TECHNICAL DATA

LIST OF PROPERTY SYMBOLS COMPLYING WITH ISO13399

Alphabetical

Source: ISO13399 standard

URL : https://www.iso.org/search/x/query/13399

ISO13399 Property Symbols	Content
ADJLX	Adjustment limit maximum
ADJRG	Adjustment range
ALF	Clearance angle radial
ALP	Clearance angle axial
AN	Clearance angle major
ANN	Clearance angle minor
APMX	Depth of cut maximum
AS	Clearance angle wiper edge
ASP	Adjusting screw protrusion
AZ	Plunge depth maximum
B	Shank width
BBD	Balanced by design
BCH	Corner chamfer length
BD	Body diameter
BDX	Body diameter maximum
BHCC	Bolt hole circle count
BHTA	Body half taper angle
BMC	Body material code
BS	Wiper edge length
BSR	Wiper edge radius
CASC	Cartridge size code
CB	Chip breaker face count
CBDP	Connection bore depth
CBMD	Chip breaker manufacturers designation
CBP	Chip breaker property
CCMS	Connection code machine side
CCWS	Connection code workpiece side
CCP	Chamfer corner property
CDI	Insert cutting diameter
CDX	Cutting depth maximum
CEATC	Tool cutting edge angle type code
CECC	Cutting edge condition code
CEDC	Cutting edge count
CF	Spot chamfer
CHW	Corner chamfer width
CICT	Cutting item count
CNC	Corner count
CND	Coolant entry diameter
CNSC	Coolant entry style code
CNT	Coolant entry thread size
CP	Coolant pressure
CRE	Spot radius
CRKS	Connection retention knob thread size
CSP	Coolant supply property
CTP	Coating property
CTX	Cutting point translation X-direction
CTY	Cutting point translation Y-direction
CUTDIA	Work piece parting diameter maximum
CUB	Connection unit basis
CW	Cutting width
CWX	Cutting width maximum
CXD	Coolant exit diameter

ISO13399 Property Symbols	Content
CXSC	Coolant exit style code
CZC	Connection size code
D1	Fixing hole diameter
DAH	Diameter access hole
DAXN	Axial groove outside diameter minimum
DAXX	Axial groove outside diameter maximum
DBC	Diameter bolt circle
DC	Cutting diameter
DCB	Connection bore diameter
DCBN	Connection bore diameter minimum
DCBX	Connection bore diameter maximum
DCC	Design configuration style code
DCCB	Counterbore diameter connection bore
DCIN	Cutting diameter internal
DCINN	Cutting diameter internal minimum
DCINX	Cutting diameter internal maximum
DCN	Cutting diameter minimum
DCON	Connection diameter
DCONMS	Connection diameter machine side
DCONWS	Connection diameter workpiece side
DCSC	Cutting diameter size code
DCSFMS	Contact surface diameter machine side
DCX	Cutting diameter maximum
DF	Flange diameter
DHUB	Hub diameter
DMIN	Minimum bore diameter
DMM	Shank diameter
DN	Neck diameter
DRVA	Drive angle
EPSR	Insert included angle
FHA	Flute helix angle
FHCSA	Fixing hole countersunk angle
FHCSD	Fixing hole countersunk diameter
FLGT	Flange thickness
FMT	Form type
FXHLP	Fixing hole property
GAMF	Rake angle radial
GAMN	Rake angle normal
GAMO	Rake angle orthogonal
GAMP	Rake angle axial
GAN	Insert rake angle
H	Shank height
HA	Thread height theoretical
HAND	Hand
HBH	Head bottom offset height
HBKL	Head back offset length
HBKW	Head back offset width
HBL	Head bottom offset length
HC	Thread height actual
HF	Functional height
HHUB	Hub height
HTB	Body height
IC	Inscribed circle diameter
IFS	Insert mounting style code
IIC	Insert interface code
INSL	Insert length
KAPR	Tool cutting edge angle
KCH	Corner chamfer angle

LIST OF PROPERTY SYMBOLS COMPLYING WITH ISO13399

ISO13399 Property Symbols	Content
KRINS	Cutting edge angle major
KWL	Keyway length
KWW	Keyway width
KYP	Keyway property
L	Cutting edge length
LAMS	Inclination angle
LB	Body length
LBB	Chip breaker width
LBX	Body length maximum
LCCB	Counterbore depth connection bore
LCF	Length chip flute
LDRED	Reduced body diameter length
LE	Cutting edge effective length
LF	Functional length
LFA	A dimension on lf
LH	Head length
LPR	Protruding length
LS	Shank length
LSC	Clamping length
LSCN	Clamping length minimum
LSCX	Clamping length maximum
LTA	LTA length (length from MCS to CRP)
LU	Usable length
LUX	Usable length maximum
M	M-dimension
M2	Distance between the nominal inscribed circle and the corner of an insert that has the secondary included angle
MHA	Mounting hole angle
MHD	Mounting hole distance
MHH	Mounting hole height
MIID	Master insert identification
MTP	Clamping type code
NCE	Cutting end count
NOF	Flute count
NOI	Insert index count
NT	Tooth count
OAH	Overall height
OAL	Overall length
OAW	Overall width
PDPT	Profile depth insert
PDX	Profile distance ex
PDY	Profile distance ey
PFS	Profile style code
PL	Point length
PNA	Profile included angle
PSIR	Tool lead angle
PSIRL	Cutting edge angle major left hand
PSIRR	Cutting edge angle major right hand
RAL	Relief angle left hand
RAR	Relief angle right hand
RCP	Rounded corner property
RE	Corner radius
REL	Corner radius left hand
RER	Corner radius right hand
RMPX	Ramping angle maximum
RPMX	Rotational speed maximum
S	Insert thickness
S1	Insert thickness total

ISO13399 Property Symbols	Content
SC	Insert shape code
SDL	Step diameter length
SIG	Point angle
SSC	Insert seat size code
SX	Shank cross section shape code
TC	Tolerance class insert
TCE	Tipped cutting edge code
TCTR	Thread tolerance class
TD	Thread diameter
THFT	Thread form type
THL	Threading length
THLGTH	Thread length
THSC	Tool holder shape code
THUB	Hub thickness
TP	Thread pitch
TPI	Threads per inch
TPIN	Threads per inch minimum
TPIX	Threads per inch maximum
TPN	Thread pitch minimum
TPT	Thread profile type
TPX	Thread pitch maximum
TQ	Torque
TSYC	Tool style code
TTP	Thread type
ULDR	Usable length diameter ratio
UST	Unit system
W1	Insert width
WEP	Wiper edge property
WF	Functional width
WF2	Distance between the cutting reference point and the front seating surface of a turning tool
WFS	Functional width secondary
WT	Weight of item
ZEFF	Face effective cutting edge count
ZEFP	Peripheral effective cutting edge count
ZNC	Cutting edge centre count
ZNF	Face mounted insert count
ZNP	Peripheral mounted insert count

LIST OF REFERENCE SYMBOLS COMPLYING WITH ISO13399

ISO13399 Reference Symbols	Content
CIP	Coordinate system in process
CRP	Cutting reference point
CSW	Coordinate system workpiece side
MCS	Mounting coordinate system
PCS	Primary coordinate system

TROUBLE SHOOTING FOR TURNING

Trouble		Factors \ Solution	Insert Grade Selection				Cutting Conditions					Style and Design of the Tool							Machine, Installation of Tool		
							Up ↗ Down ↘			Coolant			Up ↗ Down ↘								
			Select a harder grade	Select a tougher grade	Select a grade with better thermal shock resistance	Select a grade with better adhesion resistance	Cutting speed	Feed	Depth of cut	Do not use water-soluble cutting fluid	Determine dry or wet cutting	Select chip breaker	Rake	Corner radius	Lead angle	Honing strengthens the cutting edge	Class of insert	Improve tool holder rigidity	Increase clamping rigidity of the tool and workpiece	Decrease holder overhang	Decrease power and machine backlash
Deterioration of Tool Life	Insert wear quickly generated	Improper tool grade	●																		
		Improper cutting edge geometry										●	●↗	●↗	●↗	●↘					
		Improper cutting speed					●↘	●↗			● Wet										
	Chipping or fracturing of cutting edge	Improper tool grade		●																	
		Improper cutting conditions						●↘	●↘												
		Lack of cutting edge strength.										●		●↗		●↗					
		Thermal crack occurs			●		●↘	●↘	●↘	●	● Dry										
		Build-up edge occurs				●	●↗	●↗		●	● Wet										
		Lack of rigidity																●	●	●	●
Out of Tolerance	Dimensions are not constant	Poor insert accuracy															●				
		Large cutting resistance and cutting edge flank										●	●	●↘	●↘	●↘		●	●	●	●
	Necessary to adjust often because of over-size	Improper tool grade	●																		
		Improper cutting conditions					●↘	●↗													
Deterioration of Surface Finish	Poor finished surface	Welding occurs					●↗			●	● Wet										
		Improper cutting edge geometry										●		●↗							
		Chattering					●↘	●↘	●↘									●	●	●	●
Generation of Heat	Workpiece over heating can cause poor accuracy and short life of insert	Improper cutting conditions					●↘	●↘	●↘												
		Improper cutting edge geometry										●	●↗			●↘					

