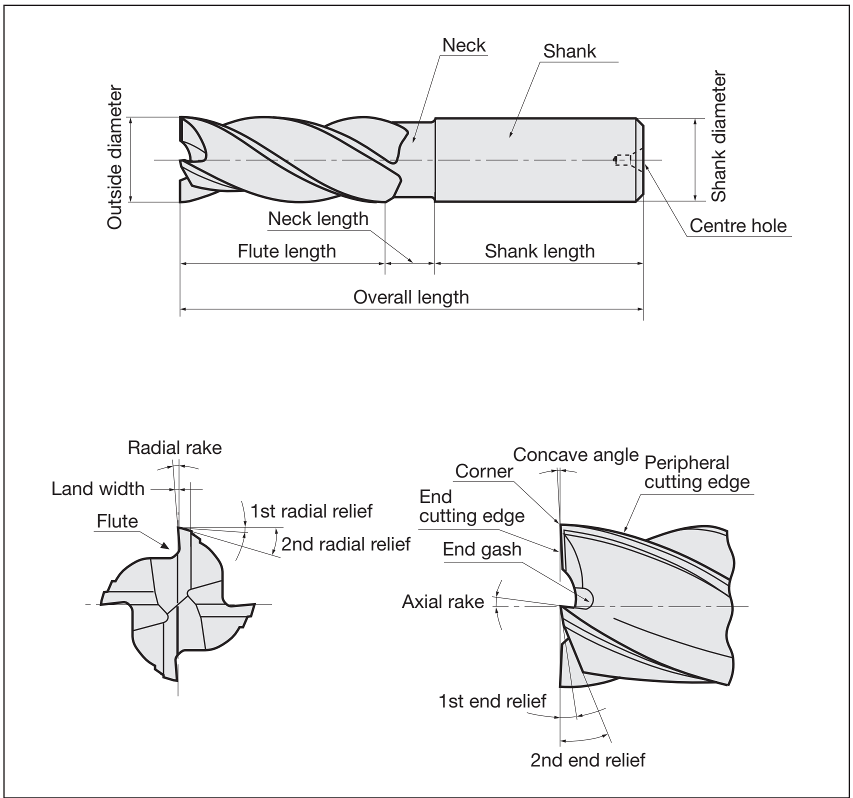
Milling Tools

Trouble shooting in face milling

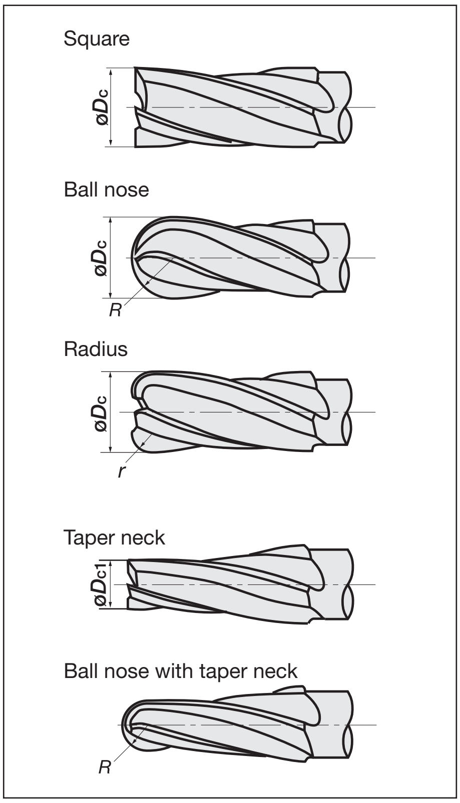
Trouble	Possible causes	Countermeasures
Rapid wear of cutting edge	• Improper insert grade selection (Insufficient wear resistance)	• P30 (Cemented carbide) → Cermet, coated grade (For steels) • K10 (Cemented carbide) → Coated grade (For cast irons)
	• Excessive cutting speed	• Select cutting speed suited for work material and insert grade
	• Inadequate feed	• Use standard cutting condition in catalog as guide
Rapid chipping of cutting edge	• Improper Insert grade selection (Insufficient toughness)	• Cermet → P30 (For steels), K10 → K20 (For cast irons)
	• Cutting hard material and unfavorable surface condition	• Decrease cutting speed • Use cutter with strong cutting edge
	• Excessive feed	• Proper selection of feed conditions, using recommended cutting conditions in catalog as guide
	• Excessive pressure applied on cutting edge	• Proper selection of engaging angle
	• Machining superalloys	• Use a negative-positive type cutter with large corner angle (Examples: T/EAW13, T/EME4400, etc.)
Fracturing	• Cracking due to thermal shock	• Select insert grade of stronger thermal shock resistance such as T3130 • Decrease cutting speed
	• Continuous use of excessively worn insert	• Shorten replacement standard time of insert
	• Cutting hard material	• Use cutter with stronger cutting edge such as T/ERD6000 • Use cutter of larger corner angle such as T/EAW13, T/EME4400, etc.
	• Obstruction to chip flow • Recutting of chips after chip welding	• Use cutter with better chip expulsion such as T/EAW13, etc. • Select insert grades difficult for chips to adhere Cemented carbides → cermets, coated grades • Use air blow
	• Excessively slow cutting, too fine feed	• Select cutting speed and feed optimized for insert grade and work material
Excessive chip welding or build-up on cutting edge	• Cutting soft material such as aluminium, copper, mild steel	• Use cutter with large rake angle such as T/EAW13
	• Cutting stainless steel	• P30 → coated grades (AH140, AH120)
	• Use of cutter with negative rake or too small rake angle	• Use cutter with large rake angle such as T/EAW13, T/EME4400, T/EPW13 or T/ESE4000
Rough finish	• Effect of built-up edge	• Increase cutting speed • Appropriate cutting depth (finish allowance) • Change insert grade For steels: P → coated → cermet For cast irons: K → coated
	• Effect of face cutting edge run out	• Proper installing of inserts • Use insert of high dimensional accuracy • Cleaning of insert pocket
	• Continuous use of excessively worn insert	• Shorten replacement standard time of insert
	• Remarkable feed marks	• Feed per revolution to be set within flatland width • Use wiper insert type cutter such as T/EAW13 • Use cutter exclusively for finishing such as type NMS and S/EFP4000
Chattering	• Unstable clamping of workpiece	• Check clamping method of workpiece
	• Cutting of welded construction of thin steel plate	• Adopt cutter of large rake angle and small corner angle such as T/EPW13 or T/ESE4000
	• Excessive cutting condition	• Re-examine allowable chip removal rate according to motor HP
	• Face milling of narrow width workpiece	• Use cutter of small cutter diameter and with many teeth
	• Too many simultaneous cutting teeth engagement	• Reduce No. of teeth or adopt irregular pitch cutter

Solid Carbide Endmills

Part details

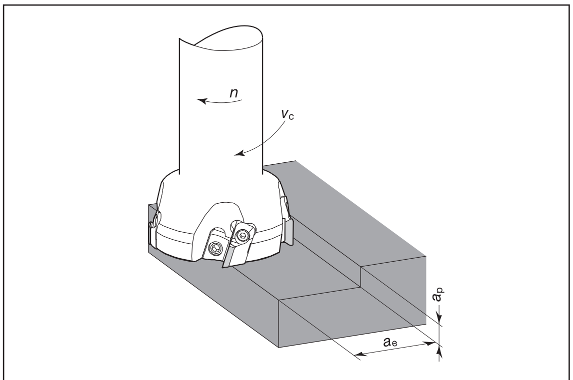


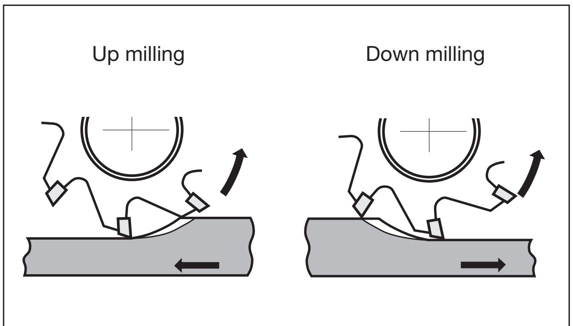
Types



Cutting condition of Endmills

● **Cutting speed**





● **Cutting speed** (Calculated from number of revolutions)

$$v_c = \frac{\pi \times øD_c \times n}{1000} \quad \text{(m/min)}$$

v_c : Cutting speed (m/min)
$øD_c$: Effective diameter (mm)
n : Number of revolutions (min^{-1})
$\pi \approx 3.14$

● **Number of revolution** (Calculated from cutting speed)

$$n = \frac{1000 \times v_c}{\pi \times øD_c} \quad (min^{-1})$$

● **Feed speed and feed per tooth**

$$v_f = f_z \times z \times n \quad \text{(mm/min)}$$

v_f : Feed speed (mm/min)
f_z : Feed per tooth (mm/t)
z : No. of teeth of the endmills
n : Number of revolutions (min^{-1})

● **Cutting**

The necessary capacity of the machine is limited by the length of cut edge of the endmill.

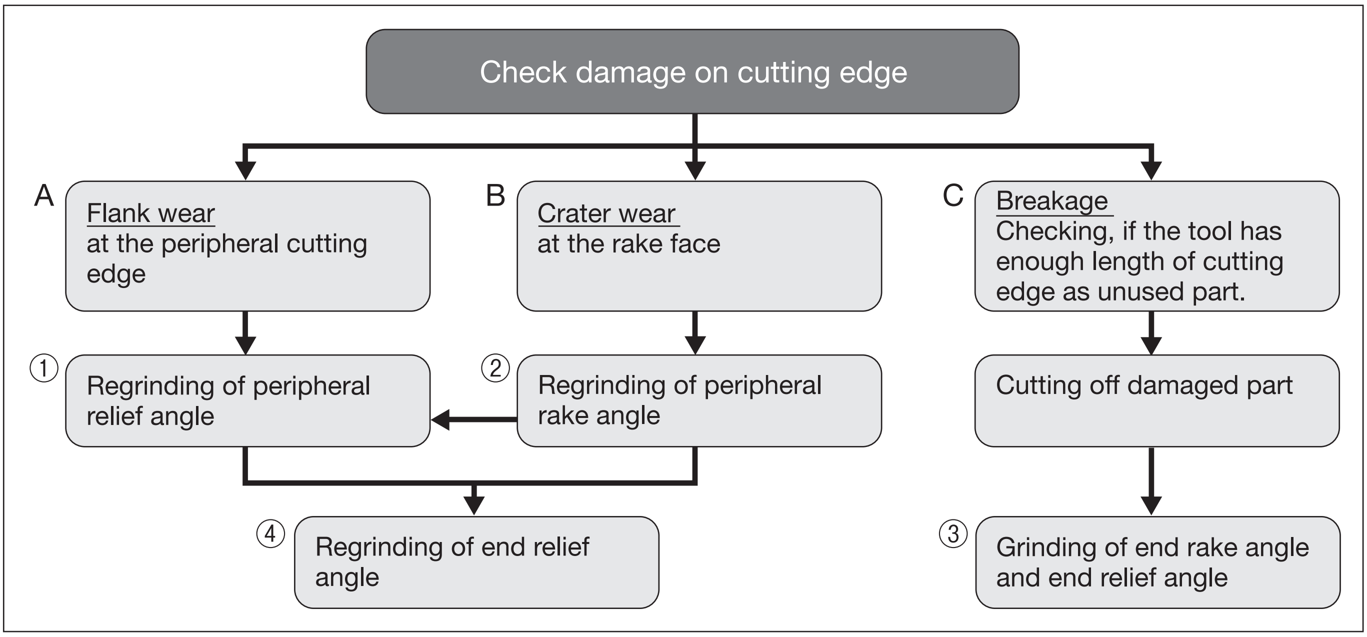
● **Up milling and down milling**

Down milling generally produces better tool life and surface roughness.

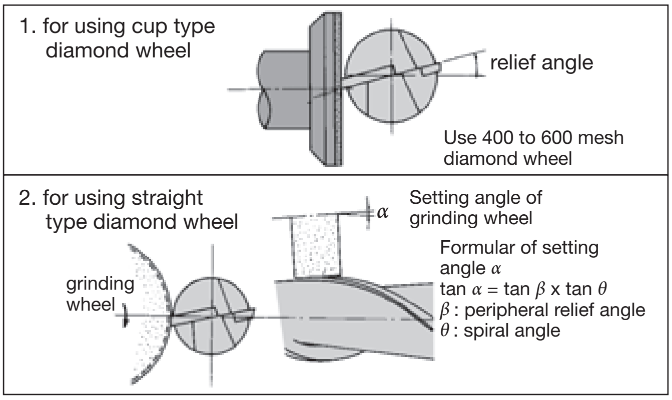
In case of cast iron sand inclusion or welding surface, up milling is recommended.

Solid Carbide Endmills

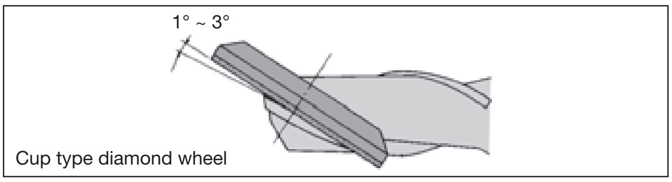
Regrinding procedures of solid carbide endmill



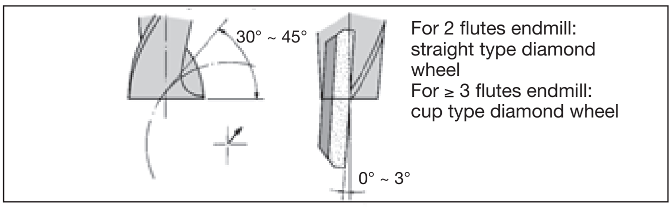
1 Regrinding of end relief angle



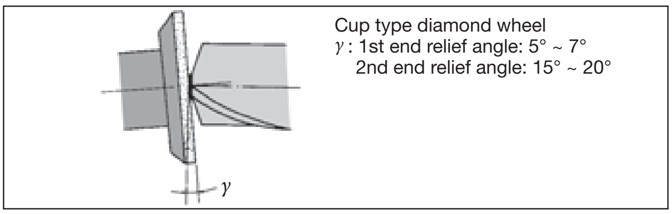
2 Regrinding of peripheral rake angle



3 Regrinding of end rake angle (End gash)



4 Regrinding of end relief angle



Notice of regrinding

(1) If, after checking the damage of the cutting edge, the damage is as case "A" or "B" of the flow chart, the tool must be reground.
Too much damage of the cutting edge requires too much stock removal and thus reduces tool life.

(2) Please use diamond grinding wheel.

(3) Peripheral relief angle must be ground between 18° and 10°.
Relief angle of small diameter cutters for aluminium machining must be a large degree.

(4) First check if "C" in flow chart can be adapted for the case of coated endmill or not.
If procedure "C" can be adapted for regrinding, tool life after the grinding would be more improved than new one. The reason is remaining coated layer of cutting edge and shorter tool length will keep much higher rigidity of the tool than before regrinding.

(5) Please check run out of peripheral cutting edge, face cutting edge, with Vee block after regrinding.
The value of the run out must be controlled within 0.01 mm.

Notice for regrinding of ball nose endmill

- Regrinding of relief angle only is available. The dimension of nose radius will be smaller after grinding.
- Honing of cutting edge is necessary after regrinding.

Trouble shooting in Endmilling

Trouble	Possible causes	Countermeasures
Breakage (In case of solid carbide endmill and brazed endmill with small diameter)	● At the start of machining ● At the end of machining	● Reduce feed. ● Reduce tool overhang length. ● Exchange to short cutting edge tool.
	When usual machining	● Reduce feed. ● Managing tool life → Exchange in shorter time. ● Replace chuck or collet to new one. ● Reduce tool overhang length. ● Make optimum honing on the edge. ● Reduce flutes. E.g. 4 flutes → 3flutes, or 2flutes. ● Use enough coolant. Change direction of supplying coolant.
	When change the direction of feed	● Use the circular interpolation in NC machine. Stop feed shortly before changing. ● Lower feed around changing part. ● Replace chuck or collet to new one.
Fracture on cutting edge	Chipping on corner edge	● Chamfer the corner with hand-stick grinder. ● Down cutting ⇒ Upward milling.
	Chipping on boundary part	● Change cutting direction, Down cutting → Upward milling. ● Reduce cutting speed.
	Chipping on central part or all edges.	● Make slight honing on the edge. Or make honing bigger. ● Change spindle revolution number. ● Increase cutting speed. ● If chattering, increase feed. ● Use coolant or air blast. ● Replace chuck or collet to new one. ● Decrease cutting speed.
	Fracture on cutting edge	● Decrease feed. ● Reduce flutes. E.g. 4 flutes → 3flutes, or 2flutes. ● Make slight honing on the edge. Or make honing bigger. ● Replace chuck or collet to new one. **【For Solid carbide endmill】** ● Decrease cutting speed. ● Use enough coolant. Change direction of supplying coolant. **【For brazed endmill】** ● If wet cutting, change to dry cutting with air-blast. Change direction of supplying air-blast. ● In slot milling of steel, change to optimum cutting condition. (In low cutting speed-chipping or adhesion may cause.) (In high cutting speed-chip packing or thermal crack may cause.)
Large wear in short time		● Decrease cutting speed. ● Change cutting direction, Upward milling → down cutting. ● Increase feed. ● Use coolant or air blast. ● In reground tool, grind flank face with FINER wheel.

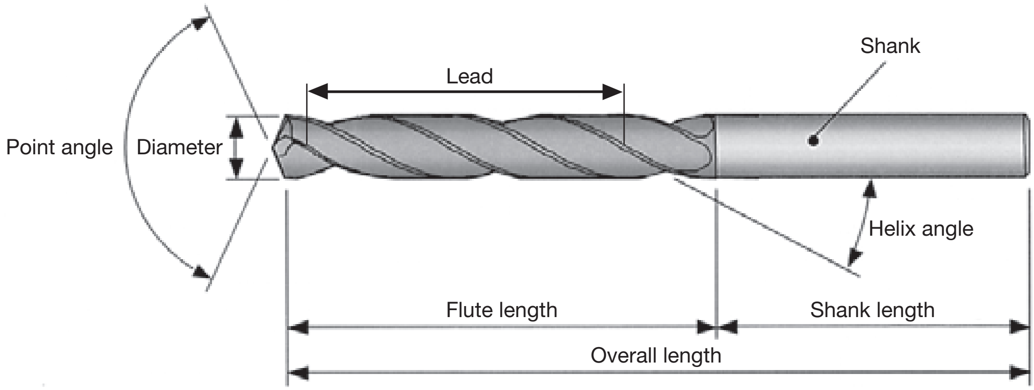
(Continued on next page)

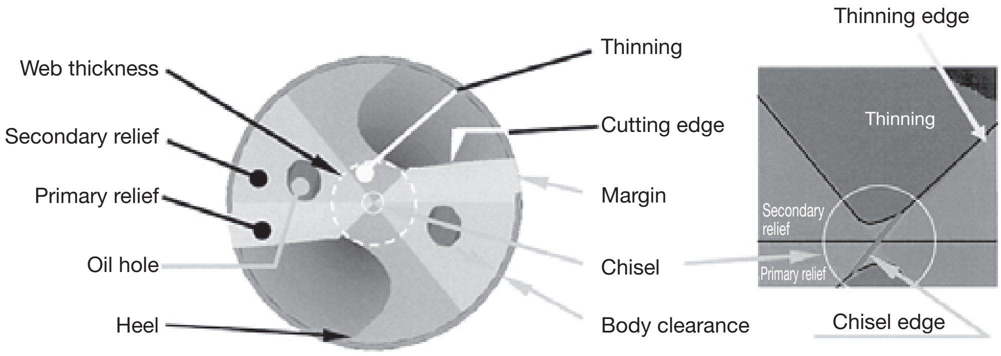
Solid Carbide Endmills

Trouble	Possible causes	Countermeasures
Poor surface finish	Bright, but Wavy surface	● Reduce feed per tooth. ● Increase flutes; E.g. 2 flutes → 3flutes, or 4flutes.
	Small chips are welded on surface.	● Increase cutting speed. ● Use coolant or air blast, or increase coolant. ● Make slight honing on the edge. ● Upward milling → Down cutting. ● Increase feed per tooth. Increase Depth of Cut.
	Scratches on the surface	● Make slight honing on the edge. ● Use non-water soluble coolant. ● Down cutting → Upward milling.
	Poor surface by over cutting	● Reduce depth of cut. ● Increase cutting speed. ● Reduce feed per tooth.
Poor accuracy	Finish size becomes a minus tendency.	● Upward milling → Down cutting. ● Reduce depth of cut. ● Replace chuck or collet to new one. ● Reduce overhang length. ● Increase cutting speed.
	Poor straightness	● Reduce depth of cut. ● Replace chuck or collet to new one. ● Reduce overhang length. ● Increase cutting speed. ● Increase flutes; E.g. 2 flutes → 4flutes. ● Reduce feed per tooth. ● Check the edge. Change tool, when needed.
Chattering		● Increase feed per tooth. Reduce feed per tooth, when current feed is more than 0.07 mm/t. ● Change cutting speed. ● Replace chuck or collet to new one. ● Reduce overhang length. ● Use 2 flutes tool in roughing. Use 4 flutes tool in finishing. ● Down cutting → Upward milling.