Trouble		Factors \ Solution	Insert Grade Selection: Select a harder grade	Insert Grade Selection: Select a tougher grade	Insert Grade Selection: Select a grade with better thermal shock resistance	Insert Grade Selection: Select a grade with better adhesion resistance	Cutting Conditions (Up ↗ Down ↘): Cutting speed	Cutting Conditions (Up ↗ Down ↘): Feed	Cutting Conditions (Up ↗ Down ↘): Depth of cut	Coolant: Do not use water-soluble cutting fluid	Coolant: Determine dry or wet cutting	Style and Design of the Tool: Select chip breaker	Style and Design of the Tool (Up ↗ Down ↘): Rake	Style and Design of the Tool (Up ↗ Down ↘): Corner radius	Style and Design of the Tool (Up ↗ Down ↘): Lead angle	Style and Design of the Tool (Up ↗ Down ↘): Honing strengthens the cutting edge	Style and Design of the Tool: Class of insert	Machine, Installation of Tool: Improve tool holder rigidity	Machine, Installation of Tool: Increase clamping rigidity of the tool and workpiece	Machine, Installation of Tool: Decrease holder overhang	Machine, Installation of Tool: Decrease power and machine backlash
Burrs, Chipping etc.	Burrs (Steel, Aluminium)	Notch wear	●																		
Burrs, Chipping etc.	Burrs (Steel, Aluminium)	Improper cutting conditions					● ↘	↗ ●			● Wet										
Burrs, Chipping etc.	Burrs (Steel, Aluminium)	Improper cutting edge geometry										●	↗ ●	● ↘	● ↘	● ↘					
Burrs, Chipping etc.	Workpiece chipping (Cast iron)	Improper cutting conditions						● ↘	● ↘												
Burrs, Chipping etc.	Workpiece chipping (Cast iron)	Improper cutting edge geometry										●	↗ ●	↗ ●	↗ ●	● ↘					
Burrs, Chipping etc.	Workpiece chipping (Cast iron)	Vibration occurs																●	●	●	●
Burrs, Chipping etc.	Burrs (Mild steel)	Improper tool grade				●															
Burrs, Chipping etc.	Burrs (Mild steel)	Improper cutting conditions					↗ ●			●	● Wet										
Burrs, Chipping etc.	Burrs (Mild steel)	Improper cutting edge geometry										●	↗ ●			● ↘					
Burrs, Chipping etc.	Burrs (Mild steel)	Vibration occurs																●	●	●	●
Poor Chip Dispersal	Long chips	Improper cutting conditions					● ↘	↗ ●	↗ ●		● Wet										
Poor Chip Dispersal	Long chips	Large chip control range										●									
Poor Chip Dispersal	Long chips	Improper cutting edge geometry												● ↘	● ↘						
Poor Chip Dispersal	Chips are short and scattered	Improper cutting conditions						● ↘	● ↘		● Dry										
Poor Chip Dispersal	Chips are short and scattered	Small chip control range										●									
Poor Chip Dispersal	Chips are short and scattered	Improper cutting edge geometry												↗ ●	↗ ●						

TECHNICAL DATA

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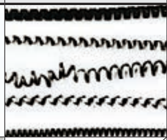
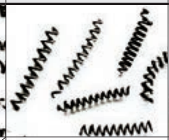
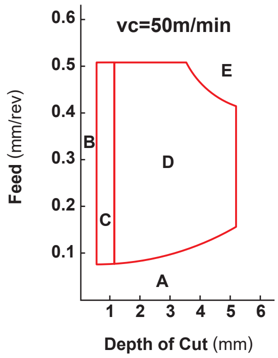
CHIP CONTROL FOR TURNING

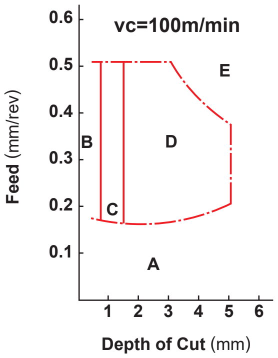
■CHIP BREAKING CONDITIONS IN STEEL TURNING

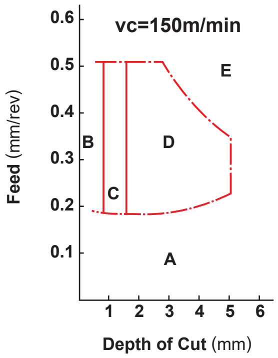
Type	A Type	B Type	C Type	D Type	E Type
Small Depth of Cut d < 7mm					
Small Depth of Cut d=7−15mm					
Curl Length l	Curless	l ≥ 50mm	l ≤ 50mm 1—5 Curl	≒ 1 Curl	Less Than 1 Curl Half a Curl
Note	●Irregular continuous shape ●Tangle around tool and workpiece	●Regular continuous shape ●Long chips	Good	Good	●Chip scattering ●Chattering ●Poor finished surface ●Maximum

●Cutting speed and chip control range of chip breaker

In general, when cutting speed increases, the chip control range tends to become narrower.



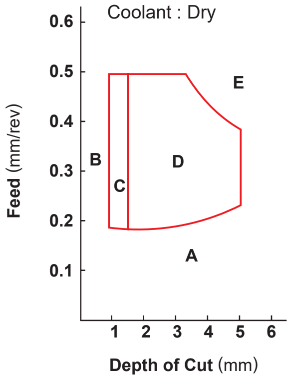


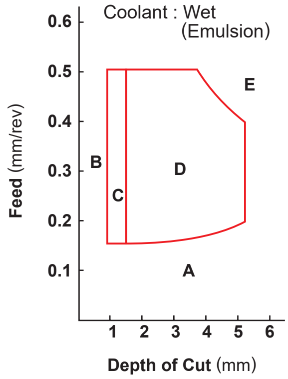


Workpiece : **S45C(180HB)**
Insert : **TNMG160408**
Grade : **P10**Cemented Carbide
Tool : **MTJNR2525M16N**
Dry Cutting

●Effects of coolant on the chip control range of a chip breaker

If the cutting speed is the same, the range of chip control differs according to whether coolant is used or not.





Workpiece : **S45C**
Cutting Conditions : **vc=100m/min**

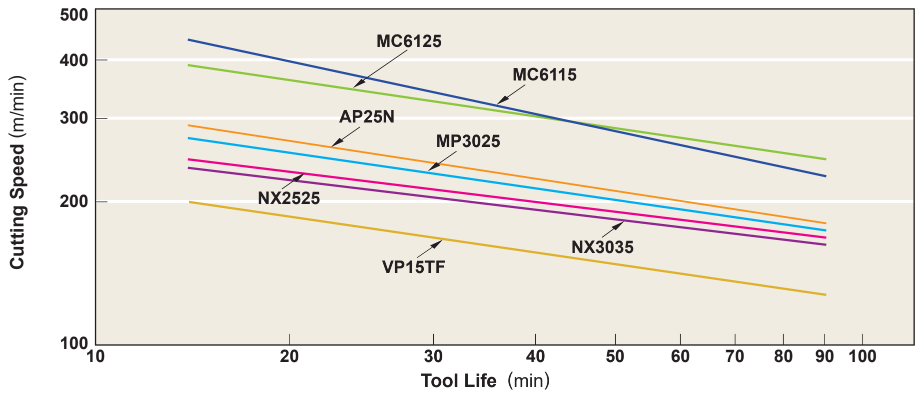
EFFECTS OF CUTTING CONDITIONS FOR TURNING

■EFFECTS OF CUTTING CONDITIONS

Ideal conditions for cutting are short cutting time, long tool life, and high cutting accuracy. In order to obtain these conditions, selection of efficient cutting conditions and tools, based on workpiece material, hardness, shape and machine capability is necessary.

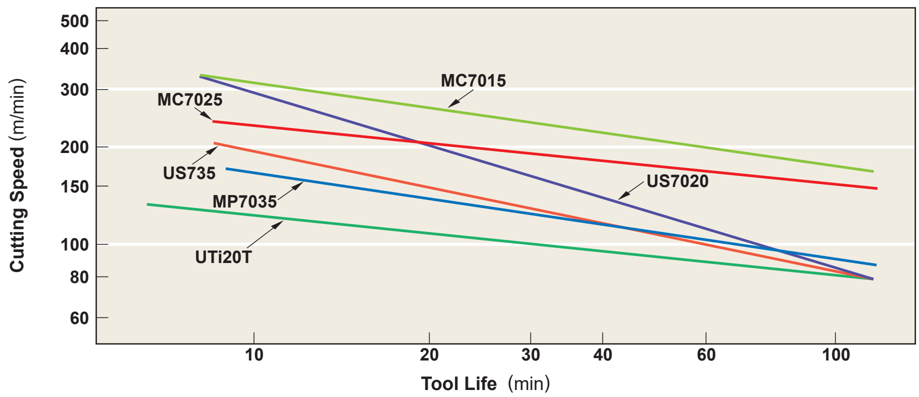
■CUTTING SPEED

Cutting speed effects tool life greatly. Increasing cutting speed increases cutting temperature and results in shortening tool life. Cutting speed varies depending on the type and hardness of the workpiece material. Selecting a tool grade suitable for the cutting speed is necessary.



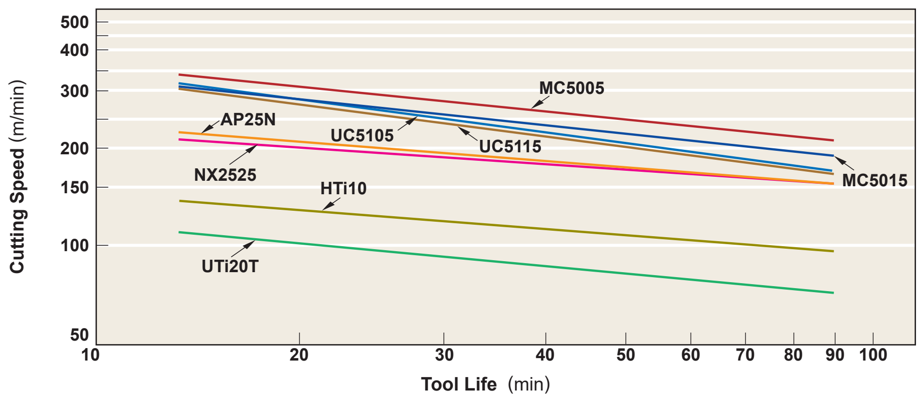
P Class Grade Tool Life

Workpiece : **JIS S45C 180HB**
Tool Life Standard : **VB = 0.3mm**
Depth of Cut : **1.5mm**
Feed : **0.3mm/rev**
Holder : **PCLNR2525M12**
Insert : **CNMG120408**
Dry Cutting



M Class Grade Tool Life

Workpiece : **JIS SUS304 200HB**
Tool Life Standard : **VB = 0.3mm**
Depth of Cut : **1.5mm**
Feed : **0.3mm/rev**
Holder : **PCLNR2525M12**
Insert : **CNMG120408-MA**
Dry Cutting



K Class Grade Tool Life

Workpiece : **JIS FC300 180HB**
Tool Life Standard : **VB = 0.3mm**
Depth of Cut : **1.5mm**
Feed : **0.3mm/rev**
Holder : **PCLNR2525M12**
Insert : **CNMG120408**
Dry Cutting

●Effects of Cutting Speed

1. Increasing cutting speed by 20% decreases tool life by 50%. Increasing cutting speed by 50% decreases tool life by 80%.
2. Cutting at low cutting speed (20−40m/min) tends to cause chattering. Thus, tool life is shortened.

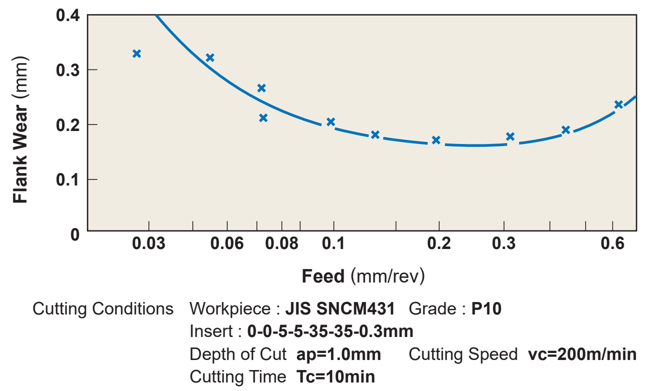
EFFECTS OF CUTTING CONDITIONS FOR TURNING

■FEED

When cutting with a general type holder, feed is the distance a holder moves per workpiece revolution. When milling, feed is the distance a machine table moves per cutter revolution divided by the number of inserts. Thus, it is indicated as feed per tooth. Feed rate relates to finished surface roughness.

●Effects of Feed

1. Decreasing feed rate results in flank wear and shortens tool life.
2. Increasing feed rate increases cutting temperature and flank wear. However, effects on the tool life is minimal compared to cutting speed.
3. Increasing feed rate improves machining efficiency.



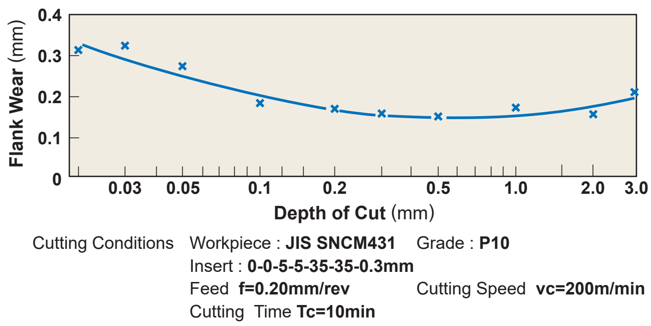
Feed and Flank Wear Relationship in Steel Turning

■DEPTH OF CUT

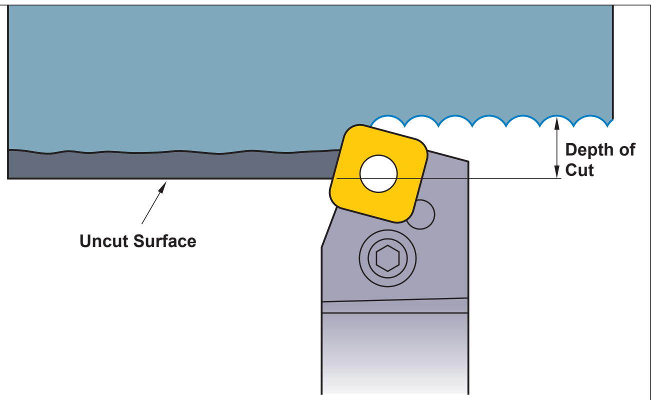
Depth of cut is determined according to the required stock removal, shape of workpiece, power and rigidity of the machine and tool rigidity.

●Effects of Depth of Cut

1. Changing depth of cut doesn't effect tool life greatly.
2. Small depths of cut result in friction when cutting the hardened layer of a workpiece. Thus tool life is shortened.
3. When cutting uncut surfaces or cast iron surfaces, the depth of cut needs to be increased as much as the machine power allows in order to avoid cutting impure hard layers with the tip of cutting edge to prevent chipping and abnormal wear.



Depth of Cut and Flank Wear Relationship in Steel Turning

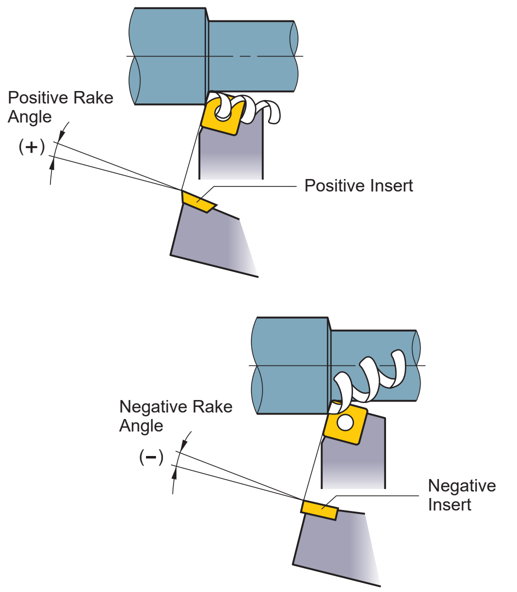


Roughing of Surface Layer that Includes Uncut Surface

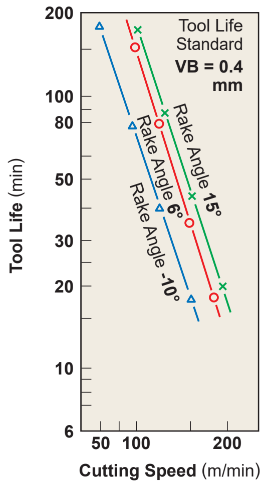
FUNCTION OF TOOL FEATURES FOR TURNING

■RAKE ANGLE

Rake angle is cutting edge angle that has a large effect on cutting resistance, chip disposal, cutting temperature and tool life.

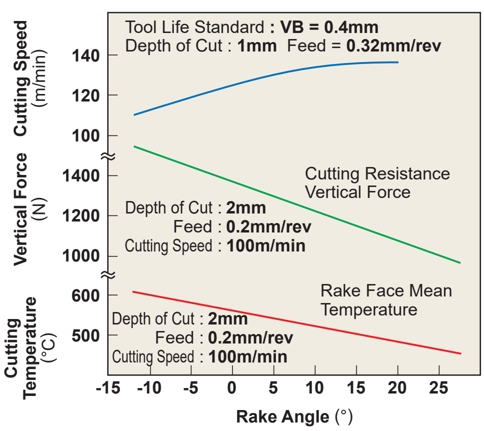


Chip Disposal and Rake Angle



Cutting Conditions
Grade : **P10**
Depth of Cut : **1mm** Feed : **0.32mm/rev**
Workpiece : **JIS SK5**

Rake Angle and Tool Life



Cutting Conditions
Workpiece : **JIS SK5** Grade : **P10**
Insert : **0-Var-5-5-20-20-0.5mm**
Dry Cutting

Effects of Rake Angle on Cutting Speed, Vertical Force, and Cutting Temperature

●Effects of Rake Angle

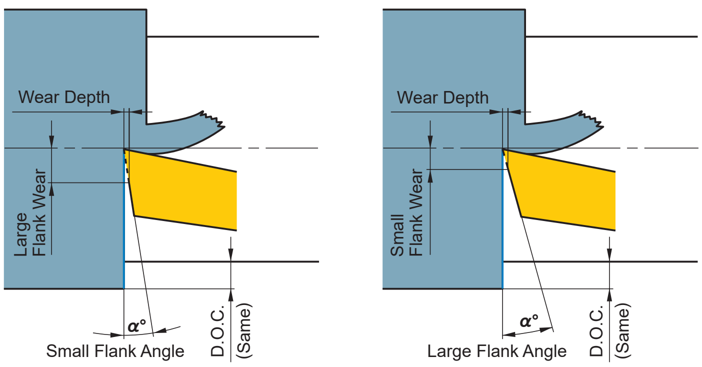
1. Increasing rake angle in the positive (+) direction improves sharpness.
2. Increasing rake angle by 1° in the positive (+) direction decreases cutting power by about 1%.
3. Increasing rake angle in the positive (+) direction lowers cutting edge strength and in the negative (-) direction increases cutting resistance.