Drilling Tools

Nomenclature for drills





Cutting forces and power requirement

● Twist drill

Power requirement

$$P_c = K \phi D_c^2 n \left(0.647 + 17.29f\right) \times 10^{-6}$$
(kW)

Thrust force

$$T_c = 570 K \phi D_c f^{0.85}$$
(N)

Torque

$$M_c = \frac{K \phi D_c^2 \left(0.630 + 16.84f\right)}{100}$$
(N·m)

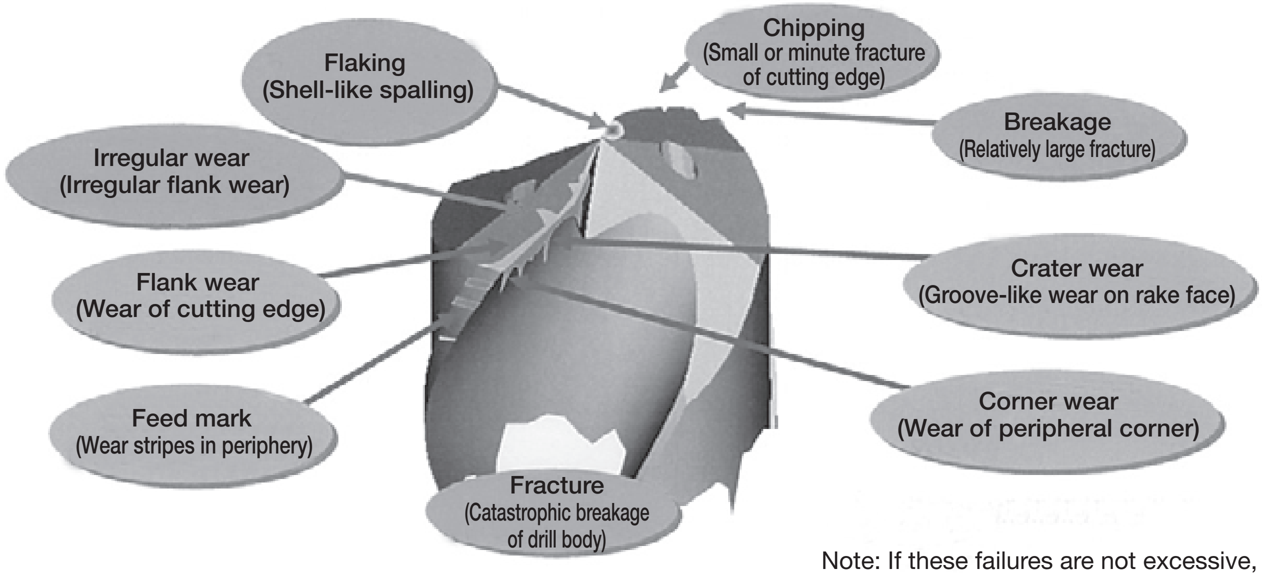
P_c : Power requirement (kW)
T_c : Thrust force (N)
M_c : Torque (N·m)
ϕD_c : Drill diameter (mm)
f : Feed (mm/rev)
n : No. of revolutions (min^{-1})
K : Material constant···· Refer to the Table at right

●Material constant compensating for power requirement and thrust force

Work material	Tensile strength		Brinell hardness (HB)	Material constant (K)
	MPa (N/mm^2)	Kgf/mm^2		
Cast iron	210	21	177	1.00
Cast iron	280	28	198	1.39
Cast iron	350	35	224	1.88
Aluminium	250	25	100	1.01
Low carbon steel (JIS S20C)	550	55	160	2.22
Free cutting steel (JIS SUM32)	620	62	183	1.42
Manganese steel (JIS SMn438)	630	63	197	1.45
Nickel chromium steel (JIS SNC236)	690	69	174	2.02
4115 steel Cr0.5, Mo0.11, Mn0.8	630	63	167	1.62
Chromium molybdenum steel (JIS SCM430)	770	77	229	2.10
Chromium molybdenum steel (JIS SCM440)	940	94	269	2.41
Nickel chromium molybdenum steel (JIS SNCM420)	750	75	212	2.12
Nickel chromium molybdenum steel (JIS SNCM625)	1,400	140	390	3.44
Chromium vanadium steel				
Cr0.6, Mn0.6, V0.12	580	58	174	2.08
Cr0.8, Mn0.8, V0.1	800	80	255	2.22

Drilling Tools

Cutting edge failure of drilling tools



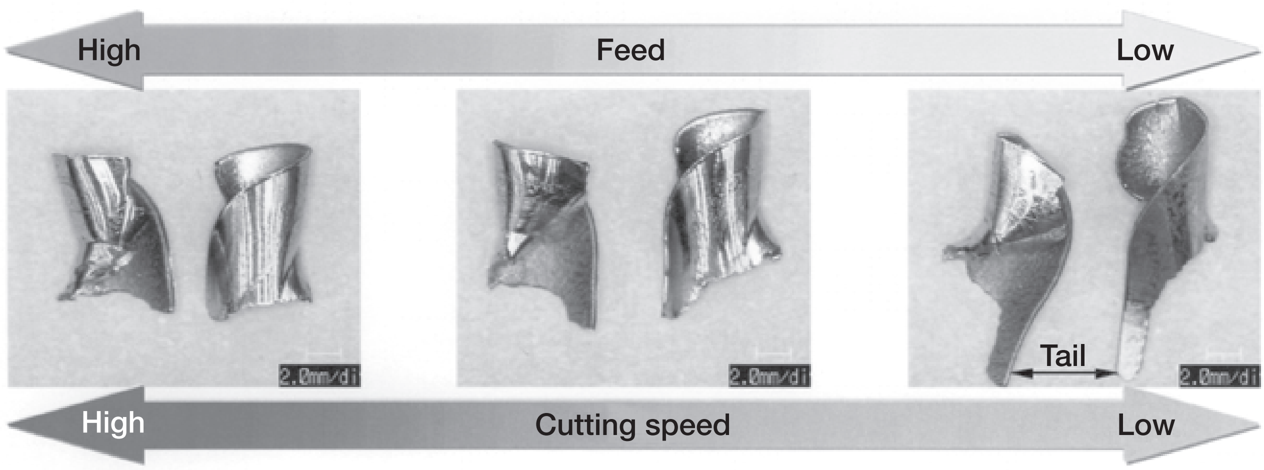
Note: If these failures are not excessive, the tool is in a normal condition.

Change of chip shapes in drilling

● **Change of chip shapes relating to cutting conditions**

Photographs below show the change of chip shapes relating to change of the feed and the cutting speed. These chip shapes are all well controlled in a proper condition range.

When the speed and feed are low, the chip shows whitish colour and the tail of the chip tends to lengthen gradually. In contrast, as the speed or the feed increases, the chip tends to increase in brightness and becomes a compact shape with a short tail. These changes in the shape depend on the cutting temperature. As the temperature increases, chips tend to be broken.

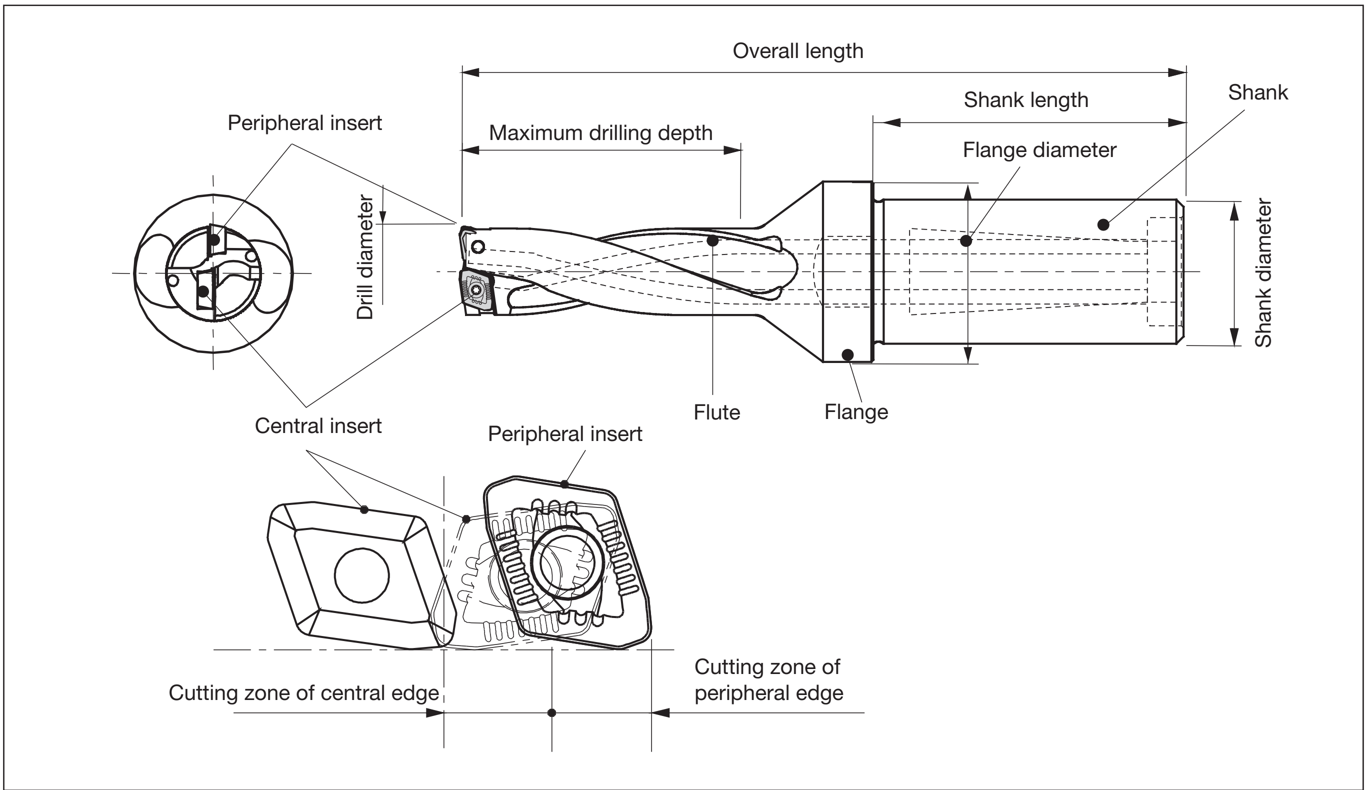


Troubleshooting for solid drills

Problem		Cause	Countermeasure
Abnormal wear	Relief surface	•Inappropriate cutting speed	•Increase the cutting speed by 10 % within standard conditions if abnormal wear is around center. •Lower the cutting speed by 10 % within standard conditions if abnormal wear is on the periphery.
		•Inappropriate cutting fluid	•Check the filter. •Use the cutting fluid superior in lubricity. (Increase the dilution rate)
	Margin	•Inappropriate cutting speed	•Lower the cutting speed by 10 %.
		•Regrinding timing, insufficient reground amount	•Shorten the regrinding timing.
		•Insufficient rigidity of the machine and workpiece	•Change the clamp method to the one with rigidity.
		•Insufficient drill rigidity	•Use smallest possible overhang.
		•Inappropriate cutting fluid	•Check the filter. •Use the cutting fluid superior in lubricity. (increase the dilution rate)
		•Intermittent cutting when entering	•Avoid interruption at entry and exit. •Lower the feed by about 50 % during entering into and leaving from the workpiece.
Chipping and fracture	Chisel section (center of drill cutting edge)	•Insufficient rigidity of the drill	•Reduce the drill overhang as much as possible. •Increase the feed at entry when the low speed feed is selected in standard cutting condition range. •Use a bushing or a center drill.
		•Insufficient rigidity of the machine and workpiece	•Change the clamp method to the one with rigidity.
		•Inappropriate entry into the workpiece	•Avoid interruption at entry into the workpiece. •Lower the feed by 10 % at entry.
		•High workpiece hardness	•Lower the feed by 10 %.
		•Inappropriate honing	•Check if honing has been made to the center of cutting edge.
	Peripheral cutting edge	•Insufficient drill rigidity	•Lower the cutting speed by 10 %. •Increase the feed at entry when the low speed feed is selected in standard cutting condition range.
		•Inappropriate drill mounting accuracy	•Check the run out accuracy after drill installation. (0.03 mm or less)
		•Insufficient machinery and workpiece rigidity	•Change the clamp method to the one with rigidity. •Lower the feed during entering into and leaving from the workpiece.
		•Inappropriate honing	•Check if honing has been made to the cutting edge periphery.
	Margin	•Insufficient machine and workpiece rigidity	•Change the clamp method to the one with rigidity.
		•Insufficient drill rigidity	•Use smallest possible overhang. •Use a bushing or center drill.
		•Regrinding timing and insufficient amount of reground stock	•Shorten the regrinding timing.
		•Intermittent cutting when entering or exiting the cut	•Avoid interruption at entry and exit. •Lower the feed by about 50 % during entering into and leaving from the workpiece.
Breakage		•Tendency to cause chipping or develop abnormal wear	•Check the failure mode condition before breakage and find out the wear and chip countermeasures.
		•Chip packing in the drill flutes	•Review the cutting conditions. •For internal coolant supply, raise the supply pressure of cutting fluid. •Use peck feed for deep holes.
		•Insufficient machine output	•Review the cutting conditions. •Use the machine with high power.
Insufficient hole accuracy		•Insufficient rigidity of the machinery and workpiece	•Change to the clamp method with rigidity
		•Inappropriate drill installation accuracy	•Check the run out accuracy of drill mounting. (0.03 mm or less)
		•Chip packing in the flutes.	•Review the cutting conditions. •Raise the cutting oil supply pressure. •Use peck-feed for deep holes.
		•Inappropriate edge sharpening accuracy	•Check the edge shape accuracy.
Prolonged chips		•Inappropriate cutting conditions	•Increase the feed by 10 % within standard conditions.
		•Inappropriate honing	•Provide the appropriate honing.
		•Cutting edge with chipping or breakage	•Lower the cutting speed by 10 %.

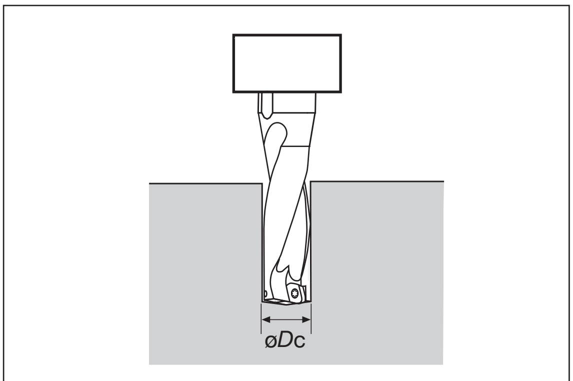
Drilling Tools

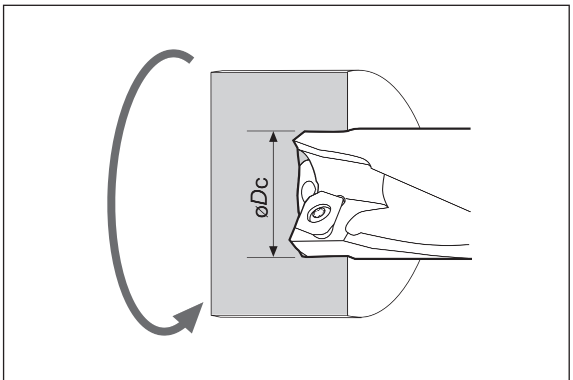
Nomenclature for TAC drill



Calculation formulas for TAC drill

●Cutting speed





●When calculating cutting speed from number of revolutions: (Drilling formulas)

$$\underset{(m/min)}{v_c} = \frac{\pi \times øD_c \times n}{1000}$$

v_c : Cutting speed (m/min)
$øD_c$: Drill diameter (mm)
n : Number of revolution (min^{-1})
$\pi \approx 3.14$

●When calculating required number of revolutions from cutting speed: (Drilling formulas)

$$\underset{(min^{-1})}{n} = \frac{1000 \times v_c}{\pi \times øD_c}$$

●When calculating cutting speed from number of revolutions: (Where the workpiece rotates.)

$$\underset{(m/min)}{v_c} = \frac{\pi \times øD_c \times n}{1000}$$

v_c : Cutting speed (m/min)
$øD_c$: Drilling diameter (mm)
n : Number of revolution (min^{-1})
$\pi \approx 3.14$

●When calculating required number of revolutions from cutting speed: (Where the workpiece rotates.)

$$\underset{(min^{-1})}{n} = \frac{1000 \times v_c}{\pi \times øD_c}$$

●Calculation of feed speed

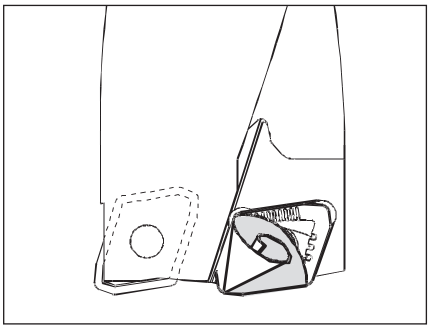
$$\underset{(mm/min)}{v_f} = f \times n$$

v_f : Feed speed (mm/min)
f : Feed (mm/rev)
n : Number of revolution (min^{-1})

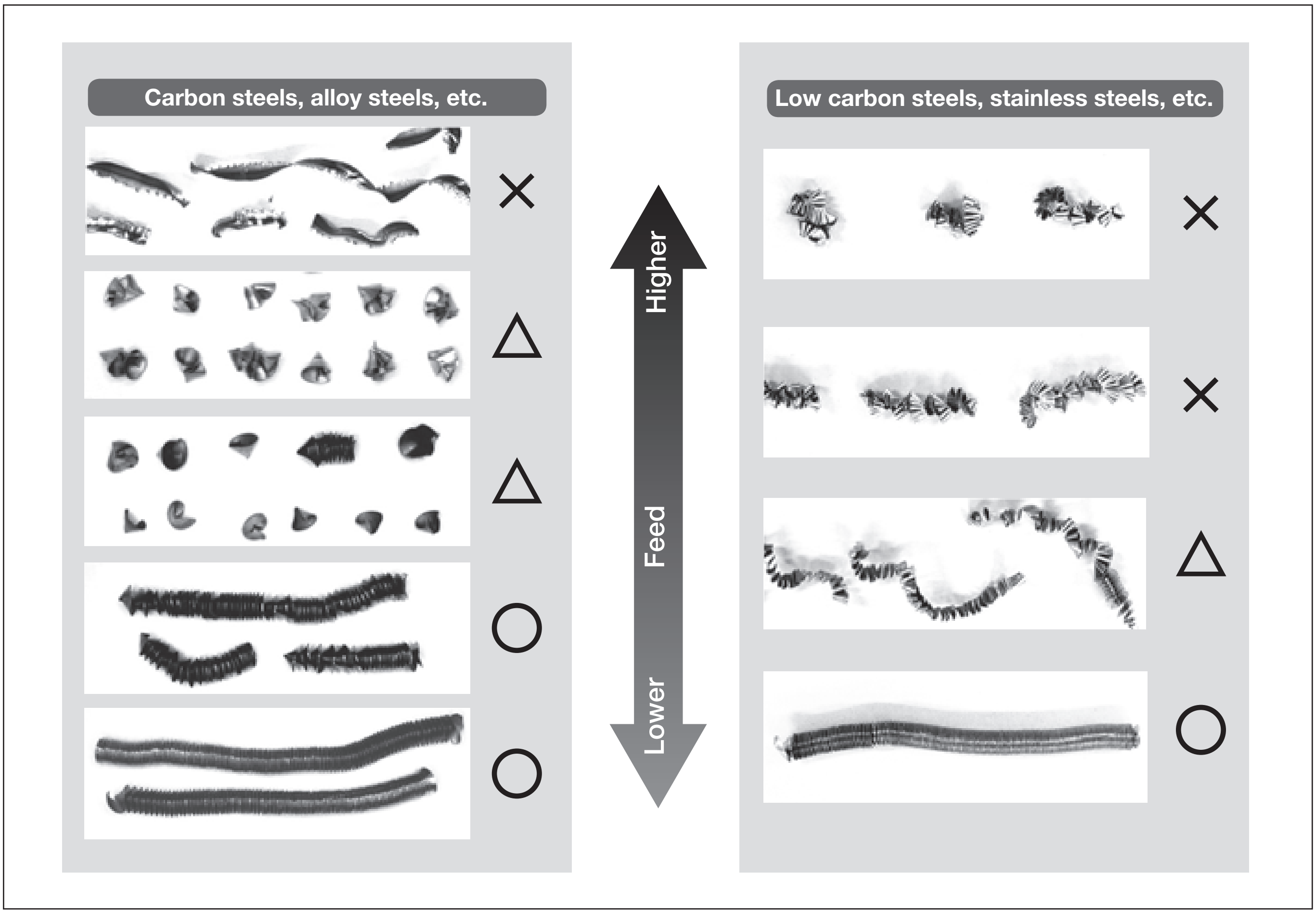
Chip shapes

● Chip shape produced with central insert

- A conical coil shape whose apex point coincides with the rotating center of the drill is the basic shape. The chips are broken into small sections with increases in feed. However, excessively high feed causes the chip to increase in thickness and develops vibration which disturbs stable machining.
- In TDX drills, ○ marked chips shown below are the most preferable shapes. This type of chip is broken into adequate lengths by centrifugal forces when used in tool-rotating condition. On the other hand, when used in work-rotating condition such as on a lathe, a continuously long chip is often produced without entangling.

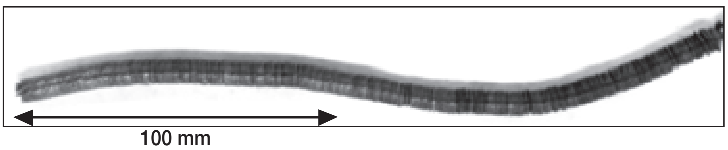


● Relation between chip shapes and feeds (In the case of central insert)



● Example of chip shape in work-rotating applications (In the case of central insert)

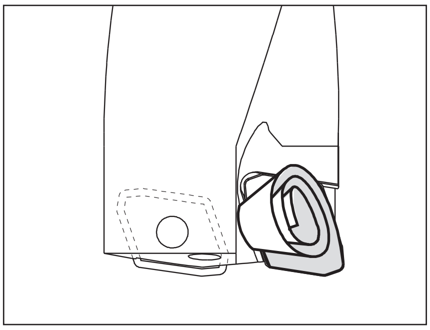
(ø26, S45C, V_c = 100 m/min, f = 0.1 mm/rev)



Drilling Tools

● Chip shape produced with peripheral insert

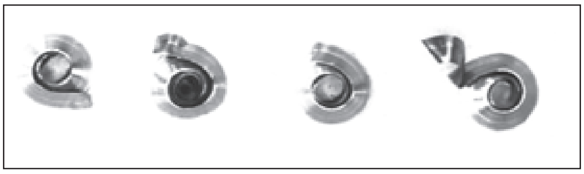
- Chip problems such as entangling are mainly caused by chips produced with the peripheral insert. These problems are dependent on the types of work material and the cutting conditions.
- As shown below, when the feed is extremely low, the chips jump over the chipbreaker groove and the continuously long chips may wrap around the drill body.
- When the feed is too high, the chips increase in thickness and can not be curled.
- Therefore, it is important to select proper cutting conditions to suit the machining so that well controlled chips will be formed.



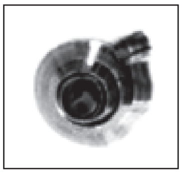
Medium to high carbon steels, alloy steels, etc.

As shown below, several turns of coil are an ideal shape.
As the feed increases, the curl radius and the number of turns tend to decrease.

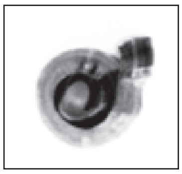
● Typical chip shapes of general steels



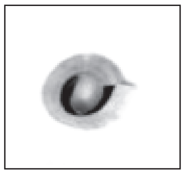
● Variation of chip shapes relating to feeds



f = 0.07 mm/rev



f = 0.1 mm/rev

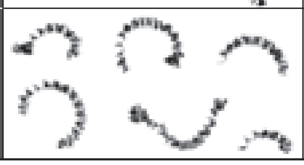
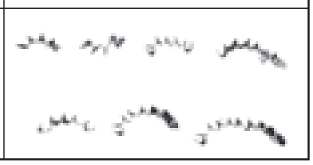


f = 0.13 mm/rev

Stainless steels, low-carbon steels, low-alloy steels, etc.

- When machining long-chip materials such as stainless steels and mild steels, the wrong selection of cutting conditions results in chip entangling and tool breakage at worst. Therefore, cutting conditions should be carefully selected.
- "C" shaped, continuous coils of several to ten turns having adequately divided lengths are the ideal shape.

● Ideal chip shapes

	Stainless steel (JIS SUS 304) (ø22, *V*c = 100 m/min, *f* = 0.1 mm/rev)	Mild steel (JIS SS400) (ø22, *V*c = 160 m/min, *f* = 0.08 mm/rev)
DS chipbreaker		
DJ chipbreaker		

For machining stainless steels or low carbon steels, DS chipbreaker is recommended.
When using a TDX drill in tool-rotating condition, DS chipbreaker produces compact chips and allows more stable machining than DJ chipbreaker. When using it in work-rotating condition, DS chipbreaker provides outstanding affect on chip control.

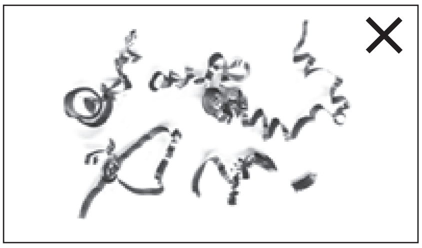
● Chip shapes which tend to entangle and remedies against them

① Apple-peel-like chips

These chips are often produced in machining mild steels or low-carbon steels at low-speeds and low-feeds.

Remedies

Increase the cutting speed in stages by 20% within the range of standard cutting conditions. If there is no effect, increase the feed by about 10 % as the cutting speed is raised by 20%.



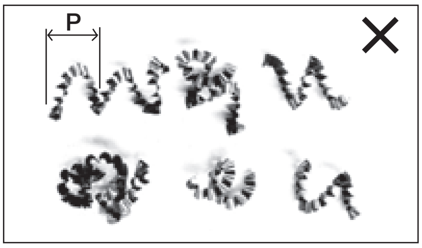
Apple-peel-like chips (Without curling)

② Short-lead chips

These chips are often produced in machining stainless steels at low-feeds and tend to entangle to the tool in spite of short length.

Remedies

Increase the feed by about 10 %. If there is no effect, increase the cutting speed in stages by 10% within the range of standard cutting conditions.



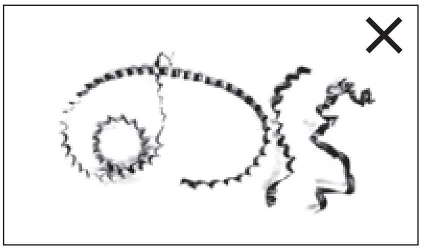
Continuously curled “C” shape chips with short lead (P).

③ Very long chips

Often produced in machining mild steels or low-carbon steels under improper cutting conditions.

Remedies

Increase the cutting speed in stages by 20% within the range of standard cutting conditions. If there is no effect, decrease the feed by about 10 % as the cutting speed is raised by 20%.

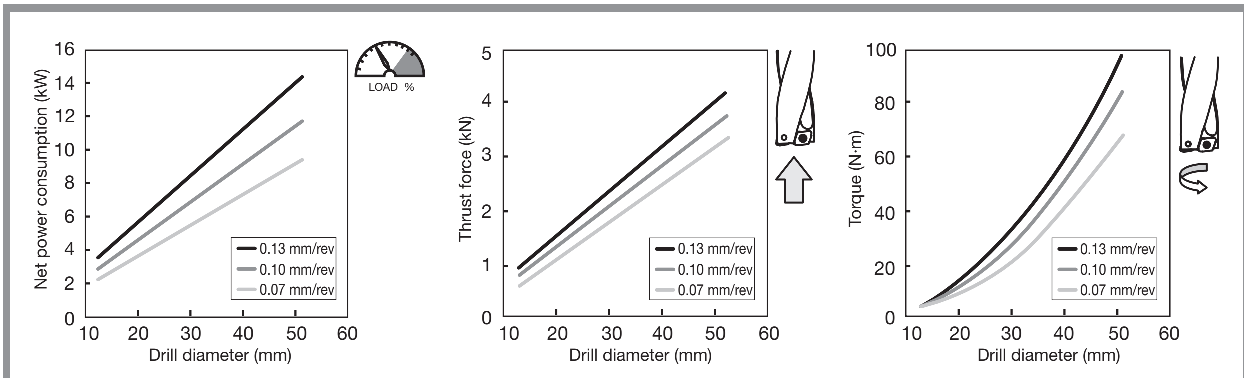


Continuously coiled long chips

Cutting forces

The charts below show a guideline for cutting forces. Use TDX drills on a machine with ample power and sufficient rigidity.

● Guidelines for cutting forces



Cutting speed: v_c = 100 m/min
Work material: Alloy steel (JIS SCM440), 240HB
Cutting fluid: Used

Drilling Tools

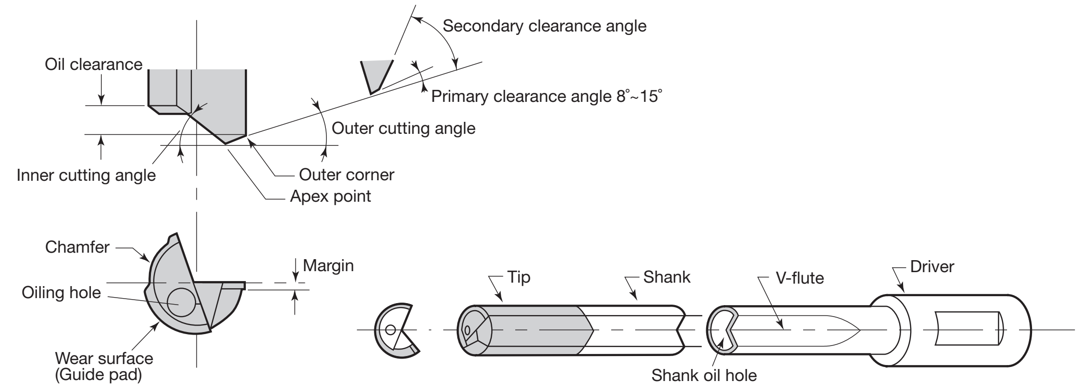
Troubleshooting for indexable drills

Problem			Cause	Countermeasure
Abnormal wear	Central cutting edge	Relief surface	Inappropriate cutting conditions	● Increase the cutting speed by 10 % within standard conditions. ● Lower the feed by 10 %.
Abnormal wear	Peripheral cutting edge	Relief surface	Inappropriate cutting conditions	● Increase the cutting speed by 10 % within standard conditions. ● When the feed is extremely low or high, set up it within standard conditions.
Abnormal wear	Common	Relief surface	Varieties and supply of cutting fluid	● Confirm that the cutting fluid flow is higher than 7 liter/min. ● The concentration of cutting fluid must be higher than 5 %. ● Use the cutting fluid superior in lubricity. ● Change to internal cutting fluid supply from external one.
Abnormal wear	Common	Relief surface	Vibration in drilling	● Change to the machine with higher torque. ● Change to the clamp method with rigidity. ● Change the drill setting method.
Abnormal wear	Common	Relief surface	Unsuitable for selection of grade	● Change the grade to high wear resistant.
Abnormal wear	Common	Relief surface	Looseness of screws	● Tighten the screw.
Abnormal wear	Common	Crater	Cutting heat is too high	● Change to internal cutting fluid supply from external one. ● Increase the supply rate of the cutting fluid. (Higher than 10 liter/min.) ● Lower the feed by 20 % within standard conditions. ● Lower the cutting speed by 20 % within standard conditions.
Abnormal wear	Common	Crater	Excessive chip welding	● Lower the feed by 20 % within standard conditions. ● Lower the cutting speed by 20 % within standard conditions.
Abnormal wear	Common	Chipbreaker	Chip packing	● Increase the cutting speed by 20% and lower the feed by 20% within standard conditions. ● Raise the fluid pressure (for higher than 1.5 MPa).
Chipping and fracture	Central cutting edge	The rotation center of drill	Misalignment for workpiece rotation	● Set the misalignment to 0 ~ 0.2 mm.
Chipping and fracture	Central cutting edge	The rotation center of drill	Large offset	● Check the manual and use the tool in the allowable offset range.
Chipping and fracture	Central cutting edge	The rotation center of drill	No flatness of machined surface	● Flatten the entry surface in pre-machining. ● Set the feed for lower than 0.05 mm/rev in rough surface area.
Chipping and fracture	Central cutting edge	The rotation center of drill	High feed	● Lower the feed by 20 ~ 50 % within standard conditions.
Chipping and fracture	Central cutting edge	The rotation center of drill	Using a chipping corner	● Confirm the corner when exchanging inserts.
Chipping and fracture	Peripheral cutting edge	Peripheral corner area	Using inserts in excess of tool-life	● Exchange the corner or the insert before the nose wear reaches 0.3 mm.
Chipping and fracture	Peripheral cutting edge	Peripheral corner area	No flatness of machined surface	● Flatten the entry surface in pre-machining. ● Set the feed for lower than 0.05 mm/rev at rough surface area.
Chipping and fracture	Peripheral cutting edge	Peripheral corner area	The existence of interrupted area	● Set the feed for lower than 0.05 mm/rev in interrupted area.
Chipping and fracture	Peripheral cutting edge	Peripheral corner area	Using a chipped corner	● Confirm the corner when exchanging inserts.
Chipping and fracture	Common	The unused corner area and cutting edge	High hardness of workpiece	● Increase the cutting speed by 20 % and lower the feed by 20 % within standard conditions. ● Raise the fluid pressure (for higher than 1.5 MPa).
Chipping and fracture	Common	The unused corner area and cutting edge	Chip packing	● Lower the feed by 20 % within standard conditions.
Chipping and fracture	Common	The unused corner area and cutting edge	Machinery impact	● Change to continuous feed in case of pick feeding.
Chipping and fracture	Common	Contact boundary	Using inserts in excess of tool-life	● Exchange the corner or the insert before the nose wear reaches 0.3 mm.
Chipping and fracture	Common	Contact boundary	Vibration in drilling	● Change to the machine with higher rigidity. ● Change to the clamp method with rigidity. ● Change the drill setting method.
Chipping and fracture	Common	Flaking	High hardness of workpiece	● Set the feed for lower than 0.05 mm/rev.
Chipping and fracture	Common	Flaking	Thermal impact	● Change to internal cutting fluid supply from external one. ● Lower the feed by 20 % within standard conditions.
Chipping and fracture	Common	Common	Unsuitable for selection of grade	● Change the grade to toughress.
Chipping and fracture	Common	Common	Looseness of screws	● Tighten the screw.

Problem		Cause	Countermeasure
Scratch marks on the tool	The tool periphery	Misalignment of workpiece rotation	● Set the misalignment to 0 ~ 0.2 mm.
		Offset machining in excess of allowable range	● Use the tool in the allowable offset range.
		Offset direction reduced diameter of workpiece	● Set offset direction extended diameter of workpiece
		No flatness of the entry surface	● Flatten the entry surface in pre-machining. ● Set the feed for lower than 0.05 mm/rev in rough surface area.
		Chipping of peripheral cutting edge	● Exchange the insert.
		Bend of workpiece	● Change to the clamp method with rigidity.
		Chip packing	● Increase the cutting speed by 20 % and lower the feed by 20 % within standard conditions. ● Raise the fluid pressure (for higher than 1.5 MPa).
Inappropriate hole accuracy	Hole diameter	Misalignment for workpiece rotation	● Set the misalignment to 0 ~ 0.2 mm.
		Inappropriate offset contents	● Adjust offset contents.
		No flatness of the entry surface	● Flatten the entry surface in pre-machining. ● Set the feed for lower than 0.05 mm/rev at rough surface area.
		Bend of workpiece	● Change to the clamp method with rigidity.
	Roughness	Varieties and supply of cutting fluid	● The concentration of cutting fluid must be higher than 5 %. ● Use the cutting fluid superior in lubricity. ● Change to internal cutting fluid supply from external one.
		Inappropriate cutting conditions	● Increase the cutting speed by 20 % within standard conditions. ● Lower the feed by 20 % within standard conditions.
	Common	Failures of inserts	● Exchange the insert.
		Chip packing	● Increase the cutting speed by 20 % and lower the feed by 20 % within standard conditions. ● Raise the fluid pressure (for higher than 1.5 MPa).
		Looseness of screws	● Tighten the screw.
Chip control	Prolonged and twisted of chips	Inappropriate cutting conditions	● Work within standard conditions. ● Increase the cutting speed by 10 % within standard conditions. ● Increase the feed by 10 % within standard conditions.
		Failures of inserts	● Exchange inserts.
		Machining by external fluid supply	● Change to internal cutting fluid supply from external one. ● Work by step feed. ● Use dwell function for 0.1 sec approximately.
		Chips around the central cutting edge	● There is a tendency to shorten the chips when shifting to higher speed and feed.
	Chip packing	Fluid supply	● Change to internal cutting fluid supply from external one. ● Raise the fluid pressure (for higher than 1.5 MPa).
		Inappropriate cutting conditions	● Increase the cutting speed by 20 % and lower the feed by 20 % within standard conditions. ● Raise the fluid pressure (for higher than 1.5 MPa).
	Common	Large failure of drill holders	● Exchange the drill holder.
		Looseness of screws	● Tighten the screw.
Others	Chatter	Inappropriate cutting conditionss	● Lower the cutting speed by 20 % within standard conditions. ● Increase the feed by 10 % within standard conditions.
		Large wear of inserts	● Exchange the insert.
		Vibration in drilling	● Change to the machine with higher torque rigidity. ● Change to the clamp method with rigidity. ● Change the drill setting method.
		Looseness of screws	● Tighten the screw.
	Machine stop	Insufficient machine power and torque	● Use the range of number of revolutions suited machine spec. Lower the feed by 20 ~ 50%.
		Burned inserts	● Exchange inserts before the failure becomes larger. ● Check the oil-hole plug screw is tightly screwed in place. ● Check that the fluid flows powerfully from the drill. ● Lower the cutting speed and the feed by 20 % within standard conditions.
	Large burr	Failures of inserts	● Exchange the insert.
		Inappropriate cutting conditions	● Lower the feed by 20 ~ 50% just before leaving from the workpiece.