When to Increase Rake Angle in the Negative (-) Direction
○ Hard workpieces. ○ When the cutting edge strength is required such as for uncut surfaces and interrupted cutting.

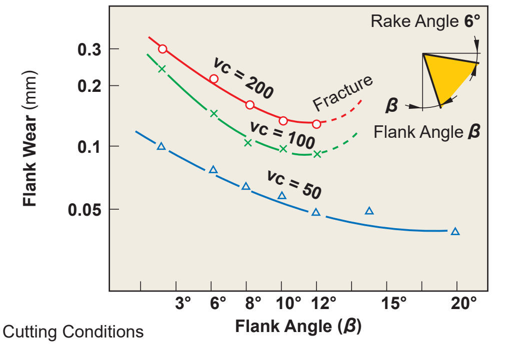
When to Increase Rake Angle in the Positive (+) Direction
○ Soft workpieces. ○ Workpiece is easily machined. ○ When the workpiece or the machine have poor rigidity.

■FLANK ANGLE

Flank angle prevents friction between flank face and workpiece resulting in smooth feed.



Flank angle creates a space between tool and workpiece.
Flank angle relates to flank wear.



Cutting Conditions
Workpiece : **JIS SNCM431 (200HB)**
Grade : **P20** Insert : **0-6-β-β-20-20-0.5mm**
Depth of Cut : **1mm** Feed : **0.32mm/rev** Cutting Time : **20min**

Flank Angle and Flank Wear Relationship

●Effects of Rake Angle

1. Increasing flank angle decreases flank wear occurrence.
2. Increasing flank angle lowers cutting edge strength.

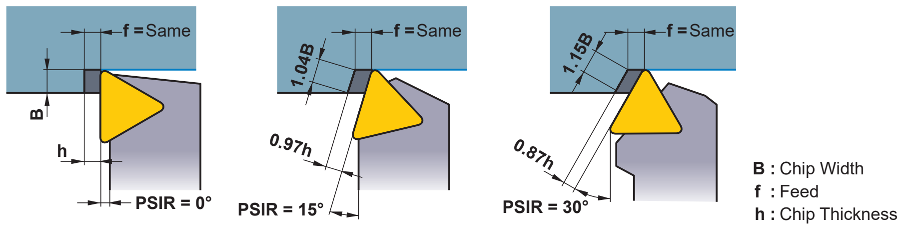
When to Decrease Flank Angle
○ Hard workpieces. ○ When cutting edge strength is required.

When to Increase Flank Angle
○ Soft workpieces. ○ Workpieces suffer from work hardening easily.

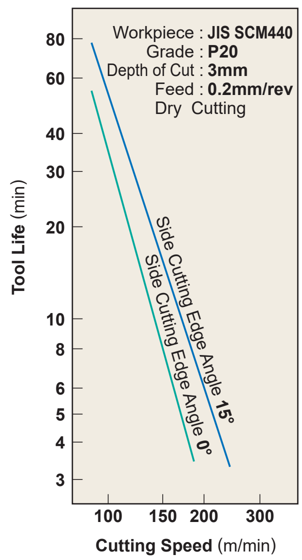
FUNCTION OF TOOL FEATURES FOR TURNING

■SIDE CUTTING EDGE ANGLE (LEAD ANGLE)

The side cutting edge angle reduces impact load and effects the amount of feed force, back force and chip thickness.



Side Cutting Edge Angle and Chip Thickness



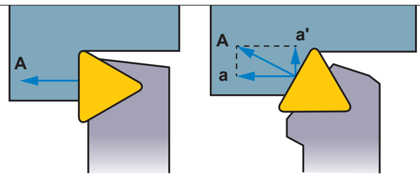
Side Cutting Edge and Tool Life

●Effects of Side Cutting Edge Angle (Lead Angle)

1. At the same feed rate, increasing the side cutting edge angle increases the chip contact length and decreases chip thickness. As a result, the cutting force is dispersed on a longer cutting edge and tool life is prolonged. (Refer to the chart.)
2. Increasing the side cutting edge angle increases force a'. Thus, thin, long workpieces suffer from bending in some cases.
3. Increasing the side cutting edge angle decreases chip control.
4. Increasing the side cutting edge angle decreases the chip thickness and increases chip width. Thus, breaking chips is difficult.

When to Decrease Lead Angle
○ Finishing with small depth of cut. ○ Thin, long workpieces. ○ When the machine has poor rigidity.

When to Increase Lead Angle
○ Hard workpieces which produce high cutting temperature. ○ When roughing a workpiece with large diameter. ○ When the machine has high rigidity.

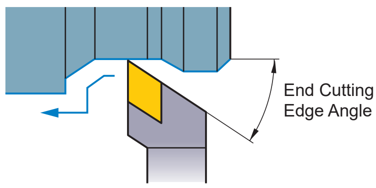


Receive force A.

Force A is divided into a and a'.

■END CUTTING EDGE ANGLE

The end cutting edge angle avoids interference between the machined surface and the tool (end cutting edge). Usually 5°–15°.

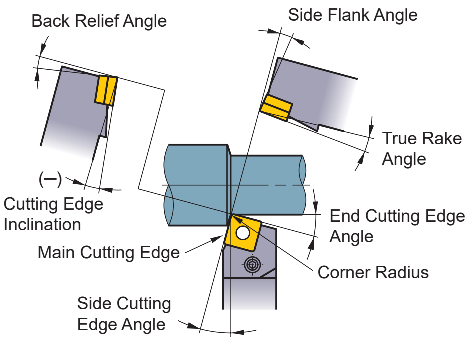


●Effects of End Cutting Edge Angle

1. Decreasing the end cutting edge angle increases cutting edge strength, but it also increases cutting edge temperature.
2. Decreasing the end cutting edge angle increases the back force and can result in chattering and vibration while machining.
3. Small end cutting edge angle for roughing and large angle for finishing are recommended.

■CUTTING EDGE INCLINATION

Cutting edge inclination indicates inclination of the rake face. During heavy cutting, the cutting edge receives an extremely large shock at the beginning of each cut. Cutting edge inclination keeps the cutting edge from receiving this shock and prevents fracturing. 3°–5° in turning and 10°–15° in milling are recommended.

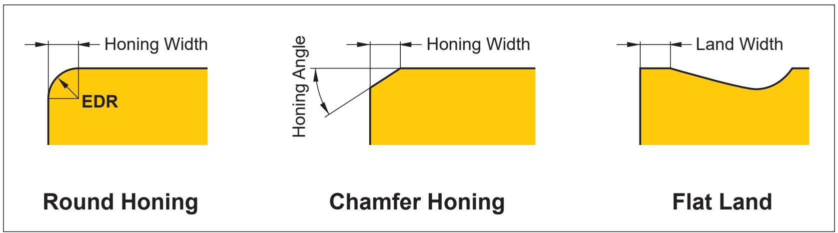


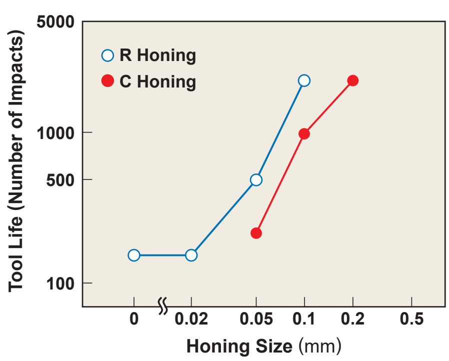
●Effects of Cutting Edge Inclination

1. Negative (–) cutting edge inclination disposes chips in the workpiece direction, and positive (+) disposes chips in the opposite direction.
2. Negative (–) cutting edge inclination increases cutting edge strength, but it also increases the back force of cutting resistance. Thus, chattering can easily occur.

■HONING AND LAND

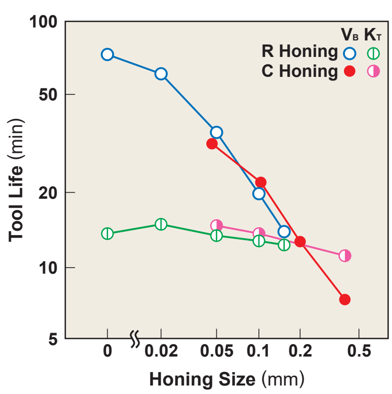
Honing and land are cutting edge shapes that maintain cutting edge strength.
Honing can be round or chamfer type. The optimal honing width is approximately 1/2 of the feed.
Land is the narrow flat area on the rake or flank face.