Drilling Tools

Nomenclature for gun drill



Troubleshooting in gun drilling

Trouble		Possible causes	Countermeasures
Breaking of drill	At entry into workpiece	Cause in machine	Is workpiece clamp loose?
			Is the guide bushing not separated from entry surface?
			Is machining under rapid feed?
			Is alignment of bushing set correctly?
			Is the shape of bushing correct?
		Cause in drill	Is the gun drill set properly?
			Is regrinding in order?
		Inappropriate cutting condition	Is the feed too high?
		Cause in workpiece	Is engaging not slanted?
	During drilling	Cause in machine	Is workpiece clamp loose?
			Is the shape of bushing correct?
			Is the feed speed (v_f) uniform?
			Is number of revolutions uniform?
		Cause in drill	Is there an abnormal failure?
		Inappropriate cutting condition	Is the feed (f) set properly?
		Cause in workpiece	Change to standard gun drill.
		Others	Is there chip packing?
	At exit from workpiece	Cause in drill	Is tip length too long?
			Is selection of guide pad appropriate?
			Is fluid hole clearance excessive?
		Inappropriate cutting condition	Is the feed too high at breaking-through?
		Cause in workpiece	Is there inclined surface?
	During retracting	Cause in machine	Is workpiece clamp loose in machining?
		Inappropriate cutting condition	Is there increase of burnishing torque due to small hole diameter?

Troubleshooting in gun drilling

Trouble		Possible causes	Countermeasures
Short tool life	Abnormal wear	Cause in machine	Is selection of cutting fluid correct?
			Carry out through filtration of cutting fluid.
			Is clearance between guide bushing and drilling excessive?
			Is alignment of bushing set correct?
			Check concentricity of spindle and guide bushing.
			In case fluid temperature too high, increase tank capacity.
		Cause in drill	Appropriate selection of guide pad.
			Is regrinding correct?
			Is drill overall length excessive?
			In case wear too large, regrind the gun drill (or check tool life criterion).
		Inappropriate cutting condition	Is the cutting speed too high?
			Is the feed (*f*) too high?
			Is the fluid pressure too high?
		Cause in workpiece	Is material quality uniform?
Chip control	Chip packing	Cause in machine	Is the shape of bushing correct?
			Is the feed speed (v_f) uniform?
			Is number of revolutions uniform?
			Enlarge chip box.
		Inappropriate cutting condition	Correct selection of the feed (*f*).
			Correct selection of fluid amount.
		Cause in workpiece	Change to machining with standard gun drill.
			Change the shape of cutting edge so that cores become small .
			Is material quality uniform?
	Chip entanglement	Cause in drill	Is cutting edge broken or chipped?
			Is outer corner wear excessive?
		Inappropriate cutting condition	Correct selection of the feed (*f*).
		Cause in workpiece	Make center hole as large as drilling diameter or smaller than it. Lower fluid pressure.

Drilling Tools

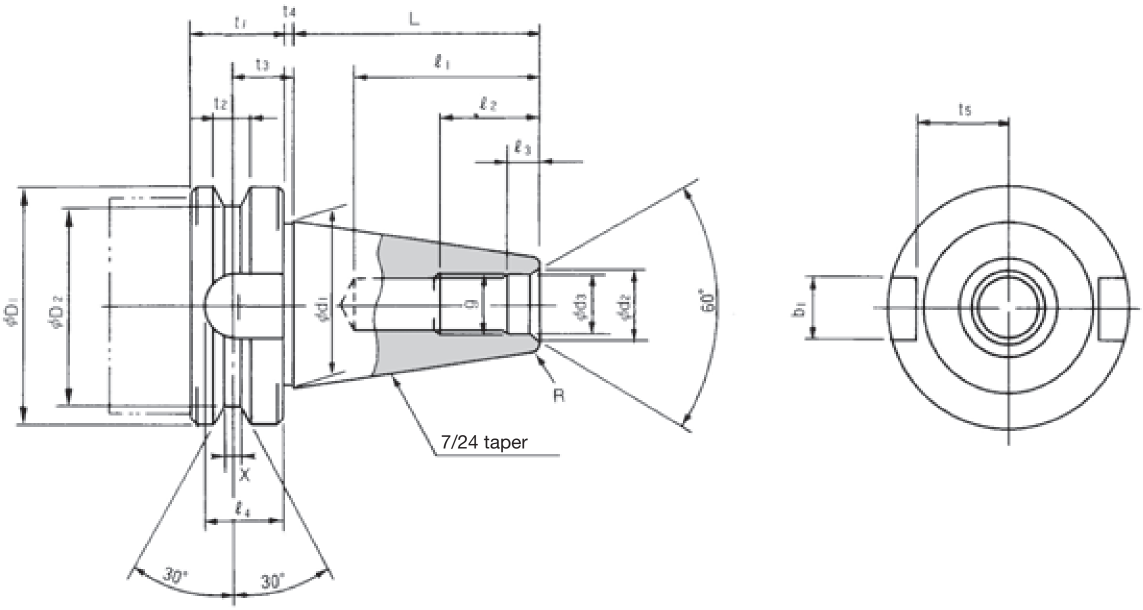
Troubleshooting in gun drilling

Trouble		Possible causes	Countermeasures
Hole accuracy	Rough finish	Cause in machine	Is workpiece clamp loose?
			Use non-water soluble cutting fluid.
			Carry out through filtration of cutting fluid.
			Is spindle run out too large?
			Is clearance between guide bushing and drilling excessive?
			Is the feed speed (v_f) uniform?
			Is number of revolutions uniform?
		Cause in drill	Is there an abnormal failure?
			Is regrinding correct?
		Inappropriate cutting condition	Is the feed (*f*) too high?
		Others	Is there chip packing?
	Unacceptable roughness, cylindricity, and oversize	Cause in machine	Is clearance between guide bushing and drilling excessive?
			Is the guide bushing not separated from entry surface?
			Use non-water soluble cutting fluid.
			Decrease concentrity of guide bushing and spindle.
		Cause in drill	Is there an abnormal failure?
			Is regrinding correct?
		IInappropriate cutting condition	Correct selection of the feed (*f*).
		Cause in workpiece	Change to machining with standard gun drill.
		Others	Is there chip packing?
	Bending of hole	Cause in machine	Is workpiece clamp loose?
			Is the guide bushing not separated from entry surface?
			Decrease concentrity of guide bushing and spindle.
			Is clearance between guide bushing and drilling excessive?
		Cause in drill	Change the shape of guide pad.
			Is regrinding correct?
		Inappropriate cutting condition	Is the feed (*f*) too high?
		Cause in workpiece	Are there faults and unevenness?
			Is engaging not slanted?
			Change to machining with standard gun drill.

MEMO

Standards on Tapers

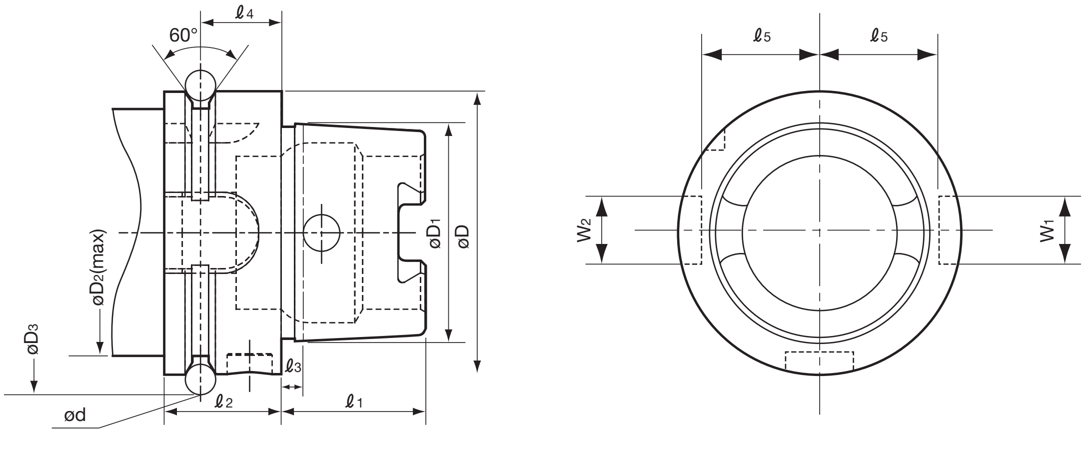
Taper shank for machining center (Japan Machine-Tool Builder's Association Standard)



(unit : mm)

Code	øD1	øD2	t1	t2	t3	t4	ød1	ød2	ød3	L	ℓ1 (min.)	ℓ2 (min.)	ℓ3	g	ℓ4 (min.)	b1	t5
BT30	46	38	20	8	13.6	2	31.75	14	12.5	48.4	34	24	7	M12	17	16.1	16.3
BT40	63	53	25	10	16.6	2	44.45	19	17	65.4	43	30	9	M16	21	16.1	22.6
BT45	85	73	30	12	21.2	3	57.15	23	21	82.8	53	38	11	M20	26	19.3	29.1
BT50	100	85	35	15	23.2	3	69.85	27	25	101.8	62	45	13	M24	31	25.7	35.4

HSK Taper Shank (Hollow taper interface with flange contact surface. ISO12164-1:2001(E))

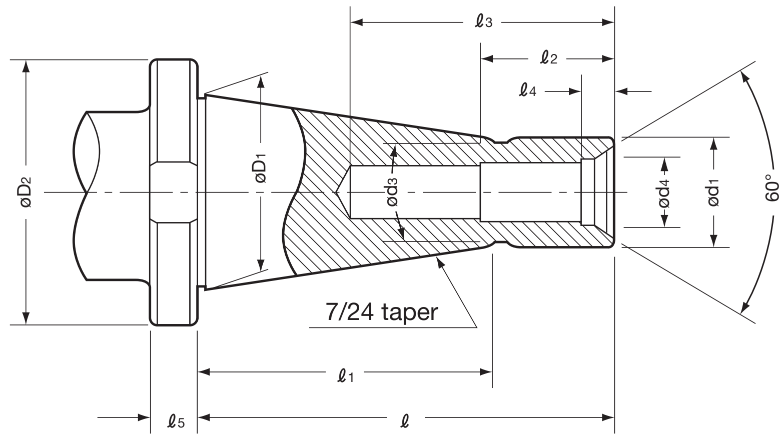


(unit : mm)

Style A	øD	øD1	øD2	øD3	ød	ℓ1	ℓ2	ℓ3	ℓ4	ℓ5	W1	W2
HSK-A32	32	24	26	37	4	16	20	3.2	16	13	9	7
HSK-A40	40	30	34	45		20		4		17	11	9
HSK-A50	50	38	42	59.3	7	25	26	5	18	21	14	12
HSK-A63	63	48	53	72.3		32		6.3		26.5	18	16
HSK-A80	80	60	67	88.8		40		8		34	20	18
HSK-A100	100	75	85	109.75		50	29	10	20	44	22	20

Standards on Tapers

7/24 taper arbor (Conformed to JIS)

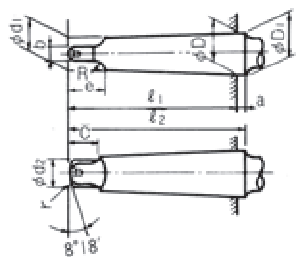


(unit : mm)

NT No.	øD1	ød1	ℓ	ℓ1	g	ℓ2	ℓ3	ød3	ød4	ℓ4
					ISO				ISO	
30	31.75	17.4	70	50	M12	24	34	16.5	13	6
40	44.45	25.3	95	67	M16	30	43	24	17	8
45	57.15	32.4	110	86	M20	40	53	30	21	10
50	69.85	39.6	130	105	M24	45	60	38	26	11.5

Morse taper shank (Conformed to JIS)

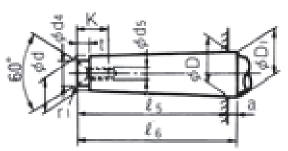
●With tang



(unit : mm)

MT. No	øD	a	øD1 (approx)	ød1 (approx)	ℓ1 (max.)	ℓ2 (max.)	ød2 (max.)	b	c (max.)	e (max.)	R (max.)	r
0	9.045	3	9.2	6.1	56.5	59.5	6.0	3.9	6.5	10.5	4	1
1	12.065	3.5	12.2	9.0	62.0	65.5	8.7	5.2	8.5	13.5	5	1.2
2	17.780	5	18.0	14.0	75.0	80.0	13.5	6.3	10	16	6	1.6
3	23.825	5	24.1	19.1	94.0	99.0	18.5	7.9	13	20	7	2
4	31.267	6.5	31.6	25.2	117.5	124.0	24.5	11.9	16	24	8	2.5
5	44.399	6.5	44.7	36.5	149.5	156.0	35.7	15.9	19	29	10	3
6	63.348	8	63.8	52.4	210.0	218.0	51.0	19	27	40	13	4

●With thread



(unit : mm)

MT. No	øD	a	øD1 (approx)	ød (approx)	ℓ5 (max.)	ℓ6 (max.)	ød4 (max.)	ød5	K (max.)	t (max.)
0	9.045	3	9.2	6.4	50	53	6	-	-	4
1	12.065	3.5	12.2	9.4	53.5	57	9	M 6	16	5
2	17.780	5	18.0	14.6	64	69	14	M 10	24	5
3	23.825	5	24.1	19.8	81	86	19	M 12	28	7
4	31.267	6.5	31.6	25.9	102.5	109	25	M 16	32	9
5	44.399	6.5	44.7	37.6	129.5	136	35.7	M 20	40	9
6	63.348	8	63.8	53.9	182	190	51	M 24	50	12

International Tolerance (IT Grades)

International Tolerance (IT Grades)

IT grades shows a tolerance allowable for difference of the diameters of a hole and a shaft. As the number added after IT increases, the tolerance becomes rough. Depending on the basic size, the tolerance value in each grade varies.
In the catalog, IT grades are shown as a guide of dimensional dispersion in the diameters of holes machined with the drill. For information, H8 tolerance for a ø8.0 hole is 0 to + 0.022 mm, the width of the value is the same as that of IT 8.
In the Table shown below, tolerance areas attainable with typical drilling tools are distinguished by using different colours. Solid drills are generally used for machining holes of IT 9 to 12. For machining a hole of better than IT 8, finishing process such as reaming is required. For a hole better than IT 5, high-precision finishing is required. Above description is based on machining of general steel. In practice, the IT grade attained with the tool varies widely depending on the hardness and the composition of the work material.

● IT (International Tolerance) Grades

Basic sizes (mm)		International Tolerance Grades																	
		IT1	IT2	IT3	IT4	IT5	IT6	IT7	IT8	IT9	IT10	IT11	IT12	IT13	IT14	IT15	IT16	IT17	IT18
>	≤						(µm)									(mm)			
-	3	0.8	1.2	2	3	4	6	10	14	25	40	60	0.1	0.14	0.25	0.4	0.6	1	1.4
3	6	1	1.5	2.5	4	5	8	12	18	30	48	75	0.12	0.18	0.3	0.48	0.75	1.2	1.8
6	10	1	1.5	2.5	4	6	9	15	22	36	58	90	0.15	0.22	0.36	0.58	0.9	1.5	2.2
10	18	1.2	2	3	5	8	11	18	27	43	70	110	0.18	0.27	0.43	0.7	1.1	1.8	2.7
18	30	1.5	2.5	4	6	9	13	21	33	52	84	130	0.21	0.33	0.52	0.84	1.3	2.1	3.3
30	50	1.5	2.5	4	7	11	16	25	39	62	100	160	0.25	0.39	0.62	1	1.6	2.5	3.9
50	80	2	3	5	8	13	19	30	46	74	120	190	0.3	0.46	0.74	1.2	1.9	3	4.6
80	120	2.5	4	6	10	15	22	35	54	87	140	220	0.35	0.54	0.87	1.4	2.2	3.5	5.4
120	180	3.5	5	8	12	18	25	40	63	100	160	250	0.4	0.63	1	1.6	2.5	4	6.3
180	250	4.5	7	10	14	20	29	46	72	115	185	290	0.46	0.72	1.15	1.85	2.9	4.6	7.2
250	315	6	8	12	16	23	32	52	81	130	210	320	0.52	0.81	1.3	2.1	3.2	5.2	8.1
315	400	7	9	13	18	25	36	57	89	140	230	360	0.57	0.89	1.4	2.3	3.6	5.7	8.9
400	500	8	10	15	20	27	40	63	97	155	250	400	0.63	0.97	1.55	2.5	4	6.3	9.7
500	630	9	11	16	22	32	44	70	110	175	280	440	0.7	1.1	1.75	2.8	4.4	7	11
630	800	10	13	18	25	36	50	80	125	200	320	500	0.8	1.25	2	3.2	5	8	12.5
800	1000	11	15	21	28	40	56	90	140	230	360	560	0.9	1.4	2.3	3.6	5.6	9	14
1000	1250	13	18	24	33	47	66	105	165	260	420	660	1.05	1.65	2.6	4.2	6.6	10.5	16.5
1250	1600	15	21	29	39	55	73	125	195	310	500	780	1.25	1.95	3.1	5	7.8	12.5	19.5
1600	2000	18	25	35	46	65	92	150	230	370	600	920	1.5	2.3	3.7	6	9.2	15	23
2000	2500	22	30	41	55	78	110	175	280	440	700	1100	1.75	2.8	4.4	7	11	17.5	28
2500	3150	26	36	50	68	96	135	210	330	540	860	1350	2.1	3.3	5.4	8.6	13.5	21	33

Tolerance area requiring finishing process such as with a reamer.

Tolerance area attainable with a solid drill.

Tolerance area attainable with an indexable drill.

Deviations of Shafts to be Used in Commonly Used Fits.

Deviations of Shafts to be Used in Commonly Used Fits. (JIS B0401 extrac)

Basic size step (mm)		Tolerance zone class of shaft (μm)															
>	≤	e9	f6	f7	f8	g5	g6	h5	h6	h7	h8	h9	js5	js6	js7	k5	k6
–	3	−14 −39	−6 −12	−6 −16	−6 −20	−2 −6	−2 −8	0 −4	0 −6	0 −10	0 −14	0 −25	±2	±3	±5	+4 0	+6 0
3	6	−20 −50	−10 −18	−10 −22	−10 −28	−4 −9	−4 −12	0 −5	0 −8	0 −12	0 −18	0 −30	±2.5	±4	±6	+6 +1	+9 +1
6	10	−25 −61	−13 −22	−13 −28	−13 −35	−5 −11	−5 −14	0 −6	0 −9	0 −15	0 −22	0 −36	±3	±4.5	±7	+7 +1	+10 +1
10	14	−32 −75	−16 −27	−16 −34	−16 −43	−6 −14	−6 −17	0 −8	0 −11	0 −18	0 −27	0 −43	±4	±5.5	±9	+9 +1	+12 +1
14	18																
18	24	−40 −92	−20 −33	−20 −41	−20 −53	−7 −16	−7 −20	0 −9	0 −13	0 −21	0 −33	0 −52	±4.5	±6.5	±10	+11 +2	+15 +2
24	30																
30	40	−50 −112	−25 −41	−25 −50	−25 −64	−9 −20	−9 −25	0 −11	0 −16	0 −25	0 −39	0 −62	±5.5	±8	±12	+13 +2	+18 +2
40	50																
50	65	−60 −134	−30 −49	−30 −60	−30 −76	−10 −23	−10 −29	0 −13	0 −19	0 −30	0 −46	0 −74	±6.5	±9.5	±15	+15 +2	+21 +2
65	80																
80	100	−72 −159	−36 −58	−36 −71	−36 −90	−12 −27	−12 −34	0 −15	0 −22	0 −35	0 −54	0 −87	±7.5	±11	±17	+18 +3	+25 +3
100	120																

In every step given in the table, the value on the upper side shows the upper deviation and the value on the lower side, the lower deviation.

Deviations of Holes to be Used in Commonly Used Fits. (JIS B0401 extrac)

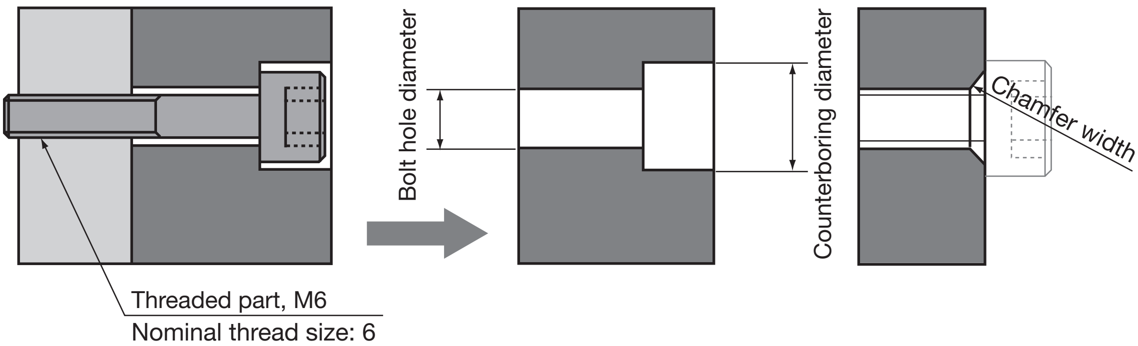
Basic size step (mm)		Tolerance zone class of hole (μm)																
>	≤	E7	E8	E9	F6	F7	F8	G6	G7	H6	H7	H8	H9	H10	JS6	JS7	K6	K7
–	3	+24 +14	+28 +14	+39 +14	+12 +6	+16 +6	+20 +6	+8 +2	+12 +2	+6 0	+10 0	+14 0	+25 0	+40 0	±3	±5	0 −6	0 −10
3	6	+32 +20	+38 +20	+50 +20	+18 +10	+22 +10	+28 +10	+12 +4	+16 +4	+8 0	+12 0	+18 0	+30 0	+48 0	±4	±6	+2 −6	+3 −9
6	10	+40 +25	+47 +25	+61 +25	+22 +13	+28 +13	+35 +13	+14 +5	+20 +5	+9 0	+15 0	+22 0	+36 0	+58 0	±4.5	±7	+2 −7	+5 −10
10	14	+50 +32	+59 +32	+75 +32	+27 +16	+34 +16	+43 +16	+17 +6	+24 +6	+11 0	+18 0	+27 0	+43 0	+70 0	±5.5	±9	+2 −9	+6 −12
14	18																	
18	24	+61 +40	+73 +40	+92 +40	+33 +20	+41 +20	+53 +20	+20 +7	+28 +7	+13 0	+21 0	+33 0	+52 0	+84 0	±6.5	±10	+2 −11	+6 −15
24	30																	
30	40	+75 +50	+89 +50	+112 +50	+41 +25	+50 +25	+64 +25	+25 +9	+34 +9	+16 0	+25 0	+39 0	+62 0	+100 0	±8	±12	+3 −13	+7 −18
40	50																	
50	65	+90 +60	+106 +60	+134 +60	+49 +30	+60 +30	+76 +30	+29 +10	+40 +10	+19 0	+30 0	+46 0	+74 0	+120 0	±9.5	±15	+4 −15	+9 −21
65	80																	
80	100	+107 +72	+126 +72	+159 +72	+58 +36	+71 +36	+90 +36	+34 +12	+47 +12	+22 0	+35 0	+54 0	+87 0	+140 0	±11	±17	+4 −18	+10 −25
100	120																	

In every step given in the table, the value on the upper side shows the upper deviation and the value on the lower side, the lower deviation.

Bolt Hole Diameters

Guideline for bolt hole diameters

A bolt hole diameter is determined as a thread diameter plus some clearance.



● Bolt hole diameter

(Unit: mm)

Nominal thread size	Bolt hole diameter			Chamfer width	Counterboring diameter
	Class 1	Class 2	Class 3		
1	1.1	1.2	1.3	0.2	3
1.2	1.3	1.4	1.5	0.2	4
1.4	1.5	1.6	1.8	0.2	4
1.6	1.7	1.8	2	0.2	5
1.7	1.8	2	2.1	0.2	5
1.8	2	2.1	2.2	0.2	5
2	2.2	2.4	2.6	0.3	7
2.2	2.4	2.6	2.8	0.3	8
2.3	2.5	2.7	2.9	0.3	8
2.5	2.7	2.9	3.1	0.3	8
2.6	2.8	3	3.2	0.3	8
3	3.2	3.4	3.6	0.3	9
3.5	3.7	3.9	4.2	0.3	10
4	4.3	4.5	4.8	0.4	11
4.5	4.8	5	5.3	0.4	13
5	5.3	5.5	5.8	0.4	13
6	6.4	6.6	7	0.4	15
7	7.4	7.6	8	0.4	18
8	8.4	9	10	0.6	20
10	10.5	11	12	0.6	24
12	13	13.5	14.5	1.1	28
14	15	15.5	16.5	1.1	32
16	17	17.5	18.5	1.1	35
18	19	20	21	1.1	39
20	21	22	24	1.2	43
22	23	24	26	1.2	46
24	25	26	28	1.2	50
27	28	30	32	1.2	55

Symbols of Metals

● Carbon steel and alloy steels for structural use

Type	Japan	International	Other countries				
			U.S.A.	Great Britain	Germany	France	Russia
	JIS	ISO	AISI SAE	BS BS/EN	DIN DIN/EN	NF NF/EN	ГОСТ
Carbon steel	S10C	C10	1010	C10 C10E C10R	C10E C10R	C10E C10R	–
	S15C	C15E4 C15M2	1015	C15 C15E C15R	C15E C15R	C15E C15R	–
	S20C	–	1020	C22, C22E C22R	C22 C22E C22R	C22 C22E C22R	–
	S25C	C25 C25E4 C25M2	1025	C25 C25E C25R	C25 C25E C25R	C25 C25E C25R	–
	S30C	C30 C30E4 C30M2	1030	C30 C30E C30R	C30 C30E C30R	C30 C30E C30R	30Г
	S35C	C35 C35E4 C35M2	1035	C35 C35E C35R	C35 C35E C35R	C35 C35E C35R	35Г
	S40C	C40 C40E4 C40M2	1039 1040	C40 C40E C40R	C40 C40E C40R	C40 C40E C40R	40Г
	S43C	–	1042 1043	080A42	–	–	40Г
	S45C	C45 C45E4 C45M2	1045 1046	C45 C45E C45R	C45 C45E C45R	C45 C45E C45R	45Г
	S48C	–	–	–	–	–	45Г
	S50C	C50 C50E4 C50M2	1049	C50 C50E C50R	C50 C50E C50R	C50 C50E C50R	50Г
	S53C	–	1050 1053	–	–	–	50Г
	S55C	C55 C55E4 C55M2	1055	C55 C55E C55R	C55 C55E C55R	C55 C55E C55R	–
	S58C	C60 C60E4 C60M2	1059 1060	C60 C60E C60R	C60 C60E C60R	C60 C60E C60R	60Г

Type		Japan	International	Other countries				
				U.S.A.	Great Britain	Germany	France	Russia
		JIS	ISO	AISI SAE	BS BS/EN	DIN DIN/EN	NF NF/EN	ГОСТ
Alloy steel	Nickel chromium steel	SNC236 SNC415(H) SNC631(H) SNC815(H) SNC836	– – – 15NiCr13 –	– – – – –	– – – 15NiCr13 –	– – – 15NiCr13 –	– – – 15NiCr13 –	40XH – 30XH3A – –
	Nickel chromium molybdenum steel	SNCM220	20NiCrMo2 20NiCrMoS2	8615 8617(H) 8620(H) 8622(H)	20NiCrMo2-2 20NiCrMoS2-2	20NiCrMo2-2 20NiCrMoS2-2	20NiCrMo2-2 20NiCrMoS2-2	–
		SNCM240	41CrNiMo2 41CrNiMoS2	8637 8640	–	–	–	–
		SNCM415 SNCM420(H) SNCM431 SNCM439 SNCM447 SNCM616 SNCM625 SNCM630 SNCM815	– – – – – – – – –	– 4320(H) – 4340 – – – – –	– – – – – – – – –	– – – – – – – – –	– – – – – – – – –	– 20XH2M(20XHM) – – – – – – –

Note: The above chart is based on published data and not authorized by each manufacturer.

Symbols of Metals

● Stainless steel, heat resistant steel

Type		Japan JIS	International ISO	Other countries U.S.A. AISI SAE	Great Britain BS BS/EN	Germany DIN DIN/EN	France NF NF/EN	Russia ГОСТ
Alloy steel	Chromium steel	SCr415(H)	–	–	17Cr3 17CrS3	17Cr3 17CrS3	17Cr3 17CrS3	15X 15XA
		SCr420(H)	20Cr4(H) 20CrS4	5120(H)	–	–	–	20X
		SCr430(H)	34Cr4 34CrS4	5130(H) 5132(H)	34Cr4 34CrS4	34Cr4 34CrS4	34Cr4 34CrS4	30X
		SCr435(H)	34Cr4 34CrS4 37Cr4 37CrS4	5132	37Cr4 37CrS4	37Cr4 37CrS4	37Cr4 37CrS4	35X
		SCr440(H)	37Cr4 37CrS4 41Cr4 41CrS4	5140(H)	530M40 41Cr4 41CrS4	41Cr4 41CrS4	41Cr4 41CrS4	40X
		SCr445(H)	–	–	–	–	–	45X
	Chromium molybdenum steel	SCM415(H)	–	–	–	–	–	–
		SCM418(H)	18CrMo4 18CrMoS4	–	18CrMo4 18CrMoS4	18CrMo4 18CrMoS4	18CrMo4 18CrMoS4	20XM
		SCM420(H)	–	–	708M20(708H20)	–	–	20XM
		SCM430	–	4130	–	–	–	30XM 30XMA
		SCM432	–	–	–	–	–	–
		SCM435(H)	34CrMo4 34CrMoS4	4137(H)	34CrMo4 34CrMoS4	34CrMo4 34CrMoS4	34CrMo4 34CrMoS4	35XM
		SCM440(H)	42CrMo4 42CrMoS4	4140(H) 4142(H)	42CrMo4 42CrMoS4	42CrMo4 42CrMoS4	42CrMo4 42CrMoS4	–
		SCM445(H)	–	4145(H) 4147(H)	–	–	–	–
	Manganese steel and manganese chromium steel	SMn420(H)	22Mn6(H)	1522(H)		–	–	–
		SMn433(H)	–	1534	–	–	–	30Г2 35Г2
		SMn438(H)	36Mn6(H)	1541(H)	–	–	–	35Г2 40Г2
		SMn443(H)	42Mn6(H)	1541(H)	–	–	–	40Г2 45Г2
		SMnC420(H)	–	–	–	–	–	–
		SMnC443(H)	–	–	–	–	–	–
	Aluminium chromium molybdenum steel	SACM645	41CrAlMo74	–	–	–	–	–

● Stainless steel, heat resistant steel

Type		Japan JIS	International ISO	Other countries U.S.A. UNS	U.S.A. AISI SAE	Great Britain BS BS/EN	Germany DIN DIN/EN	France NF NF/EN	Russia ГОСТ
Stainless steel	Austenitic	SUS201	X12CrMnNiN17-7-5	S20100	201			Z12CMN17-07Az	
		SUS202	X12CrMnNiN18-9-5	S20200	202	284S16			12X17Г9AH4
		SUS301	X10CrNi18-8	S30100	301	301S21	X12CrNi17-7	Z11CN17-08	07X16H6
		SUS301L	X2CrNiN18-7				X2CrNiN18-7		
		SUS301J1					X12CrNi17-7		
		SUS302		S30200	302	302S25		Z12CN18-09	12X18H9
		SUS302B	X12CrNiSi18-9-3	S30215	302B				
		SUS303	X10CrNiS18-9	S30300	303	303S21	X10CrNiS18-9	Z8CNF18-09	
		SUS303Se		S30323	303Se	303S41			12X18H10E
		SUS303Cu							
		SUS304	X5CrNi18-9	S30400	304	304S31	X5CrNi18-10	Z7CN18-09	08X18H10
		SUS304L	X2CrNi18-9	S30403	304L	304S11	X2CrNi19-11	Z3CN19-11	03X18H11
		SUS304N1	X5CrNiN18-8	S30451	304N			Z6CN19-09Az	
		SUS304N2		S30452					
		SUS304LN	X2CrNiN18-9	S30453	304LN		X2CrNiN18-10	Z3CN18-10Az	
		SUS304J1							
		SUS304J2							
		SUS304J3		S30431	S30431				
		SUS305	X6CrNi18-12	S30500	305	305S19	X5CrNi18-12	Z8CN18-12	06X18H11

Note: The above chart is based on published data and not authorized by each manufacturer.

● **Stainless steel, heat resistant steel**

Type		Japan	International	Other countries					
				U.S.A.		Great Britain	Germany	France	Russia
		JIS	ISO	UNS	AISI SAE	BS BS/EN	DIN DIN/EN	NF NF/EN	ГОСТ
Stainless steel	Austenitic	SUS305J1							
		SUS309S		S30908	309S			Z10CN24-13	
		SUS310S	X6CrNi25-21	S31008	310S	310S31		Z8CN25-20	10X23H18
		SUS315J1							
		SUS315J2							
		SUS316	X5CrNiMo17-12-2 X3CrNiMo17-12-3	S31600	316	316S31	X5CrNiMo17-12-2 X5CrNiMo17-13-3	Z7CND17-12-02 Z6CND18-12-03	
		SUS316F							
		SUS316L	X2CrNiMo17-12-2 X2CrNiMo17-12-3 X2CrNiMo18-14-3	S31603	316L	316S11	X2CrNiMo17-13-2 X2CrNiMo17-14-3	Z3CND17-12-02 Z3CND17-12-03	03X17H14M3
		SUS316N		S31651	316N				
		SUS316LN	X2CrNiMoN17-11-2 X2CrNiMoN17-12-3	S31653	316LN		X2CrNiMoN17-12-2 X2CrNiMoN17-13-3	Z3CND17-11Az Z3CND17-12Az	
		SUS316Ti	X6CrNiMoTi17-12-2	S31635			X6CrNiMoTi17-12-2	Z6CNDT17-12	08X17H13M2T
		SUS316J1							
		SUS316J1L							
		SUS317		S31700	317	317S16			
		SUS317L	X2CrNiMo19-14-4	S31703	317L	317S12	X2CrNiMo18-16-4	Z3CND19-15-04	
		SUS317LN	X2CrNiMoN18-12-4	S31753				Z3CND19-14Az	
		SUS317J1							
		SUS317J2							
		SUS317J3L							
		SUS836L		N08367					
		SUS890L	X1CrNiMoCu25-20-5	N08904	N08904	904S14		Z2NCDU25-20	
		SUS321	X6CrNiTi18-10	S32100	321	321S31	X6CrNiTi18-10	Z6CNT18-10	08X18H10T
		SUS347	X6CrNiNb18-10	S34700	347	347S31	X6CrNiNb18-10	Z6CNNb18-10	08X18H12Б
		SUS384	X3NiCr18-16	S38400	384			Z6CN18-16	
		SUSXM7	X3CrNiCu18-9-4	S30430	304Cu	394S17		Z2CNU18-10	
		SUSXM15J1		S38100				Z15CNS20-12	
	Austenitic Ferritic	SUS329J1		S32900	329				
		SUS329J3L	X2CrNiMoN22-5-3	S31803	31803			Z3CNDU22-05Az	08X21H6M2T
		SUS329J4L	X2CrNiMoCuN25-6-3	S32250	32250			Z3CNDU25-07Az	
	Ferritic	SUS405	X6CrAl13	S40500	405	405S17	X6CrAl13	Z8CA12	
		SUS410L						Z3C14	
		SUS429		S42900	429				
		SUS430	X6Cr17	S43000	430	430S17	X6Cr17	Z8C17	12X17
		SUS430F	X7CrS17	S43020	430F		X7CrS18	Z8CF17	
		SUS430LX	X3CrTi17 X3CrNb17	S43035			X6CrTi17	Z4CT17	
		SUS430J1L	X2CrTi17				X6CrNb17	Z4CNb17	
		SUS434	X6CrMo17-1	S43400	434	434S17	X6CrMo17-1	Z8CD17-01	
		SUS436L	X1CrMoTi16-1	S43600	436				
		SUS436J1L							
		SUS444	X2CrMoTi18-2	S44400	444			Z3CDT18-02	
		SUS445J1							
		SUS445J2							
		SUS447J1		S44700					
		SUSXM27		S44627				Z1CD26-01	
	Martensitic	SUS403		S40300	403				
		SUS410	X12Cr13	S41000	410	410S21	X10Cr13	Z13C13	
		SUS410S	X6Cr13	S41008	410S	403S17	X6Cr13	Z8C12	08X13
		SUS410F2							
		SUS410J1		S41025					
		SUS416	X12CrS13	S41600	416	416S21		Z11CF13	
		SUS420J1	X20Cr13	S42000	420	420S29	X20Cr13	Z20C13	20X13
		SUS420J2	X30Cr13	S42000	420	420S37	X30Cr13	Z33C13	30X13
		SUS420F	X29CrS13	S42020	420F			Z30CF13	
		SUS420F2							
		SUS429J1							
		SUS431	X19CrNi16-2	S43100	431	431S29	X20CrNi17-2	Z15CN16-02	20X17H2
		SUS440A	X70CrMo15	S44002	440A			Z70C15	
		SUS440B		S44003	440B				
		SUS440C	X105CrMo17	S44004	440C			Z100CD17	95X18
		SUS440F		S44020	S44020				
	Precipitation hardening type	SUS630	X5CrNiCuNb16-4	S17400	S17400			Z6CNU17-04	
		SUS631	X7CrNiAl17-7	S17700	S17700		X7CrNiAl17-7	Z9CNA17-07	09X17H7Ю
		SUS631J1							

Note: The above chart is based on published data and not authorized by each manufacturer.