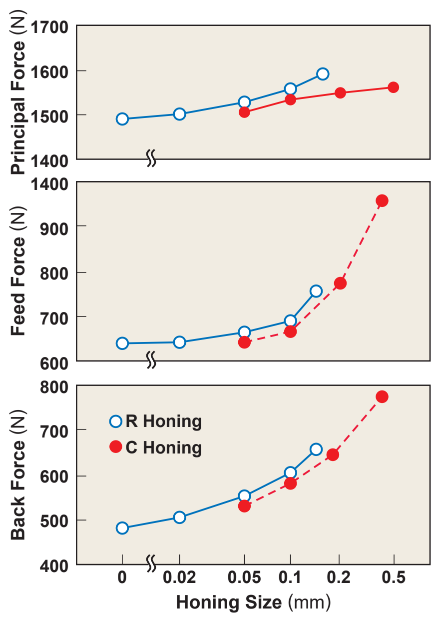
Workpiece : **JIS SNCM439 (280HB)**
Grade : **P10**
Cutting Conditions : **vc=200m/min ap=1.5mm f=0.335mm/rev**

Honing Size and Tool Life Due to Fracturing



Workpiece : **JIS SNCM439 (220HB)**
Grade : **P10**
Cutting Conditions : **vc=160m/min ap=1.5mm f=0.45mm/rev**

Honing Size and Tool Life Due to Wear



Workpiece : **JIS SNCM439 (220HB)**
Grade : **P10**
Cutting Conditions : **vc=100m/min ap=1.5mm f=0.425mm/rev**

Honing Size and Cutting Resistance

●Effects of Honing

1. Enlarging the honing increases cutting edge strength, tool life and reduces fracturing.
2. Enlarging the honing increases flank wear occurrence and shortens tool life. Honing size doesn't affect rake wear.
3. Enlarging the honing increases cutting resistance and chattering.

When to Decrease Honing Size
○ When finishing with small depth of cut and small feed.
○ Soft workpieces.
○ When the workpiece or the machine have poor rigidity.

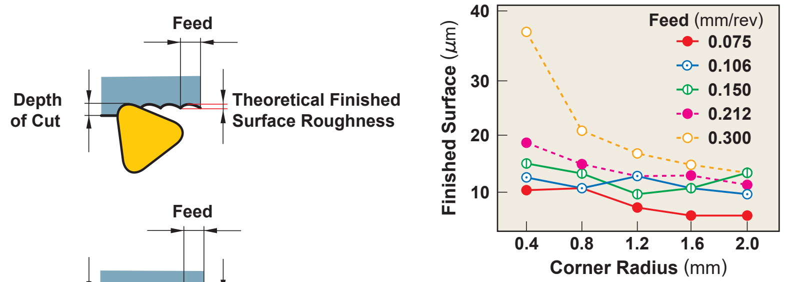
When to Increase Honing Size
○ Hard workpieces.
○ When the cutting edge strength is required such as for uncut surfaces and interrupted cutting.
○ When the machine has high rigidity.

Note 1) Cemented carbide, coated diamond, and indexable cermet inserts have round honing as standard.

FUNCTION OF TOOL FEATURES FOR TURNING

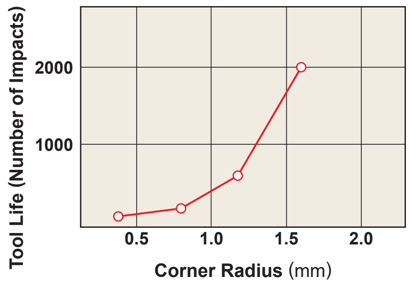
■RADIUS

Radius effects the cutting edge strength and finished surface. In general, a corner radius 2–3 times the feed is recommended.



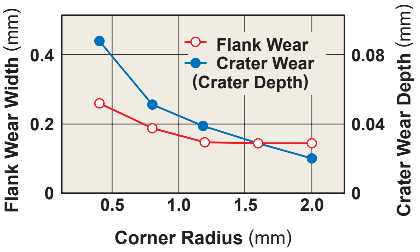
Workpiece : **JIS SNCM439 (200HB)**
Grade : **P20**
Cutting Conditions : **vc=120m/min ap=0.5mm**

Corner Radius and Finished Surface



Workpiece : **JIS SNCM440 (280HB)**
Grade : **P10**
Cutting Conditions : **vc=100m/min ap=2mm f=0.335mm/rev**

Corner Radius Size and Tool Life Due to Fracturing



Workpiece : **JIS SNCM439 (200HB)**
Grade : **P10**
Cutting Conditions : **vc=140m/min ap=2mm f=0.212mm/rev Tc=10min**

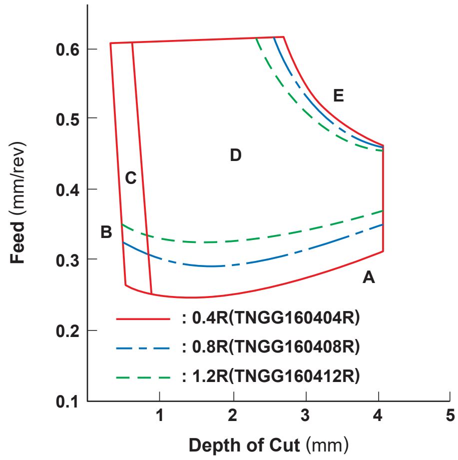
Corner Radius Size and Tool Wear

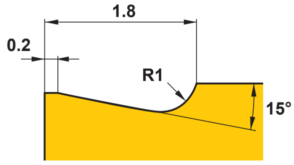
●Effects of Corner Radius

1. Increasing the corner radius improves the surface finish.
2. Increasing the corner radius improves cutting edge strength.
3. Increasing the corner radius too much increases the cutting resistance and causes chattering.
4. Increasing the corner radius decreases flank and rake wear.
5. Increasing the corner radius too much results in poor chip control.

When to Decrease Corner Radius	When to Increase Corner Radius
○Finishing with small depth of cut. ○Thin, long workpieces. ○When the machine has poor rigidity.	○When the cutting edge strength is required such as in intrrupted cutting and uncut surface cutting. ○When roughing a workpiece with large diameter. ○When the machine has high rigidity.

●Corner Radius and Chip Control Range





Workpiece : **JIS S45C (180HB)**
Insert : **TNGG160404R**
TNGG160408R
TNGG160412R
(P10)
Holder : **ETJNR33K16**
(Side Cutting Edge angle 3°)
Cutting Speed : **vc=100m/min**
Dry Cutting

*Refer to Q008 for "Shape of Chips in Steel Turning" for A, B, C, D, E in the graph above.

FORMULAE FOR CUTTING POWER

■CUTTING POWER (Pc)

$$Pc = \frac{ap \cdot f \cdot vc \cdot Kc}{60 \times 10^3 \times \eta} \ (kW)$$

Pc (kW) : Actual Cutting Power
f (mm/rev) : Feed per Revolution
Kc (MPa) : Specific Cutting Force
ap (mm) : Depth of Cut
vc (m/min) : Cutting Speed
η : (Machine Coefficient)

(Problem) What is the cutting power required for machining mild steel at cutting speed 120m/min with depth of cut 3mm and feed 0.2mm/rev (Machine coefficient 80%) ?

(Answer) Substitute the specific cutting force Kc=3100MPa into the formula.

$$Pc = \frac{3 \times 0.2 \times 120 \times 3100}{60 \times 10^3 \times 0.8} = 4.65 (kW)$$

● Kc

Workpiece Material	Tensile Strength(MPa) and Hardness	Specific Cutting Force Kc (MPa)				
		0.1 (mm/rev)	0.2 (mm/rev)	0.3 (mm/rev)	0.4 (mm/rev)	0.6 (mm/rev)
Mild Steel	**520**	3610	3100	2720	2500	2280
Medium Steel	**620**	3080	2700	2570	2450	2300
Hard Steel	**720**	4050	3600	3250	2950	2640
Tool Steel	**670**	3040	2800	2630	2500	2400
Tool Steel	**770**	3150	2850	2620	2450	2340
Chrome Manganese Steel	**770**	3830	3250	2900	2650	2400
Chrome Manganese Steel	**630**	4510	3900	3240	2900	2630
Chrome Molybdenum Steel	**730**	4500	3900	3400	3150	2850
Chrome Molybdenum Steel	**600**	3610	3200	2880	2700	2500
Nickel Chrome Molybdenum Steel	**900**	3070	2650	2350	2200	1980
Nickel Chrome Molybdenum Steel	**352HB**	3310	2900	2580	2400	2200
Hard Cast Iron	**46HRC**	3190	2800	2600	2450	2270
Meehanite Cast Iron	**360**	2300	1930	1730	1600	1450
Grey Cast Iron	**200HB**	2110	1800	1600	1400	1330

■CUTTING SPEED (vc)

$$vc = \frac{\pi \cdot Dm \cdot n}{1000} \ (m/min)$$

vc (m/min) : Cutting Speed
Dm (mm) : Workpiece Diameter
π (3.14) : Pi
n (min^{-1}) : Main Axis Spindle Speed

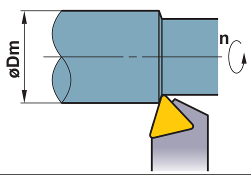
*Divide by 1000 to change to m from mm.