Technical Reference

15

Symbols of Metals

Type		Japan	International	Other countries					
				U.S.A.		Great Britain	Germany	France	Russia
		JIS	ISO	UNS	AISI SAE	BS BS/EN	DIN DIN/EN	NF NF/EN	ГОСТ
Heat resistant steel	Austenitic	SUH31				331S42		Z35CNWS14-14	45X14H14B2M
		SUH35		S63008		349S52		Z52CMN21-09Az	
		SUH36				349S54	X53CrMnNi21-9	Z55CMN21-09Az	55X20Г9 AH4
		SUH37		S63017		381S34			
		SUH38							
		SUH309		S30900	309	309S24		Z15CN24-13	
		SUH310		S31000	310	310S24	CrNi2520	Z15CN25-20	20X25H20C2
		SUH330		N08330	N08330			Z12NCS35-16	
		SUH660		S66286				Z6NCTV25-20	
		SUH661		R30155					
	Ferritic	SUH21					CrAl1205		
		SUH409	X6CrTi12	S40900	409	409S19	X6CrTi12	Z6CT12	
		SUH409L	X2CrTi12					Z3CT12	
		SUH446		S44600	446			Z12C25	15X28
	Martensitic	SUH1		S65007		401S45	X45CrSi9-3	Z45CS9	
		SUH3						Z40CSD10	40X10C2M
		SUH4				443S65		Z80CSN20-02	
		SUH11							40X9C2
		SUH600							20X12BHMБФP
		SUH616		S42200					

● Tool steel

Type	Japan	International	U.S.A.
	JIS	ISO	AISI ASTM
Carbon tool steel	SK140	–	–
	SK120	C120U	W1-11 1/2
	SK105	C105U	W1-10
	SK95	–	W1-9
	SK90	C90U	–
	SK85	–	W1-8
	SK80	C80U	–
	SK75	–	–
	SK70	C70U	–
	SK65	–	–
	SK60	–	–
High speed steel	SKH2	HS18-0-1	T1
	SKH3	–	T4
	SKH4	–	T5
	SKH10	–	T15
	SKH40	HS6-5-3-8	–
	SKH50	HS1-8-1	–
	SKH51	HS6-5-2	M2
	SKH52	HS6-6-2	M3-1
	SKH53	HS6-5-3	M3-2
	SKH54	HS6-5-4	M4
	SKH55	HS6-5-2-5	–
	SKH56	–	M36
	SKH57	HS10-4-3-10	–
	SKH58	HS2-9-2	M7
	SKH59	HS2-9-1-8	M42
Alloy tool steel	SKS11	–	F2
	SKS2	–	–
	SKS21	–	–

Type	Japan	International	U.S.A.
	JIS	ISO	AISI ASTM
Alloy tool steel	SKS5	–	–
	SKS51	–	L6
	SKS7	–	–
	SKS81	–	–
	SKS8	–	–
	SKS4	–	–
	SKS41	–	–
	SKS43	105V	W2-9 1/2
	SKS44	–	W2-8 1/2
	SKS3	–	–
	SKS31	–	–
	SKS93	–	–
	SKS94	–	–
	SKS95	–	–
	SKD1	X210Cr12	D3
	SKD2	X210CrW12	–
	SKD10	X153CrMoV12	–
	SKD11	–	D2
	SKD12	X100CrMoV5	A2
	SKD4	–	–
	SKD5	X30WCrV9-3	H21
	SKD6	–	H11
	SKD61	X40CrMoV5-1	H13
	SKD62	X35CrWMoV5	H12
	SKD7	32CrMoV12-28	H10
	SKD8	38CrCoWV18-17-17	H19
	SKT3	–	–
	SKT4	55NiCrMoV7	–
	SKT6	45NiCrMo16	–

● Special use steels

Type	Japan	International	U.S.A.
	JIS	ISO	AISI ASTM
Free cutting carbon steels	SUM11	–	1110
	SUM12	–	1109
	SUM21	9S20	1212
	SUM22	11SMn28	1213
	SUM22L	11SMnPb28	–
	SUM23	–	1215
	SUM23L	–	–
	SUM24L	11SMnPb28	12L14
	SUM25	12SMn35	–
	SUM31	–	1117
	SUM31L	–	–

Type	Japan	International	U.S.A.
	JIS	ISO	AISI ASTM
Free cutting carbon steels	SUM32	–	–
	SUM41	–	1137
	SUM42	–	1141
	SUM43	44SMn28	1144
High carbon chromium	SUJ1	–	–
	SUJ2	B1	52100
	SUJ3	B2	ASTM A 485 Grade 1
	SUJ4	–	–
	SUJ5	–	–

Note: The above chart is based on published data and not authorized by each manufacturer.

● Casting or forging steels

Type		Japan	International	Other countries				
				U.S.A.	Great Britain	Germany	France	Russia
		JIS	ISO	AISI ASTM	BS BS/EN	DIN DIN/EN	NF NF/EN	ГОСТ
Casting steel	Carbon steel casting	SC	200-400, 230-450, 270-480	U-	A1, A2	GS-	GE230, GE280, GE320	–
	Steel casting for welded structure	SCW	200-400W, 230-450W, 270-480W, 340-550W	WCA, WCB, WCC	A4	–	GE230, GE280	–
	Heat resisting steel casting	SCH	GX40CrSi24, GX40CrNiSi22-10, GX40NiCrSi38-19	Grade HC, HD, HF	309C30, 310C45, 330C12	–	GX40NiCrNb45-35, GX50NiCrCoW35-25-15-5	–
	Steel casting for high temperature and high pressure service	SCPH	–	Grade WC1, WC6, WC9	A1, A2, B1, B2, B3, B4, B5, B7	G20Mo5, G17CrMo5-5, G17CrMo5-10	G17CrMo9-10, GX15CrMo5, GP240GH, GP280GH	–
	Steel casting for low temperature and high pressure service	SCPL	–	Grade LCB, LC1, LC2, LC3	AL1, BL2	–	FB-M, FC1-M, FC2-M,FC3-M	–
Casting iron	Grey iron casting	FC	100,150,200,250, 300,350	No.20,25,30,35, 40,45,50	EN-GJL-	EN-GJL-	EN-GJL-	–
	Spheroidal graphite iron casting	FCD	700-2, 600-3, 500-7, 450-10, 400-15, 400-18, 350-22	60-40-18, 65-45-12, 8-55-06, 100-70-03, 120-90-02	EN-GJS-	EN-GJS-	EN-GJS-	ВЧ
	Austempered spheroidal graphite iron casting	FCAD	–	–	EN-GJS-	EN-GJS-	EN-GJS-	–
	Austenitic iron casting	FCA- FCDA-	L-, S-	Type 1, 2, Type D-2, D-3A Class 1, 2	F1, F2, S2W, S5S	GGL-, GGG-	L-, S-	–
Forging steel	Carbon steel forging for general use	SF	–	Class A, B, C, D, E, F	C22, C25, C30, C35, C40, C45, C50, C55, C60	P285, P355	P245, P280, P305	–
	Chromium molybdenum steel forgings for general use	SFCM	–	Class E, F, G, I Grade 3A, 4 Class G, J, K, L, M	–	–	–	–
	Nickel Chromium molybdenum steel forgings for general use	SFNCM	–	Class G, H, I, J Class 3A, 4, 5, 6 Class K, L, M	–	–	–	–

● Non-ferrous alloys

Type		Japan	International	Other countries			
				U.S.A.		Great Britain	Germany
		JIS	ISO	ASTM	SAE	BS BS/EN	DIN DIN/EN
Copper alloy, Nickel alloy	Copper alloy casting	CAC101	–	–	–	–	
		CAC102	–	–	–	Cu-C(CC040AgrodeC)	
		CAC103	–	–	–	Cu-C(CC040AgrodeA,B)	
	Brass casting	CAC201	–	–	–	CuZn15As-C(CC760S)	
		CAC202	–	C85400	–	CuZn33Pb2-C(CC750S)	
		CAC203	–	C85700	–	CuZn39Pb1-C(CC754S)	
	High strength brass casting	CAC301	–	C86500	–	CuZn35Mn2Al1Fe-C(CC765S)	
		CAC302	–	C86400	–	CuZn34Mn3Al2Fe1-C(CC764S)	
		CAC303	–	C86200	–	CuZn25Al5Mn4Fe3-C(CC762S)	
		CAC304	–	C86300	–	CuZn25Al5Mn4Fe3-C(CC762S)	
	Bronze casting	CAC401	–	C84400	–	CuSn3Zn8Pb5-C(CC490K)	
		CAC402	–	C90300	–	–	
		CAC403	–	C90500	–	–	
		CAC406	–	C83600	–	CuSn5Zn5Pb5-C(CC490K)	
		CAC407	–	C92200	–	–	
	Phosphor bronze casting	CAC502A	–	C90700 C90800	–	CuSn10-C(CC480K) CuSn12-C(CC483K)	
		CAC502B	–		–		
		CAC503A	–		–		
		CAC503B	–		–		
	Aluminium bronze casting	CAC701	–	C95200	–	CuAl10Fe2-C(CC331G)	
		CAC702	–	C95400	–	CuAl10Ni3Fe2-C(CC332G)	
			–	C95410	–		
		CAC703	–	C95800	–	CuAl10Fe5Ni5-C(CC333G)	
		CAC704	–	C95700	–	–	
	Silicon bronze castings	CAC801	–	–	–	–	
		CAC802	–	C87500	–	–	
		CAC803	–	C87400	–	CuZn16Si4-C(CC761S)	

Note: The above chart is based on published data and not authorized by each manufacturer.

Symbols of Metals

<table>
<tr><th rowspan="3" colspan="2">Type</th><th>Japan</th><th>International</th><th colspan="4">Other countries</th></tr>
<tr><th rowspan="2">JIS</th><th rowspan="2">ISO</th><th>U.S.A.</th><th>Great Britain</th><th>Germany</th><th>France</th></tr>
<tr><th>ASTM
SAE</th><th>BS
BS/EN</th><th>DIN
DIN/EN</th><th>NF
NF/EN</th></tr>
<tr><td rowspan="25">Aluminium alloy</td><td rowspan="16">Aluminium alloy ingots for casting</td><td>AC1B</td><td>Al-Cu4MgTi</td><td>204.0</td><td colspan="3">EN AC-2100</td></tr>
<tr><td>AC2A</td><td>–</td><td>–</td><td colspan="3">–</td></tr>
<tr><td>AC2B</td><td>–</td><td>319.0</td><td colspan="3">–</td></tr>
<tr><td>AC3A</td><td>–</td><td>–</td><td colspan="3">EN AC-44100</td></tr>
<tr><td>AC4A</td><td>–</td><td>–</td><td colspan="3">–</td></tr>
<tr><td>AC4B</td><td>Al-Si8Cu3</td><td>333.0</td><td colspan="3">EN AC-46200</td></tr>
<tr><td>AC4C</td><td>Al-Si7Mg(Fe)</td><td>356.0</td><td colspan="3">EN AC-42000</td></tr>
<tr><td>AC4CH</td><td>Al-Si7Mg0.3</td><td>A356.0</td><td colspan="3">EN AC-42100</td></tr>
<tr><td>AC4D</td><td>–</td><td>355.0</td><td colspan="3">EN AC-45300</td></tr>
<tr><td>AC5A</td><td>Al-Cu4Ni2Mg2</td><td>242.0</td><td colspan="3">–</td></tr>
<tr><td>AC7A</td><td>–</td><td>514.0</td><td colspan="3">–</td></tr>
<tr><td>AC8A</td><td>Al-Si12CuNiMg</td><td>–</td><td colspan="3">EN AC-48000</td></tr>
<tr><td>AC8B</td><td>–</td><td>–</td><td colspan="3">–</td></tr>
<tr><td>AC8C</td><td>–</td><td>332.0</td><td colspan="3">–</td></tr>
<tr><td>AC9A</td><td>–</td><td>–</td><td colspan="3">–</td></tr>
<tr><td>AC9B</td><td>–</td><td>–</td><td colspan="3">–</td></tr>
<tr><td rowspan="9">Aluminium alloy die casting</td><td>ADC1</td><td>–</td><td>A413.0</td><td colspan="3">–</td></tr>
<tr><td>ADC3</td><td>–</td><td>A360.0</td><td colspan="3">–</td></tr>
<tr><td>ADC5</td><td>–</td><td>518.0</td><td colspan="3">–</td></tr>
<tr><td>ADC6</td><td>–</td><td>–</td><td colspan="3">–</td></tr>
<tr><td>ADC10</td><td>–</td><td>–</td><td colspan="3">–</td></tr>
<tr><td>ADC10Z</td><td>–</td><td>A380.0</td><td colspan="3">–</td></tr>
<tr><td>ADC12</td><td>–</td><td>–</td><td colspan="3">–</td></tr>
<tr><td>ADC12Z</td><td>–</td><td>383.0</td><td colspan="3">–</td></tr>
<tr><td>ADC14</td><td>–</td><td>B390.0</td><td colspan="3">–</td></tr>
<tr><td rowspan="10">Magnesium alloy</td><td rowspan="6">Magnesium alloy casting</td><td>MC5</td><td>–</td><td>AM100A</td><td colspan="3">–</td></tr>
<tr><td>MC6</td><td>–</td><td>ZK51A</td><td colspan="3">–</td></tr>
<tr><td>MC7</td><td>–</td><td>ZK61A</td><td colspan="3">–</td></tr>
<tr><td>MC8</td><td>MgRE3Zn2Zr</td><td>EZ33A</td><td colspan="3">EN MC65120</td></tr>
<tr><td>MC9</td><td>MgAg3RE2Zr</td><td>QE22A</td><td colspan="3">EN MC65210</td></tr>
<tr><td>MC10</td><td>MgZn4RE1Zr</td><td>ZE41A</td><td colspan="3">EN MC35110</td></tr>
<tr><td rowspan="4">Magnesium alloy die casting</td><td>MD1A</td><td>–</td><td>AZ91A</td><td colspan="3">G-A9Z1Y4</td></tr>
<tr><td>MDC1B</td><td>–</td><td>AZ91B</td><td colspan="3">–</td></tr>
<tr><td>MDC1D</td><td>MgAl9Zn1(A)</td><td>AZ91D</td><td colspan="3">EN MC21120</td></tr>
<tr><td>MDC2B</td><td>MgAl6Mn</td><td>AM60B</td><td colspan="3">EN MC21320</td></tr>
<tr><th rowspan="3" colspan="2">Type</th><th>Japan</th><th>International</th><th colspan="4">Other countries</th></tr>
<tr><th rowspan="2">JIS</th><th rowspan="2">ISO</th><th>U.S.A.</th><th>Great Britain</th><th>Germany</th><th>France</th></tr>
<tr><th>ASTM
AA</th><th>BS
BS/EN</th><th>DIN
DIN/EN</th><th>NF
NF/EN</th></tr>
<tr><td rowspan="9">Aluminium alloy</td><td rowspan="9">Aluminium alloy extruded shapes</td><td>A5052S</td><td>–</td><td>5052</td><td colspan="3">EN AW-5052</td></tr>
<tr><td>A5454S</td><td>–</td><td>5454</td><td colspan="3">EN AW-5454</td></tr>
<tr><td>A5083S</td><td>AlMg4.5Mn0.7</td><td>5083</td><td colspan="3">EN AW-5083</td></tr>
<tr><td>A5086S</td><td>–</td><td>5086</td><td colspan="3">EN AW-5086</td></tr>
<tr><td>A6061S</td><td>AlMg1SiCu</td><td>6061</td><td colspan="3">EN AW-6061</td></tr>
<tr><td>A6063S</td><td>AlMg0.7Si</td><td>6063</td><td colspan="3">EN AW-6063</td></tr>
<tr><td>A7003S</td><td>–</td><td>–</td><td colspan="3">EN AW-7003</td></tr>
<tr><td>A7N01S</td><td>–</td><td>–</td><td colspan="3">–</td></tr>
<tr><td>A7075S</td><td>AlZn5.5MgCu</td><td>7075</td><td colspan="3">EN AW-7075</td></tr>
</table>

Note: The above chart is based on published data and not authorized by each manufacturer.

Approximate Conversion Table of Hardness

● Approximate conversion value for Brinell hardness.

(The source: JIS HB Ferrous Materials and Metallurgy I -2005)

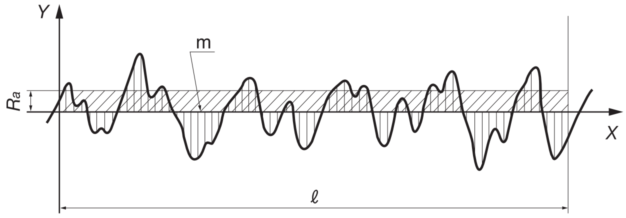
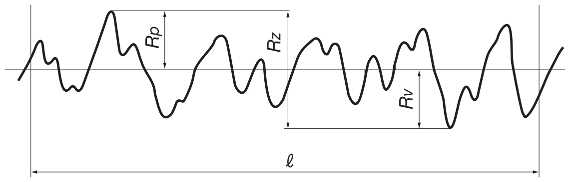
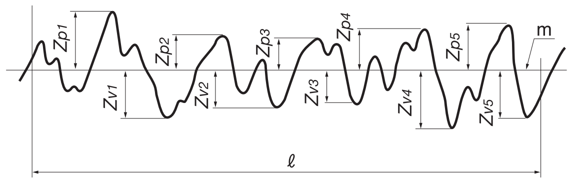
HB Brinell, 10mm ball, Load 3000kg		HV	Rockwell				HS	Approx. tensile strength (Mpa)
Standard ball	Tungsten carbide ball	Vickers	HRA A Scale, Load 60kg, Brale Diamond	HRB B Scale, Load 100kg, Diameter 1/16 in. Steel ball	HRC C Scale, Load 150kg, brale diamond	HRD D Scale, Load 100kg, Brale Diamond	Shore	
–	–	940	85.6	–	68.0	76.9	97	–
–	–	920	85.3	–	67.5	76.5	96	–
–	–	900	85.0	–	67.0	76.1	95	–
–	(767)	880	84.7	–	66.4	75.7	93	–
–	(757)	860	84.4	–	65.9	75.3	92	–
–	(745)	840	84.1	–	65.3	74.8	91	–
–	(733)	820	83.8	–	64.7	74.3	90	–
–	(722)	800	83.4	–	64.0	73.8	88	–
–	(712)	–	–	–	–	–	–	–
–	(710)	780	83.0	–	63.3	73.3	87	–
–	(698)	760	82.6	–	62.5	72.6	86	–
–	(684)	740	82.2	–	61.8	72.1	–	–
–	(682)	737	82.2	–	61.7	72.0	84	–
–	(670)	720	81.8	–	61.0	71.5	83	–
–	(656)	700	81.3	–	60.1	70.8	–	–
–	(653)	697	81.2	–	60.0	70.7	81	–
–	(647)	690	81.1	–	59.7	70.5	–	–
–	(638)	680	80.8	–	59.2	70.1	80	–
–	630	670	80.6	–	58.8	69.8	–	–
–	627	667	80.5	–	58.7	69.7	79	–
–	–	677	80.7	–	59.1	70.0	–	–
–	601	640	79.8	–	57.3	68.7	77	–
–	–	640	79.8	–	57.3	68.7	–	–
–	578	615	79.1	–	56.0	67.7	75	–
–	–	607	78.8	–	55.6	67.4	–	–
–	555	591	78.4	–	54.7	66.7	73	2055
–	–	579	78.0	–	54.0	66.1	–	2015
–	534	569	77.8	–	53.5	65.8	71	1985
–	–	553	77.1	–	52.5	65.0	–	1915
–	514	547	76.9	–	52.1	64.7	70	1890
(495)	–	539	76.7	–	51.6	64.3	–	1855
–	–	530	76.4	–	51.1	63.9	–	1825
–	495	528	76.3	–	51.0	63.8	68	1820
(477)	–	516	75.9	–	50.3	63.2	–	1780
–	–	508	75.6	–	49.6	62.7	–	1740
–	477	508	75.6	–	49.6	62.7	66	1740
(461)	–	495	75.1	–	48.8	61.9	–	1680
–	–	491	74.9	–	48.5	61.7	–	1670
–	461	491	74.9	–	48.5	61.7	65	1670
444	–	474	74.3	–	47.2	61.0	–	1595
–	–	472	74.2	–	47.1	60.8	–	1585
–	444	472	74.2	–	47.1	60.8	63	1585

HB Brinell, 10mm ball, Load 3000kg		HV	Rockwell				HS	Approx. tensile strength (Mpa)
Standard ball	Tungsten carbide ball	Vickers	HRA A Scale, Load 60kg, Brale Diamond	HRB B Scale, Load 100kg, Diameter 1/16 in. Steel ball	HRC C Scale, Load 150kg, brale diamond	HRD D Scale, Load 100kg, Brale Diamond	Shore	
429	429	455	73.4	–	45.7	59.7	61	1510
415	415	440	72.8	–	44.5	58.8	59	1460
401	401	425	72.0	–	43.1	57.8	58	1390
388	388	410	71.4	–	41.8	56.8	56	1330
375	375	396	70.6	–	40.4	55.7	54	1270
363	363	383	70.0	–	39.1	54.6	52	1220
352	352	372	69.3	(110.0)	37.9	53.8	51	1180
341	341	360	68.7	(109.0)	36.6	52.8	50	1130
331	331	350	68.1	(108.5)	35.5	51.9	48	1095
321	321	339	67.5	(108.0)	34.3	51.0	47	1060
311	311	328	66.9	(107.5)	33.1	50.0	46	1025
302	302	319	66.3	(107.0)	32.1	49.3	45	1005
293	293	309	65.7	(106.0)	30.9	48.3	43	970
285	285	301	65.3	(105.5)	29.9	47.6	–	950
277	277	292	64.6	(104.5)	28.8	46.7	41	925
269	269	284	64.1	(104.0)	27.6	45.9	40	895
262	262	276	63.6	(103.0)	26.6	45.0	39	875
255	255	269	63.0	(102.0)	25.4	44.2	38	850
248	248	261	62.5	(101.0)	24.2	43.2	37	825
241	241	253	61.8	100.0	22.8	42.0	36	800
235	235	247	61.4	99.0	21.7	41.4	35	785
229	229	241	60.8	98.2	20.5	40.5	34	765
223	223	234	–	97.3	(18.8)	–	–	–
217	217	228	–	96.4	(17.5)	–	33	725
212	212	222	–	95.5	(16.0)	–	–	705
207	207	218	–	94.6	(15.2)	–	32	690
201	201	212	–	93.8	(13.8)	–	31	675
197	197	207	–	92.8	(12.7)	–	30	655
192	192	202	–	91.9	(11.5)	–	29	640
187	187	196	–	90.7	(10.0)	–	–	620
183	183	192	–	90.0	(9.0)	–	28	615
179	179	188	–	89.0	(8.0)	–	27	600
174	174	182	–	87.8	(6.4)	–	–	585
170	170	178	–	86.8	(5.4)	–	26	570
167	167	175	–	86.0	(4.4)	–	–	560
163	163	171	–	85.0	(3.3)	–	25	545
156	156	163	–	82.9	(0.9)	–	–	525
149	149	156	–	80.8	–	–	23	505
143	143	150	–	78.7	–	–	22	490
137	137	143	–	76.4	–	–	21	460
131	131	137	–	74.0	–	–	–	450
126	126	132	–	72.0	–	–	20	435
121	121	127	–	69.8	–	–	19	415
116	116	122	–	67.6	–	–	18	400
111	111	117	–	65.7	–	–	15	385

Note : Figures in ( ) are not commonly used.

Surface Roughness

(According to JIS B 0601, 2001 and its explanation.)

Type	Symbol	How to determine	Example (Fig.)
Arithmetic mean roughness	*Ra*	*Ra* means the value obtained by the following formula and expressed in micrometer (μm) when sampling only the reference length from the roughness curve in the direction of mean line, taking X-axis in the direction of mean line and Y-axis in the direction of longitudinal magnification of this sampled part and the roughness curve is expressed by *y- f* (x): $$Ra=\frac{1}{\ell}\int_0^{\ell}\lvert f(x)\rvert dx$$ where, ℓ : reference length	
Maximum height	*Rz*	*Rz* shall be that only the reference length is sampled from the roughness curve in the direction of mean line, the distance between the top of profile peak line and the bottom of profile valley line on this sampled portion is measured in the longitudinal magnification direction of roughness curve and the obtained value is expressed in micrometer (μm). $$R_z=R_p+R_v$$	
Ten point mean roughness	Rz_{JIS}	Rz_{JIS} shall be that only the reference length is sampled from the roughness curve in the direction of its mean line, the sum of the average value of absolute values of the heights of five highest profile peaks (*Zp*) and the depths of five deepest profile valleys (*Zv*) measured in the vertical magnification direction from the mean line of this sampled portion and this sum is expressed in micrometer (μm) $$Rz_{JIS}=\frac{\lvert Zp1+Zp2+Zp3+Zp4+Zp5\rvert+\lvert Zv1+Zv2+Zv3+Zv4+Zv5\rvert}{5}$$	 where, Z_{p1}, Z_{p2}, Z_{p3}, Z_{p4}, Z_{p5} : altitudes of the heights of five highest profile peaks of the sampled portion corresponding to the reference length l where, Z_{v1}, Z_{v2}, Z_{v3}, Z_{v4}, Z_{v5} : altitudes of the depths of five deepest profile valleys of the sampled portion corresponding to the reference length l

Grade Comparison Charts

●CVD Coated Grades

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Sandvik	Kyocera	Hitachi Tool	Dijet	NTK	Seco Tool	Kennametal	Iscar	Ingersoll	TaeguTec	Widia	Walter	Ceratizit
P Steel	P01	**T9105**	UE6105	AC810P ACP100	GC4205 GC3005	CA5505	HG8010	JC110V JC5003	CP7	TP0500 TP1500	KC9105 KCP05	IC8150 IC9150 IC9015		TT1500	TN10P TN20K	WPP01 WPP05	
	P10	**T9105** **T9115**	UE6105 UE6110 FH7020	AC810P AC820P ACP100	GC1525 GC4205 GC4215 GC1515 GC3005 GC4220 GC4230	CA5505 CA5515	HG8010 GM8020	JC110V JC215V	CP7 CP5	TP0500 TP1500 TP2500 MP1500	KC9110 KC9125 KC9105 KCP10 KCP25	IC8150 IC9150 IC428 IC5005 IC8080 IC9080 IC9015	IN5015	TT1500 TT3500	TN10P TN20K HC-10P WP15CT	WPP01 WPP05 WPP10 WAK20	CTC1110 CTC1115 CTC3110 TCC410
	P20	**T9115** **T9125**	UE6110 UE6020 FH7020 F7030	AC820P AC830P ACP100	GC1525 GC4215 GC1515 GC3005 GC4220 GC4230 GC3020	CA5515 CA5525	HG8010 GM8020 GM8025 GM25	JC110V JC215V	CP7 CP5	TP1500 TP2500 TP3500 TP200 MP1500 MP2500	KC9110 KC9215 KC9225 KC9325	IC8150 IC9150 IC9015 IC8250 IC9250 IC4100 IC5100	IN5015 IN6515	TT3500 TT5100	TN10P TN15M WP10CT HC-P25 WP15CT	WPP10 WPP20 WKP25 WPP30	CTC1110 CTC1115 CTC1125 CTC1130 CTC1425 CTCP125
	P30	**T9125** **T9135** **T3130**	UE6020 UE6035 UH6400 F7030	AC820P AC830P ACP100	GC4225 GC4235 GC4230 GC4240 GC2135	CA5525 CA5535 CR9025	GM8020 HG8025 GM25 GM8035	JC215V JC325V	CP5	TP2500 TP3500 TP200 MP2500	KC9125 KU30T KC935M KCP30	IC8080 IC656 IC9350 IC4050	IN5015 IN6515 IN6530	TT3500 TT5100 KT450	TN30P TN30M WP25CT WP35CT	WPP20 WPP30 WAK10 WKP35S WKP26 WKP35	CTC1125 CTC1130 CTC1135 CTC1425 CTCP125
	P40	**T9135**	UE6035 UH6400	AC830P	GC4235 GC4230 GC4240	CA5535	GM8035 GX30	JC325V JC450V		TP3500 TP40 CP500T350M	KC9140 KC9240 KC9245 KC935M	IC9350 IC635 IC4050 IC635	IN6530	TT5100 KT450	TN30P TN30M WP35CT	WPP30 WAK30 WKP35S WKP35	CTC1135 CTC1435 CTC2135 GM246
M Stainless	M10	**T9115**		AC610M	GC2015	CA6515	HG8025	JC5003 JC110C	CP2 CP5	TP2500		IC8250 IC9250 IC520M			TN15M WM15CT		CTC1110 CTC1115 CPCT125
	M20	**T6120** **T9125** **T6020**	US7020 F7030	AC610M AC630M	GC2015 GC2025	CA6525	HG8025 GM25 GM8035	JC110V	CP2 CP5	TP2500 TP3500 TP200 MP2500	KC8050 KC9225 KC925M	IC8080 IC9054 IC9025 IC9350 IC4050	IN6530	TT5100	TN15M WP25CT WM15CT		CTC1115 CTC1125 CTC1130 CTC1135 CTC1425 CPCT125
	M30	**T6130** **T3130** **T6030**	US735 F7030	AC630M AC830P AC520U	GC2025 GC235 GC2040 GC2135		GM25 GM8035 GX30	JC525X		TP3500 TP200 T350M	KC8050 KC9240 KU30T KC935M	IC635 IC656 IC4050	IN6530	TT5100	TN30M WP25CT WM25CT WM35CT		CTC1125 CTC1135 CTC1425 CTC1435 CTC2135
	M40		US735	AC520U AC530U ACP300	GC235 GC2040		GX30	JC525X		TP40 TM4000 MM4500	KC9240 KC9245	IC635 IC656	IN6530	TT5100	TN30M		CTC2135 GM246
K Cast Iron	K01	**T5105**	UC5105 MC5020	AC410K ACK200	GC3205 GC3005	CA4010 CA4505 CA5505	HG3305	JC050W JC105V JC5003	CP1	TH1500		IC9150 IC4028 IC5010		TT1300		WAK10	
	K10	**T5105** **T5115** **T1115**	UC5105 UC5115 MC5020	AC410K AC420K ACK200	GC1690 GC3205 GC3210 GC3215 GC3005 GC3115 GC3220	CA4010 CA4115 CA4505 CA4515 CA5505	HG3305 HG3315 HG8010	JC105V JC110V	CP1 CP5	TP0500 TK1500 MK1500	KC9315	IC9150 IC4028 IC5010 IC9007 IC4100 IC5100	IN5015	TT1300 TT1500	TN20K WK05CT	WPP01 WAK10 WAK15	CTC1110 CTC1115 CTC3110 TCC410 CTC3215 SR216
	K20	**T5115** **T5125**	UC5115 MC5020	AC420K AC820P ACK200	GC3210 GC3215 GC3005 K20W GC3040 GC3220	CA4115 CA4120 CA4515	HG3315 HG8010 GM8020 HG8025	JC110V JC215V	CP1 CP5	TP0500 TP1500 TP2500 MK1500 T350M	KC9110 KC9315 KC9325 KC915M T250M T200M	IC418 IC4010 IC9015 IC4100 IC5100 IC9150	IN5015 IN6510 IN6515 IN6530	TT1300 TT1500	TN10P TN20K WP10CT WK05CT WK20CT	WPP10 WAK10 WAK20 WKP25 WAK15	CTC1115 CTC1125 CTC1130 CTC1425 CTC3215 TSC30
	K30	**T5125**	MC5020	AC820P	K20W GC3040	CA4120	GM8020 HG8025 GX2030	JC215V	CP5	TP2500 TP200 MK3000	KC8050 KC9125 KC9325 KU30T KC935M	IC520M IC4050	IN5015 IN6515 IN6530		TN20P WP25CT	WPP20 WAK20 WAK30 WKP35S WKP35 WKP25	TSC30 CTCP125

Note: The above chart is based on published data and not authorized by each manufacturer.

Grades (1–1)
TAC Inserts (negative) (2–42)
TAC Inserts (positive) (2–96)
Relating Pages

Grade Comparison Charts

●PVD Coated Grades

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Sandvik	Kyocera	Hitachi Tool	Dijet	NTK	Seco Tool	Kennametal	Iscar	Ingersoll	TaeguTec	Widia	Walter	Ceratizit
P Steel	P01					PR915 PR1005	ATH80D PTH08M PCA08M PCS08M	JC8003				IC903	IN0560 IN2006		TN10U	WXN10	
	P10	**AH710**	VP10RT VP15TF	ACP200		PR915 PR930 PR1005 PR1025 PR1115 PR1225 PR730 PR830	IP2000 ACS05E PCA12M PC20M JX1005 JX1020 JP4020 CY9020	JC730U JC8015 JC5015 JC5030 JC5118	TM1 VM1 TAS	TS2000 CP200	KC5010 KC5510 KU10T KC715M	IC507 IC903 IC950	IN0560 IN2006	TT7010	TN10U TN6505	WSM10 WSM21	
	P20	**AH120** **AH725** **AH730** **SH730**	VP10RT VP15TF VP20MF VP20RT UP20M	ACP200 ACP300	GC1030 GC1145	PR930 PR1025 PR1115 PR1225 PR730 PR830 PR1225 PR1230	IP2000 JX1015 CY150 CY15	JC730U JC5030 JC8015 JC5015 JC5040 JC5118	TM1 VM1 TAS	TS2500 CP200 MP3000 F25M	KC5020 KC5525 KU25T KC522M	IC807 IC507 IC907 IC808 IC908 IC950 IC4100	IN1030 IN1540 IN2006 IN2030 IN2040	TT7010 TT9030 TT7220	TN10U WU10PT TN6505	WSM20 WSM21 WHH15 WXM15	SR226 GM127
	P30	**AH120** **AH725** **AH740** **GH330** **AH130** **GH130** **AH9030** **AH3035**	VP15TF VP20MF VP20RT UP20M	ACP200 ACP300	GC1030	PR660 PR1230	IP3000 JS4060 JX1045 CY250 CY25 HC844 PTH30E	JC5015 JC5030 JC5040 JC5118	QM3 TM4	CP500 MP3000 F30M	KC5025 KC5525 KU25T KC725M	IC250 IC350 IC354 IC508 IC950 IC900	IN1030 IN1540 IN2030 IN2040	TT7010 TT8010 TT9030 TT8020	WU25PT	WSM30	GM40 CTP1235 CTP2235 SR226 GM127 CTP1625
	P40	**AH140**	VP30RT	ACP300	GC1030		IP3000 JS4060 JX1060 GF30	JC5040 JC5118 JC8050	QM3	CP500 F40M T60M	KC735M	IC830 IC928 IC1008 IC1028 IC300 IC330	IN1540 IN2040	TT8020 TT8010 TT9030		WSP45 WSP46	CTP2440 GM40 CTP1235 CTP2235 GM127 CM45
M Stainless	M01						IP050S PCM08M		TAS			IC520 IC807	IN0560			WXM10	
	M10	**AH710**	VP10RT VP15TF	ACP200	GC1025 GC1125 GC1115 GC1030	PR915 PR1025 PR1225 PR730	IP050S IP100S PCS08M	JC730U	TAS TM1 VM1	TS2000 TS2500 CP200	KC5010 KC5510 KU10T	IC520 IC807 IC507 IC907	IN2006	TT5030 TT9030	TN10U WS10PT	WSM10 WSM20 WSM21 WXM15	
	M20	**AH630** **AH725** **AH730** **GH330** **SH730** **GH730**	VP10RT VP15TF VP20MF VP20RT UP20M	ACP200 AC520U	GC1025 GC2015 GC1125 GC1115 GC1030 GC2030	PR915 PR930 PR1025 PR1125 PR1225 PR660 PR730	IP100S JX1015 CY150 CY15	JC8015 JC730U JC5118	QM3 TM4 ZM3	TS2500 CP200 CP500 F25M	KC5010 KC5025 KC5510 KC5525 KC715M	IC354 IC3028 IC330 IC308 IC508 IC808 IC908	IN1030 IN2005 IN2006 IN2505	TT5030 TT8820 TT9030	TN10U WU10PT WU25PT WS10PT WS25PT	WSM10 WSM20 WSM30 WSM21 WXM15	CTP2120 CTP1235 SR226 GM127
	M30	**AH120** **AH645** **AH725** **AH130** **GH130**	VP15TF VP20MF VP20RT UP20M	ACP300 AC520U AC530U	GC1125 GC2035 GC1040 GC2030 GC1145	PR1125 PR660	IP100S JX1045 CY250 CY25 HC844	JC5015 JC8015 JC5118 JC8050	QM3 TM4	CP500 F30M F40M	KC5025 KC5525 KU25T KC552M	IC3028 IC330 IC250 IC300 IC830 IC928 IC1008 IC1028	IN1030 IN1530 IN2005 IN2505 IN2030	TT8020 TT9030	WU25PT WS25PT	WSM20 WSM30 WSM21 WSM35 WSM36	CTP2240 CTP1235 CTP2235 SR226 GM127
	M40	**AH140**	VP30RT	AC520U AC530U ACP300	GC2035 GC1040		JX1060 GF30	JC8050	QM3 TM4	F40M	KC725M KC735M	IC250 IC300 IC328 IC330	IN1030 IN2005 IN2505 IN2030	TT8020 TT9030		WSM30 WSP45 WSM35 WSP46 WSP36	CM40 CM45 CTP2440 CTP2235
K Cast Iron	K01	**AH110**			GC4014			JC8003	CP1			IC910					
	K10	**GH110** **AH110**			GC1210 GC1020	PR905 PR1210	PTH08M PCA08M PCS08M	JC600 JC605X JC605W JC610	CP1	CP200	KC5010 KC5510 KU10T KC510M	IC910 IC4100 IC810 IC900	IN2004 IN2010 IN2015	TT9030	TN10U TN5515 TN6505 TN6510	WHH15 WXM15	SR216 SR226 CTP4115 AMZ
	K20	**AH120**	VP10RT VP20RT VP15TF	ACK300	GC1210 GC1220 GC1020 K20	PR905 PR1210	JX1020 CY100H CY9020 JX1015	JC600 JC610 JC8015 JC5015	CP1	CP200 CP250	KC5025 KC5525 KU25T KC520M	IC910 IC308 IC508 IC350 IC380	IN1030 IN1510 IN2010 IN2015 INDD15	TT9030	TN10U WU10PT WU25PT TN6505 TN6520	WSM10 WKK25	CTP2120 CTP2440 SR216 SR226 CTP3220
	K30	**GH130**	VP10RT VP20RT VP15TF	ACK300	GC1220 GC1020 P20		JX1045 CY250 CY25	JC5015 JC5080		CP500	KC5025 KC5525 KU25T	IC350 IC830 IC828 IC1008	IN1030 IN1510 IN1530 IN2010 IN2015	TT9030	WU25PT	WSM10 WKK25	CTP2440

Note: The above chart is based on published data and not authorized by each manufacturer.

Grade Comparison Charts

●PVD Coated Grades

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Sandvik	Kyocera	Hitachi Tool	Dijet	NTK	Seco Tool	Kennametal	Iscar	Ingersoll	TaeguTec	Widia	Walter	Ceratizit
N Non-ferrous	N01						PCS08M									WXN10	
	N10	DS1100 DS1200		DL1000			SD5010 HD7010 CY100H CY10H	JC10000 JC20000		F15M F17M	KC5010 KC5410 KC5510 KU10T	IC520		TT9030	TN10U	WXN10 WXN15	
	N20		LC15TF	DL1000						F15M F17M	KC5025 KC5525 KU25T	IC808 IC908	IN2005	TT9030	TN10U WU10PT WU25PT	WXN10 WXN15	CTP2120 CTP2440
S Superalloys	S01	AH110 AH710 AH905	VP05RT	ACK300	GC1010	PR915		JC8003				IC507 IC907			WS1-PT	WSM10	
	S10	AH120 AH905	VP10RT VP20RT VP15TF MP9030	AC510U AC520U ACK300	GC1105 GC1005 GC1025 S30T GC1030 GC1010	PR915	PCS08M PTH13S JS1025	JC8015 JC5015 JC5118	QM3 ZM3	TS2000 TS2500 CP200 CP500	KC5010 KC5510 KU10T KC510M	IC507 IC903 IC907	IN2006	TT5030 TT9030	TN10U WS10PT	WSM10 WSM20 WSM21	CM40 SR226
	S20	AH730 SH730	VP10RT VP20RT VP15TF MP9030	AC520U ACP300	GC1105 GC1115 GC1005 GC1025 S30T	PR915	CY100H CY10H	JC5118 JC5015 JC8050	QM3 ZM3	TS2000 TS2500 CP200 CP500 F40M	KC5025 KC5525 KU25T KC522M	IC300 IC808 IC908 IC830 IC928	IN2005 IN2006 IN1030	TT5030 TT9030	TN10U WU10PT WU25PT WS25PT	WSM10 WSM20 WSM30 WSM21	CM45 CTP2440 GM127 CTP5110
	S30		VP15TF VP20RT MP9030	ACP300				JC8050	QM3 ZM3	CP500 F40M	KC5025 KC5525 KU25T	IC839 IC928	IN2005 IN1030	TT8020 TT9030	WU25PT WS25PT	WSM20 WSM30 WSM21 WSM35 WSM36	CTP2135 CTP2235 CTP5115
H Hard Materials	H01	AH710	MP8010					JC8003		TH1000		IC903					
	H10	AH110 AH120 SH730	MP8010 VP15TF					JC8003 JC8008 JC8015		TH1000 MH1000 F15M	KC5010 KC5510 KU10T KC635M	IC507 IC903 IC907	IN2006	TT9030	TN10U	WHH15	
	H20	AH120	VP15TF				ATH80D PTH08M PCA08M JX1005	LC8015		TS2000 MP3000 F30M	KC635M	IC808 IC908 IC1008	IN2005 IN1530	TT7010 TT9030	WU10PT	WHH15	
	H30									F30M		IC808 IC908 IC1008		TT7010			