(Problem) What is the cutting speed when main axis spindle speed is 700min^{-1} and external diameter is ϕ50 ?

(Answer) Substitute π=3.14, Dm=50, n=700 into the formula.

$$vc = \frac{\pi \cdot Dm \cdot n}{1000} = \frac{3.14 \times 50 \times 700}{1000} = 110m/min$$

Cutting speed is 110m/min.



■FEED (f)

$$f = \frac{l}{n} \ (mm/rev)$$

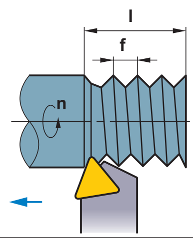
f (mm/rev) : Feed per Revolution
l (mm/min) : Cutting Length per Min.
n (min^{-1}) : Main Axis Spindle Speed

(Problem) What is the feed per revolution when main axis spindle speed is 500min^{-1} and cutting length per minute is 120mm/min ?

(Answer) Substitute n=500, l=120 into the formula.

$$f = \frac{l}{n} = \frac{120}{500} = 0.24mm/rev$$

The answer is 0.24mm/rev.



■CUTTING TIME (Tc)

$$Tc = \frac{Im}{l} \ (min)$$

Tc (min) : Cutting Time
Im (mm) : Workpiece Length
l (mm/min): Cutting Length per Min.

(Problem) What is the cutting time when 100mm workpiece is machined at 1000min^{-1} with feed = 0.2mm/rev ?

(Answer) First, calculate the cutting length per min. from the feed and spindle speed.

$$l = f \times n = 0.2 \times 1000 = 200mm/min$$

Substitute the answer above into the formula.

$$Tc = \frac{Im}{l} = \frac{100}{200} = 0.5min$$

0.5 x 60=30 (sec.) The answer is 30 sec.

■THEORETICAL FINISHED SURFACE ROUGHNESS (h)

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

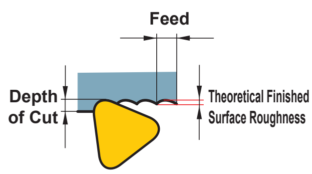
h (μm) : Finished Surface Roughness
f (mm/rev) : Feed per Revolution
RE(mm) : Insert Corner Radius

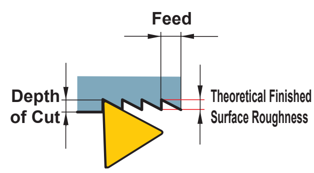
(Problem) What is the theoretical finished surface roughness when the insert corner radius is 0.8mm and feed is 0.2mm/rev ?

(Answer) Substitute f=0.2mm/rev, RE=0.8 into the formula.

$$h = \frac{0.2^2}{8 \times 0.8} \times 1000 = 6.25 \mu m$$

The theoretical finished surface roughness is 6μm.





TROUBLE SHOOTING FOR THREADING

Problems	Observation	Causes	Solutions
Low thread precision.	Threads do not mesh with each other.	Incorrect tool installation.	Set the insert centre height at 0mm.
			Check holder inclination (Lateral).
	Shallow thread.	Incorrect depth of cut.	Modify the depth of cut.
		Lack of insert wear or plastic deformation resistance.	Refer to "Quickly generated flank wear." and "Large plastic deformation." below.
Poor surface finish.	Surface damage.	Chips wrap around or clog the work pieces.	Change to flank infeed and control the chip discharge direction.
			Change to an M-class insert with a 3-D chip breaker.
		The side of the insert cutting edge interferes with the workpiece.	Check the lead angle and select an appropriate shim.
	Surface tears.	Built-up edge (Welding).	Increase cutting speed.
			Increase coolant pressure and volume.
		Cutting resistance too high.	Decrease depth of cut per pass.
	Surface vibrations.	Cutting speed too high.	Decrease the cutting speed.
		Insufficient work piece or tool clamping.	Re-check work piece and tool clamping. (Chuck pressure, clamping allowance)
		Incorrect tool installation.	Set the insert centre height at 0mm.
Short tool life.	Flank wear quickly generated.	Cutting speed too high.	Decrease the cutting speed.
		Too many passes causes abrasive wear.	Reduce the number of passes.
		Small depth of cut for the finishing pass.	Do not re-cut at 0mm depth of cut, larger than 0.05mm depth of cut is recommended.
	Non-uniform wear of the right and left sides of the cutting edge.	The work piece lead angle and the tool lead angle do not match.	Check the work piece lead angle and select an appropriate shim.
	Chipping and fracture.	Cutting speed too low.	Increase cutting speed.
		Cutting resistance too high.	Increase the number of passes and decrease the cutting resistance per pass.
		Unstable clamping.	Check work piece deflection.
			Shorten tool overhang.
			Recheck work piece and tool clamping. (Chuck pressure, clamping allowance)
		Chip packing.	Increase coolant pressure to blow away chips.
			Change the tool pass to control chips. (Lengthen each pass to allow the coolant to clear the chips.
			Change from standard internal cutting to back turning to prevent chip jamming.
		Non-chamfered work pieces causes high resistance at the start of each pass.	Chamfer the workpiece entry and exit faces.
	Large plastic deformation.	High cutting speed and large heat generation.	Decrease the cutting speed.
		Lack of coolant supply.	Check coolant is supply is sufficient.
			Increase coolant pressure and volume.
		Cutting resistance too high.	Increase the number of passes and decrease the cutting resistance per pass.

DRILL DIAMETERS FOR PREPARED HOLES

●Metric Coarse Screw Thread

Nominal	Drill Diameter	
	HSS	Carbide
M1 ×0.25	0.75	0.75
M1.1×0.25	0.85	0.85
M1.2×0.25	0.95	0.95
M1.4×0.3	1.10	1.10
M1.6×0.35	1.25	1.30
M1.7×0.35	1.35	1.40
M1.8×0.35	1.45	1.50
M2 ×0.4	1.60	1.65
M2.2×0.45	1.75	1.80
M2.3×0.4	1.90	1.95
M2.5×0.45	2.10	2.15
M2.6×0.45	2.15	2.20
M3 ×0.5	2.50	2.55
M3.5×0.6	2.90	2.95
M4 ×0.7	3.3	3.4
M4.5×0.75	3.8	3.9
M5 ×0.8	4.2	4.3
M6 ×1.0	5.0	5.1
M7 ×1.0	6.0	6.1
M8 ×1.25	6.8	6.9
M9 ×1.25	7.8	7.9
M10 ×1.5	8.5	8.6
M11 ×1.5	9.5	9.7
M12 ×1.75	10.3	10.5
M14 ×2.0	12.0	12.2
M16 ×2.0	14.0	14.2
M18 ×2.5	15.5	15.7
M20 ×2.5	17.5	17.7
M22 ×2.5	19.5	19.7
M24 ×3.0	21.0	—
M27 ×3.0	24.0	—
M30 ×3.5	26.5	—
M33 ×3.5	29.5	—
M36 ×4.0	32.0	—
M39 ×4.0	35.0	—
M42 ×4.5	37.5	—
M45 ×4.5	40.5	—
M48 ×5.0	43.0	—

●Metric Fine Screw Thread

Nominal	Drill Diameter	
	HSS	Carbide
M1 ×0.2	0.80	0.80
M1.1×0.2	0.90	0.90
M1.2×0.2	1.00	1.00
M1.4×0.2	1.20	1.20
M1.6×0.2	1.40	1.40
M1.8×0.2	1.60	1.60
M2 ×0.25	1.75	1.75
M2.2×0.25	1.95	2.00
M2.5×0.35	2.20	2.20
M3 ×0.35	2.70	2.70
M3.5×0.35	3.20	3.20
M4 ×0.5	3.50	3.55
M4.5×0.5	4.00	4.05
M5 ×0.5	4.50	4.55
M5.5×0.5	5.00	5.05
M6 ×0.75	5.30	5.35
M7 ×0.75	6.30	6.35
M8 ×1.0	7.00	7.10
M8 ×0.75	7.30	7.35
M9 ×1.0	8.00	8.10
M9 ×0.75	8.30	8.35
M10 ×1.25	8.80	8.90
M10 ×1.0	9.00	9.10
M10 ×0.75	9.30	9.35
M11 ×1.0	10.0	10.1
M11 ×0.75	10.3	10.3
M12 ×1.5	10.5	10.7
M12 ×1.25	10.8	10.9
M12 ×1.0	11.0	11.1
M14 ×1.5	12.5	12.7
M14 ×1.0	13.0	13.1
M15 ×1.5	13.5	13.7
M15 ×1.0	14.0	14.1
M16 ×1.5	14.5	14.7
M16 ×1.0	15.0	15.1
M17 ×1.5	15.5	15.7
M17 ×1.0	16.0	16.1
M18 ×2.0	16.0	16.3
M18 ×1.5	16.5	16.7
M18 ×1.0	17.0	17.1

Nominal	Drill Diameter	
	HSS	Carbide
M20 ×2.0	18.0	18.3
M20 ×1.5	18.5	18.7
M20 ×1.0	19.0	19.1
M22 ×2.0	20.0	—
M22 ×1.5	20.5	—
M22 ×1.0	21.0	—
M24 ×2.0	22.0	—
M24 ×1.5	22.5	—
M24 ×1.0	23.0	—
M25 ×2.0	23.0	—
M25 ×1.5	23.5	—
M25 ×1.0	24.0	—
M26 ×1.5	24.5	—
M27 ×2.0	25.0	—
M27 ×1.5	25.5	—
M27 ×1.0	26.0	—
M28 ×2.0	26.0	—
M28 ×1.5	26.5	—
M28 ×1.0	27.0	—
M30 ×3.0	27.0	—
M30 ×2.0	28.0	—
M30 ×1.5	28.5	—
M30 ×1.0	29.0	—
M32 ×2.0	30.0	—
M32 ×1.5	30.5	—
M33 ×3.0	30.0	—
M33 ×2.0	31.0	—
M33 ×1.5	31.5	—
M35 ×1.5	33.5	—
M36 ×3.0	33.0	—
M36 ×2.0	34.0	—
M36 ×1.5	34.5	—
M38 ×1.5	36.5	—
M39 ×3.0	36.0	—
M39 ×2.0	37.0	—
M39 ×1.5	37.5	—
M40 ×3.0	37.0	—
M40 ×2.0	38.0	—
M40 ×1.5	38.5	—
M42 ×4.0	38.0	—

Nominal	Drill Diameter	
	HSS	Carbide
M42 ×3.0	39.0	—
M42 ×2.0	40.0	—
M42 ×1.5	40.5	—
M45 ×4.0	41.0	—
M45 ×3.0	42.0	—
M45 ×2.0	43.0	—
M45 ×1.5	43.5	—
M48 ×4.0	44.0	—
M48 ×3.0	45.0	—
M48 ×2.0	46.0	—
M48 ×1.5	46.5	—
M50 ×3.0	47.0	—
M50 ×2.0	48.0	—
M50 ×1.5	48.5	—

Note 1) When using the drill diameters shown in this table, that the processed hole should be measured since the size accuracy of a drill hole may change due to the drilling condition, and that if found to be inappropriate for a prepared hole, the drill diameter must be corrected accordingly.

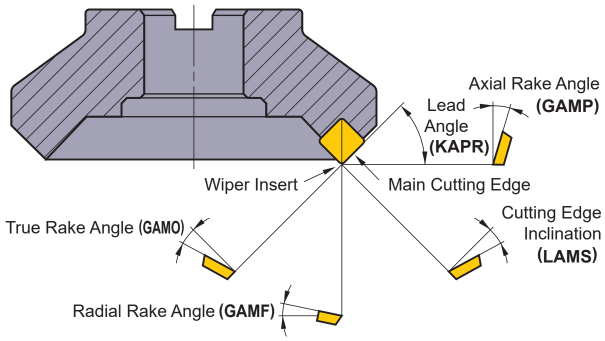
TROUBLE SHOOTING FOR FACE MILLING

Cutting Conditions: Up ↗ / Down ↘. Style and Design of the Tool: Up ↗ / Down ↘ (Number of teeth: Larger ↗ / Smaller ↘).

Trouble		Factors \ Solution	Insert Grade Selection: Select a harder grade	Insert Grade Selection: Select a tougher grade	Insert Grade Selection: Select a grade with better thermal shock resistance	Insert Grade Selection: Select a grade with better adhesion resistance	Cutting Conditions: Cutting speed	Cutting Conditions: Feed	Cutting Conditions: Depth of cut	Cutting Conditions: Engage angle (↗ Up)	Coolant: Do not use water-soluble cutting fluid	Coolant: Determine dry or wet cutting	Style and Design of the Tool: Rake	Style and Design of the Tool: Corner angle	Style and Design of the Tool: Honing strengthens the cutting edge	Style and Design of the Tool: Cutter diameter	Style and Design of the Tool: Number of teeth	Style and Design of the Tool: Wider chip pocket	Style and Design of the Tool: Use of a wiper insert	Style and Design of the Tool: Improve run-out accuracy	Style and Design of the Tool: Cutter rigidity	Machine, Installation of Tool: Increase clamping rigidity of the tool and workpiece	Machine, Installation of Tool: Decrease overhang	Machine, Installation of Tool: Decrease power and machine backlash
Deterioration of Tool Life	Insert wear quickly generated	Improper tool grade	●																					
		Improper cutting edge geometry											●↗	●↗	●↘					●				
		Improper cutting speed					●↘					● Wet												
	Chipping or fracturing of cutting edge	Improper tool grade		●																				
		Improper cutting conditions						●↘	●↘															
		Lack of cutting edge strength.													●↗									
		Thermal crack occurs			●		●↘	●↘	●↘		●	● Dry												
		Build-up edge occurs				●	●↗	●↗			●	● Wet												
		Lack of rigidity																			●	●	●	●
Deterioration of Surface Finish	Poor finished surface	Improper cutting conditions	●				●↘	●↘	●↘															
		Welding occurs				●	●↗				●	● Wet	●↗		●↘									
		Poor run-out accuracy																	●	●				
		Chattering					●↘	●↘	●↘	●↗			●↗		●↘		●↘				●	●	●	●
	Not parallel or irregular surface	Workpiece bending						●↘	●↘				●↗	●↘	●↘		●↘					●		
		Tool clearance																			●	●	●	●
		Large back force											●↗	●↘	●↘		●↘							
Burr, Workpiece Chipping	Burrs, chipping	Chip thickness is too large					●↗	●↘	●↘															
		Cutter diameter is too large								●↗						●↘								
		Low sharpness											●↗		●↘									
		A large corner angle												●↘										
	Workpiece edge chipping	Improper cutting conditions						●↘	●↘															
		Low sharpness											●↗		●↘									
		A small corner angle												●↗										
		Chattering					●↘	●↘	●↘	●↗			●↗		●↘		●↘				●	●	●	●
Chip Control	Poor chip dispersal, chip jamming and chip packing	Welding occurs					●↗																	
		Chip thickness is too thin					●↗	●↗																
		Cutter diameter is too small														●↘								
		Poor chip disposal									●	● Wet					●↘	●						

FUNCTION OF TOOL FEATURES FOR FACE MILLING

■FUNCTION OF EACH CUTTING EDGE ANGLE IN FACE MILLING

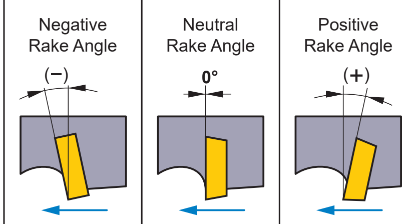


Each Cutting Edge Angle in Face Milling

Type of Angle	Symbol	Function	Effect
Axial Rake Angle	GAMP	Determines chip disposal direction.	**Positive** : Excellent machinability.
Radial Rake Angle	GAMF	Determines sharpness.	**Negative** : Excellent chip disposal.
Lead Angle	KAPR	Determines chip thickness.	**Small** : Thin chips and small cutting impact. Large back force.
True Rake Angle	GAMO	Determines actual sharpness.	**Positive (large)** : Excellent machinability. Minimal welding. **Negative (large)** : Poor machinability. Strong cutting edge.
Cutting Edge Inclination	LAMS	Determines chip disposal direction.	**Positive (large)** : Excellent chip disposal. Low cutting edge strength.

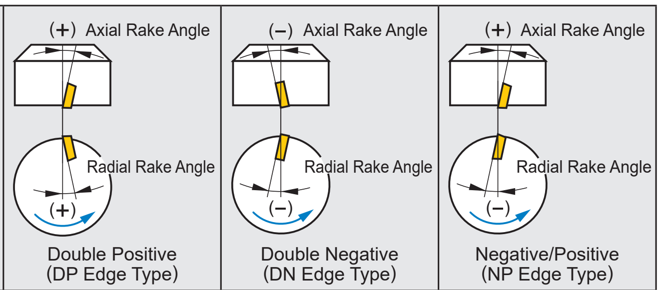
■STANDARD INSERTS

● Positive and Negative Rake Angle



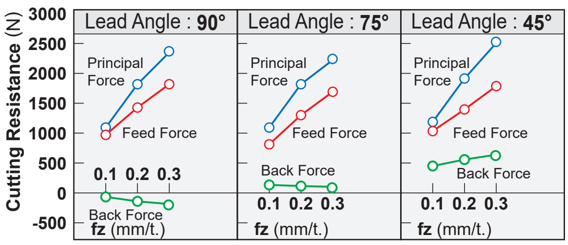
· Insert shape whose cutting edge precedes is a positive rake angle.
· Insert shape whose cutting edge follows is a negative rake angle.