●Cermet/Coated Cermet Grades

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Sandvik	Kyocera	Hitachi Tool	Dijet	NTK	Seco Tool	Kennametal	Iscar	Ingersoll	TaeguTec	Widia	Walter	Ceratizit
P Steel	P01	NS520	AP25N VP25N	T110A T1500A T2000Z T250A	CT5015	TN30 PV30 TN6010 PV7010	MZ1000 CH550	LN10	Q15 C7Z		KT315 KT1120		IN0560	PV3010 PV3030 CT3000			
	P10	GT730 GT530	AP25N VP25N NX55 NX2525	T2000Z T3000Z T1500A T250A	CT5015	TN60 TN6010 TN6020 PV7010 PV7020	MZ1000 CH350 CH550	LN10 CX50 PX75	C7Z Z15	TP1030 TP1020 C15M	KT315 KT5020	IC75T IC20N IC520N IC30N	IN0560 IN60C	PV3010 PV3030 CT3000	TT115 TT125	WCE10	TCC410 TCM10 TCM407
	P20	GT730 NS730 GT530 NS530	AP25N VP25N VP45N NX2525 NX3025	T2000Z T3000Z T1500A T250A	CT5015	TN90 TN6020 PV7020 TN100M	CZ25 CH550 CZ1025 CH7030 MZ1000 MZ2000	CX50 CX75 PX75 CX90 SC30 PX90	C7Z T15	TP1030 TP1020 C15M	KT530M KT605M KT5020	IC20N IC520N IC30N IC530N	IN60C	PV3010 CT3000 CT5000	TT125	WCE10	TCM10
	P30	NS740	VP45N NX4545	T3000Z			CZ25 CH570 CH7035 MZ3000	CX75 PX75 PX90 SC30	N40 C7X		KT5020	IC530N IC30N	IN60C	CT5000			
M Stainless	M10	NS520	AP25N VP25N NX2525	T250A T1500A		TN60 TN6020 PV7020	MZ1000 CH550	LN10 CX75 PX75	C7Z	TP1030 TP1020	KT315 KT5020	IC520N IC530N IC20N IC30N	IN0560	PV3010 CT3000 PV3030			TCC410 TCM10 TCM407
	M20	GT730 NS730 NS530	NX2525 AP25N VP25N	T250A T1500A		TN90 TN6020 PV7020 TN100M	MZ1000 CZ25 CH7030	CX75 PX75 PX90 SC30	C7X	C15M	KT530M KT605M KT5020	IC530N IC30N		PV3010 CT3000 PV3030 CT5000			
	M30	NS740	NX4545				CZ25 CH7035 MZ3000	PX90 SC30			KT5020			CT5000			
K Cast Iron	K01	NS520	AP25N VP25N	T110A		TN30 PV30 PV7005	CZ25 MZ1000 CH550	LN10			KT315 KT5020			PV3010 PV3030 CT3000			TCC410
	K10	GT730 NS730 NS530	AP25N VP25N NX2525	T110A		TN60 TN6010 PV7005 PV7010	CZ25 MZ1000 MZ2000 CH550	LN10 CX75			KT315 KT5020			PV3030 CT3000			TCC410 TCM10 TCM407
	K20		AP25N VP25N NX2525				CZ25 MZ2000 MZ3000 CH7030				KT530M KT5020			CT5000			TCM407

Note: The above chart is based on published data and not authorized by each manufacturer.

Grade Comparison Charts

●Ceramics Grades

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Sandvik	Kyocera	Hitachi Tool	Dijet	NTK	Seco Tool	Kennametal	Iscar	Ingersoll	TaeguTec	Widia	Walter	Ceratizit
K Cast Iron	K01	**LX11** **LX21**		NB90S NB90M	CC6190 CC650	KA30 A65 KT66 PT600M			HC1 HW2 SE1 HC2		KY1310 KY1615			AW20 AB30 AS10	CW2015		CTN3105 CTS3105
	K10	**CX710** **FX105**			CC6190 CC650	A65 KT66 A66N PT600M			HC1 HW2 SE1 WA1 WA5		KY1310 KY1320 KY1615 KY3400		IN70N	AB30 AS10	CW2015 CW5025	WSN10	CTN3105 CTM3110 CTI3105 CTN3110 CTS3105
	K20	**FX105** **CX710**			CC6190	KS6000			SP9 SX1 SX6 SX9		KY1320 KY3400 KY3500 KY4300		IN70N	AS10	CW5025	WSN10	CTM3110 CTN3110
S Superalloys	S01										KY1525 KY2100						
	S10			WX120	CC670 CC6060	CF1			WA1 WA5 SX9		KY1525 KY1540 KY2100 KY4300			AS20	CW3020		
H Hard Materials	H01	**LX11**		NB100C	CC6050 CC650	A65 KT66 A66N PT600M			ZC4 ZC7		KY4400			AW20	CW2015		CTS3105
	H10			NB100C	CC6050 CC650 CC6190	A65 KT66 A66N PT600M			HC4 HC7		KY1615 KY4400			AB2010 AB20 AB30	CW2015		CTS3105

Note: The above chart is based on published data and not authorized by each manufacturer.

Grades (1–1)
TAC Inserts (negative) (2–42)
TAC Inserts (positive) (2–96)
Relating Pages

Grade Comparison Charts

●PCBN and PCD Grades

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Sandvik	Kyocera	Hitachi Tool	Dijet	NTK	Seco Tool	Kennametal	Iscar	Ingersoll	TaeguTec	Widia	Walter	Ceratizit
K Cast Iron	K01	**BX930** **BX910** **BX870**	MB710 MB730 MB5015	BNS800 BN7000 BN7500 BN500 BNC500	CB7525 CB7050 CB50	KBN60M			B23 B30 B52		KB9610 KD120 KB1630			KB90	WBH10C	WCB80	TA100 CTL3215
K Cast Iron	K10	**BX470** **BX480** **BX950**	MB710 MB730	BNS800 BN7000 BN7500 BN500 BNC500	CB7525 CB7925 CB50	KBN60M KBN900	BH200	JBN795	B23 B30 B52	CBN200 CBN300 CBN300P CBN400C	KB9640 KD120 KB1630	IB05S IB10S		KB90A	WBK40U	WCB80 WCB50	TA120 TA201 CTL3215
K Cast Iron	K20	**BXC90** **BX90S**	MB730 MBS140	BNS800	CB50	KBN900	BH250		B23 B30 B52	CBN200 CBN300 CBN300P CBN400C	KB9640	IB90			WBK45U		CTL3215
K Cast Iron	K30	**BXC90** **BX90S**	MBS140	BNS800		KBN900			B16	CBN500	KB9640 KB1340 KB1345						
S Superalloys	S01	**BX950**	MB730	BN7000 BN350		KBN65B KBN65M		JBN795						KB90			
S Superalloys	S10	**BX470** **BX480**	MB4020	BNS800						CBN170	KB1630	IB05S IB10S		KB90A	WBK45U		TA201
H Hard Materials	H01	**BXM10** **BX310**	MBC010 MB810	BNC100 BNC160 BNX10 BN1000	CB20	KBN510 KBN10C KBN05M KBN10M			B52	CBN10 CBN100 CBN050C	KB9610	IB50 IB10HC		KB50	WBH10C	WCB30	
H Hard Materials	H10	**BXM10** **BX330** **BX530**	MBC020 MB8025	BNC160 BNC200 BN250 BN1000	CB7015 CB7025 CB20 CB50	KBN525 KBN25C KBN25M	BH200	JBN245	B36	CBN10 CBN100 CBN150 CBN200 CBN300 CBN050C CBN160C CBN300P CBN400C	KB9610 KB1610 KB5610	IB50 IB55 IB10H IB10HC IB20H IB25HA		KB50 TB650	WBH10C WBH10P WBH10U	WCB30 WCB50	CTL3215 TA100
H Hard Materials	H20	**BXM20** **BX360**	MBC020 BC8020 MB8025 MB825	BNC200 BN250 BNX20 BNX25 BN2000	CB7025 CB20 CB7035	KBN30M KBN35M KBN900	BH250	JBN300 JBN330	B22 B36 B40	CBN150 CBN200 CBN300 CBN350 CBN160C CBN300P CBN400C	KB5625 KB1625	IB20H IB25HC		TB650	WBH25P	WCB50 WCB80	CTL3215 TA120
H Hard Materials	H30	**BXM20** **BXC50** **BX380**	MBC020 BC8020 MB835	BNC300 BN350 BNX25		KBN35M KBN900		JBN300 JBN330	B22 B40	CBN500	KB5625 KB9640 KD120	IB25HC			WBH40C		TA201
N Non-ferrous	N01	**DX160** **DX180**	MD205	DA90	CD10	KPD001		JDA30 JDA735			KD1400 KD1405 KD100	ID5				WCD10	CTD4125
N Non-ferrous	N10	**DX140**	MD205 MD220	DA150	CD10	KPD001 KPD010 KPD230		JDA715	PD1	PCD05 PCD10	KD100 KD1400 KD1425	ID5	IN90D	KP500	WDN25U	WCD10	CTD4125 CTD4110
N Non-ferrous	N20	**DX120**	MD220 MD230	DA2200 DA1000	CD10	KPD001 KPD010 KPD230		JDA715	PD1	PCD05 PCD20	KD1425		IN90D	KP300	WDN25U	WCD10	CTD4205
N Non-ferrous	N30	**DX110**	MD230	DA2200 DA1000				JDA10		OVD20 PCD30 PCD30M				KP100			

Note: The above charts are based on published data and not authorized by each manufacturer.

Grade Comparison Charts

●Uncoated Cemented Carbide Grades

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Sandvik	Kyocera	Hitachi Tool	Dijet	NTK	Seco Tool	Kennametal	Iscar	Ingersoll	TaeguTec	Widia	Walter	Ceratizit
P Steel	P01																
	P10	**TH10**		ST10P			WS10	SRT			P10	IC70		P10	TN15U		
	P20	**KS20**	UTi20T	ST20E	SMA H10F		EX35	SRT SR20	KM1	S10M	K125M TTM	IC70	P40	P20	TN15U		
	P30	**KS15F** **UX30**	UTi20T	A30 A30N	SM30 H10F	PW30	EX40	DX30 SR30	KM3	S25M	GK K600 TTR	IC28 IC54	P40	P30			S40T
	P40			ST40E			EX45	SR30		S60M	G13	IC28 IC54		P40			S40T
M Stainless	M01																
	M10	**TH10**		U10E EH510	H10A		WA10B	UMN	KM1	890	K313	IC20		M10	TN15U WU10HT		
	M20	**KS20**	UTi20T	U2 EH520	H13A		EX35	DX25 UMS		HX 883	K68 KMF K125M TTM	IC20	IN30M	M20	TN15U WU10HT		CTW7120 H210T
	M30	**UX30**	UTi20T	A30 A30N	H10F SM30		EX45	UMS			GK K600 TTR	IC28	IN30M				
	M40							UM40			G13	IC28	IN30M	M40			S40T
K Cast Iron	K01	**KS05F**	HTi05T	H2 H1			WH01 WH05	KG03			K605			UF1	TN15U WU10HT		
	K10	**TH10**	HTi10	H1 EH10 EH510	H10	KW10	WH10	KG10 KT9 CR1	KM1	890	K313 K110M THM THM-U	IC20 IC09T	IN05S	K10	TN15U WU10HT		H210T H216T H10T
	K20	**KS15F** **KS20**	UTi20T	G10E EH20 EH520	H13A H10F	KW10 GW25	WH20	KT9 CR1 KG20 FB15		890 HX 883	K715 KMF K600	IC20 IC09T	IN05S IN10K IN15K IN30M	K20	TN15U WU10HT		CTW7120 H210T H216T H10T
	K30		UTi20T	G10E	H13A H10F	GW25		KG30		883	THR	IC28	IN10K IN15K IN30M	K30			
	K40										G13		IN30M				
N Non-ferrous	N01	**KS05F**		H1	H10	KW10					K605	IC20					
	N10	**TH10** **KS05F**	HTi10	H1	H10 H10F	GW15	WH10	KT9 CR1	KM1	890 HX KX H15	K313 K110M THM THM-U	IC20 IC28	IN05S IN10K	K10	TN15U WU10HT	WK1 WK10	H210T H216T H10T
	N20	**KS15F**			H10F H13A		WH20	KT9 CR1	KM1	890 HX KX 883	K715 KMF K600	IC20 IC28	IN10K IN15K	K20	TN15U WU10HT	WK1 WK10	CTW7120 H210T H216T H10T
	N30									883 H25	G13 THR		IN15K IN30M			WK40 WMG40	
S Superalloys	S01		RT9005									IC20					
	S10	**KS05F** **TH10**	RT9005 RT9010	EH510	H10 H10A	KW10	WH10	KG10	KM1	890 883	K10 K313 THM	IC20	IN05S IN10K	K10	TN15U WU10HT	WK1	H210T H216T H10T
	S20	**KS15F** **KS20**	RT9010 TF15	EH520	H10F H13A	GW25	WH20	KG20	KM1	890 883 H25	K715 KMF	IC20 IC28	IN10K IN15K	K20	TN15U WU10HT	WK1 WMG40	CTW7120 H210T H216T H10T
	S30		TF15							883	G13 K600 THR		IN15K IN30M			WMG40	
H Hard Materials	H01							KG03				IC20					
	H10	**TH10**			H13A			FZ05				IC20	IN10K	K10			
	H20							FZ15		890 HX 883			IN15K				

Note: The above chart is based on published data and not authorized by each manufacturer.

Grades (1–1)
TAC Inserts (negative) (2–42)
TAC Inserts (positive) (2–96)
Relating Pages

Chipbreaker Comparison Charts

●Negative inserts

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Kyocera	Sandvik	Hitachi Tool	Kenna-metal	Dijet	Iscar	TaeguTec	Widia	Walter	Ceratizit
P Steel	Precision finishing	**TF, 01**	PK	FA	DP,XP CF		FE	FF	PF	SF	FA			
	Finishing and light cutting	**TS, TSF ZF**	FH, SY, FY	FP, FL, SE	HQ, GP VF	PF,QF LC	AB, CT, BH	FN	UA, FT UR, UT	NF	FG	4	NF3	TFQ CF
		11, NS AS	FS,C SH	LU, SU, SK	XQ CJ	MF	CE			No sign	EA,SF	AP	NF4	
		AFW, ASW	SW, MW	LUW, GUW	WP, WQ	WF, WM, WR, WMX		FW,MW, RW		WF, WG	WS, WT	FW, MW	NF	
		NM CB	SA	SP	CQ		BE				EA		NM	
		C	R/L-1G, R/L-K	ST, C						C, R/LF				
			R/L-F, R/L-FS											
	Medium cutting	**TM**	MV, MZ, MA, MP	UG, UU, GE	GS, HS, PS	PM, QM	AE, AY, AH	P	PG,UB, GN	TF, PP, GN	MT	48	NM6, NS8	TMF
		DM ZM	MH MP	UX, GU, GE UA	CS, HK, XS All-round	SM R/L-K	AH	MN	GNP					
		All-round	All-round	UM, UZ, MC	GC, All-round		Y, V							
	Medium to heavy cutting	**TH**	GH	MU,MX	GT, HT, PT, PH	PR(P)	RE	RN, RP	GG,UD	TNM, NR	ET	49	NM6, NM9	TMQ
		THS		UZ		MR	AR	MG					NM5, NM9	
	Heavy cutting	**TU TRS**	HZ, HX, HV, HA	MP, HG, HP	HX, PX	PR (P)	TE, UE	RM	UC	NM, HR	HT		NR5, NR6	TR
		TUS	HAS, HBS, HCS			MR	H	RH		Without chipbreaker			NR7	
			HDS, HXD			HR,QR	HX,HE							
M Stainless	Finishing and light cutting	**SF SS**	MS FS	SU	GU MQ	MF(M) 23	SE	FP	SF				NF4	
	Medium cutting	**S**	ES, 2G	EX, UP, UG	ST		DE	MP, P	SG	TF, PP	VF			
		SM	MA	MU, MM, GU	MS, HU, MU	MM, QM	AH				MP		NM4	M42
	Heavy cutting	**TH, SH TU**		MP, HG, HP		MR (M) QR, HR					ET HT	SR	NR4 NR5, NM9	
K Cast Iron	Finishing	**CF**	SH	FX, FY	All-round, C	KF Without chipbreaker	Y, V	FN			MT			
	Medium cutting	**CM, All-round,**	All-round	UM, UX, GZ	ZS	KM QM	AE	UM, P			MG		NM5	TMR
	Heavy cutting	**CH**	Without chipbreaker	MU, UZ, MM	GC	KR (K)	RE	RP, MG	GG	GN	RT			
		Without chip-breaker			Without chipbreaker	MR	Without chipbreaker	RM	Without chipbreaker				Without chipbreaker	
						QR								
N Non-ferrous	Cutting of non-ferrous metals	**P**		UP, FY, GX	A3 AH	23 QM	R/L	MS, MP MG		PP	MP, SU			
S Superalloys	Cutting of heat resisting alloy	**HMM, SA SM**	MS ES	FY, FX, SU EX, UP	SU	23 MF, SR		FS, LF K, GP, P		PP	SU MP	SM	NM4	M52
			FJ, MJ, GJ	MU		SM (NMX)		MG-MS, UP						

Note: The above chart is based on published data and not authorized by each manufacturer.

TAC Inserts (negative) (2–42) Relating Pages

Chipbreaker Comparison Charts

●Positive inserts

	Application code	Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Kyocera	Sandvik	Hitachi Tool	Kenna-metal	Dijet	Iscar	TaeguTec	Widia	Walter	Ceratizit
P Steel	Precision finishing	**01**		FC, FW	CF		No sign	UF		SF		2		
P Steel	Finishing and light cutting	**PSF, PF** **PS, PSS** **W08 ~ 20**	FV, SQ, SV MV R/L, R/L-FD R/L-FS, R/L-MV R/L-F, R/L-L	FP, FZ, LU FK, SS, SC SU, SK, SF US W, SD FX, FY	XP, GP, DP HQ, XQ, VF R/L A, B, C, H, Y	UF, PF, WF PF(MF) PM(MM) UM R/L-K	JQ JE JQ	11, GM LF	FT	PF SM, 14, 17 19, XL R/L RF, LF No sign	FA FG GF	41	PF4 PS5	FN SMF, SF
P Steel	Medium cutting	**PM** **23** **24** **All-round** **RS**	No sign RR, RBS No sign	SU, MU UJ SC (except for G-class inserts) RP	HQ GP, DP All-round (No sign) G	PM, PR UM, UR WM 53 No mark No mark	J JE All-round RG	MF FW, MW	GG	DT, HQ	MT MT	43	PM5	SMQ
P Steel	High-feed, small depth of cut cutting	**61**	No sign			No mark	WE			No sign 14	No sign	No sign		
P Steel	Turning on small lathes	**J08 ~ 10** **JRP, JSP, JPP** **JS**	R/L-SR, R/L-SN R/L-SS SMG		F, J, U, CK FSF, USF, JSF CF, GF GQ	R/L-F			MF, MM ALU, MM1 ASF FT, ACB		GF, GW			
M Stainless	Finishing	**PSF, SS** **PSS**	FV			KF, WF KM, WN Without chipbreaker KR		GM, LF MF			FG	41	PF4	F23
K Cast Iron	Cutting of cast irons	**CM** **Without chipbreaker**	Without chipbreaker	Without chipbreaker	Without chipbreaker	KF, R/L-K. KM Without chipbreaker UM, KR	Without chipbreaker	Without chipbreaker	Without chipbreaker	19	MT Without chipbreaker		PS5, PM5 Without chipbreaker	SM
N Non-ferrous	Cutting of non-ferrous metals	**AL** **Read type**	AZ R/L-F R/L	AG, AW FY	AH A3	AL		GT-HP		AS	FL	AL1, AL2, AL3	PM2	23P, 25Q

Note: The above chart is based on published data and not authorized by each manufacturer.

TAC Inserts (positive) (2−96) Relating Pages