● Standard Cutting Edge Shape



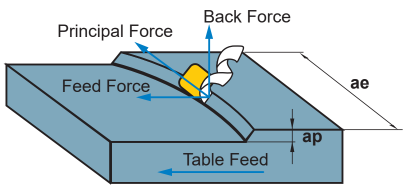
Standard Cutting Edge Combinations		Double Positive (DP Edge Type)	Double Negative (DN Edge Type)	Negative/Positive (NP Edge Type)
Axial Rake Angle (GAMP)		Positive (+)	Negative (−)	Positive (+)
Radial Rake Angle (GAMF)		Positive (+)	Negative (−)	Negative (−)
Insert Used		Positive Insert (One Sided Use)	Negative Insert (Double-Sided Use)	Positive Insert (One Sided Use)
Workpiece Material	Steel	●	−	●
	Cast Iron	−	●	●
	Aluminium Alloy	●	−	−
	Difficult-to-Cut Material	●	−	●

■LEAD ANGLE (KAPR) AND CUTTING CHARACTERISTICS

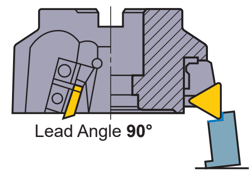
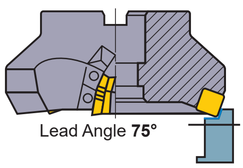
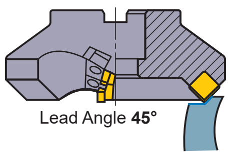


Workpiece : **JIS SCM440 (281HB)**
Tool : **ø125mm** Single Insert
Cutting Conditions : **vc=125.6m/min ap=4mm ae=110mm**

Cutting Resistance Comparison between Different Insert Shapes



Three Cutting Resistance Forces in Milling

Lead Angle	Characteristics	
0°	Back force is in the minus direction. Lifts the workpiece when workpiece clamp rigidity is low.	
15°	Lead angle 75° is recommended for face milling of workpieces with low rigidity such as thin workpieces.	
45°	The largest back force. Bends thin workpieces and lowers cutting accuracy. *Prevents workpiece edge chipping when cast iron cutting.	

* Principal force : Force is in the opposite direction of face milling rotation.
* Back force : Force that pushes in the axial direction.
* Feed force : Force is in the feed direction and is caused by table feed.

TECHNICAL DATA

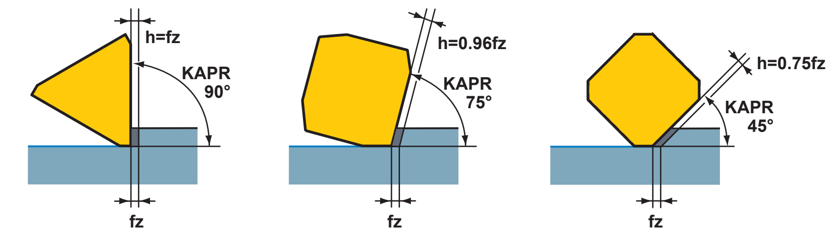
Q

FUNCTION OF TOOL FEATURES FOR FACE MILLING

■APPROACH ANGLE AND THE TOOL LIFE

● Approach Angle and Chip Thickness

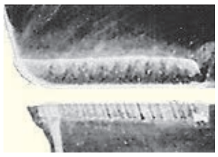
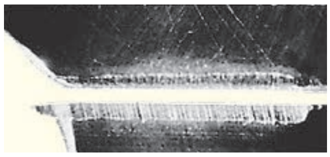
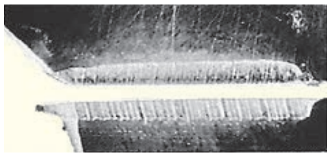
When the depth of cut and feed per tooth, fz, are fixed, the smaller the lead angle (KAPR) is, then the thinner the chip thickness (h) becomes (for a 45° KAPR, it is approx. 75% that of a 90° KAPR). This can be seen in below. Therefore as the KAPR increases, the cutting resistance decreases resulting in longer tool life. Note however, if the chip thickness is too large then the cutting resistance can increase leading to vibrations and shortened tool life.



Effects on chip thickness due to the variation of lead angles

● Approach Angle and Face Wear

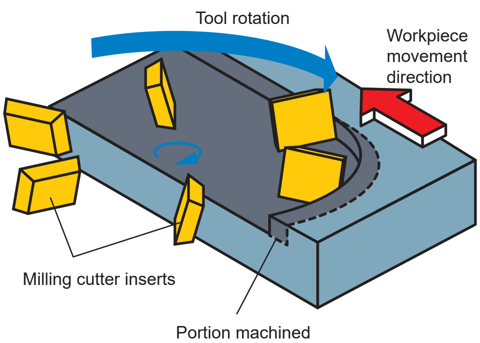
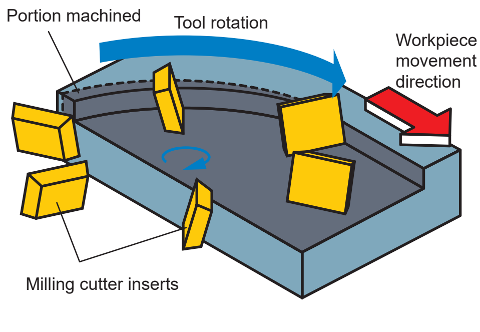
Below shows wear patterns for different lead angles. When comparing crater wear for 90° and 45° lead angles, it can be clearly seen that the cater wear for 90° lead angle is larger.

	Lead Angle **90°**	Lead Angle **75°**	Lead Angle **45°**
vc=100m/min Tc=69min			
vc=125m/min Tc=55min			
vc=160m/min Tc=31min			

Workpiece : **SNCM439 287HB**
Tools : **DC=125mm**
Insert : **M20**Cemented Carbide
Cutting Conditions : **ap=3.0mm**
ae=110mm
fz=0.2mm/t.
Dry Cutting

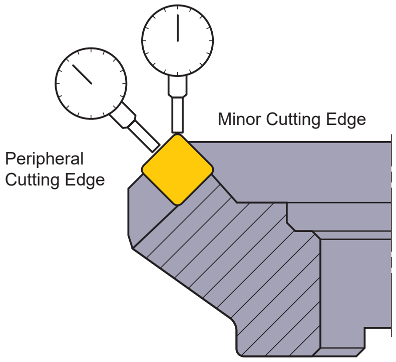
■UP AND DOWN CUT (CLIMB) MILLING

When choosing a method to machine, up cutting or down cut milling (climb milling) is decided by the conditions of the machine tool, the milling cutter and the application. However, it is said that in terms of tool life, down cut (climb) milling is more advantageous.

Up Cut	Down Cut
	

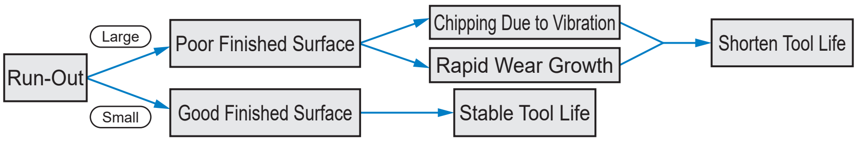
■FINISHED SURFACE

● Cutting Edge Run-Out Accuracy

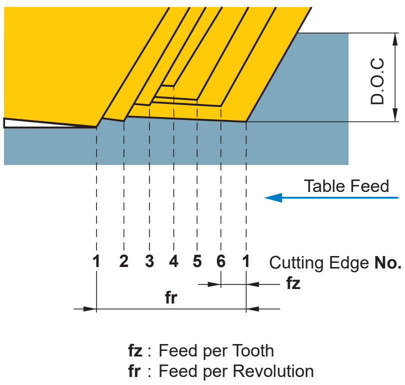


Cutting Edge Run-Out and Accuracy in Face Milling

Cutting edge run-out accuracy of indexable inserts on the cutter body greatly affects the surface finish and tool life.



● Improve Finished Surface Roughness



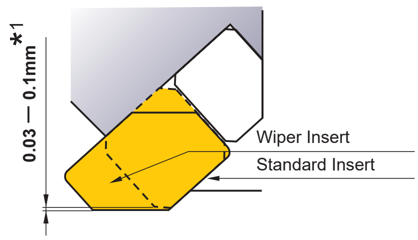
Sub Cutting Edge Run-Out and Finished Surface

Since Mitsubishi Materials' normal sub cutting edge width is 1.4mm, and the sub cutting edges are set parallel to the face of a milling cutter, theoretically the finished surface accuracy should be maintained even if run-out accuracy is low.

Actual Problems
· Cutting edge run-out. · Sub cutting edge inclination. · Milling cutter body accuracy. · Spare parts accuracy. · Welding, vibration, chattering.

Countermeasure
Wiper Insert

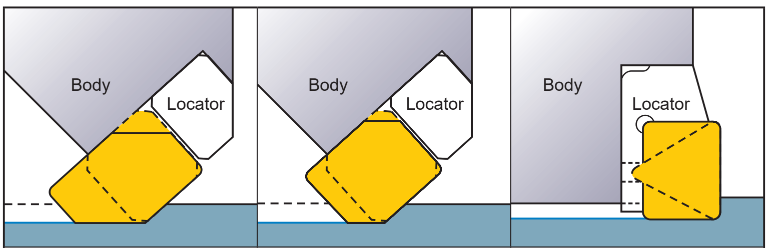
* Machine a surface that has already been per-machined in order to produce smooth finished surface.



· Replace one or two normal inserts with wiper inserts.
· Wiper inserts be set to protrude by 0.03—0.1mm from the standard inserts.

*1.Value depends on the cutting edge and insert combination.

● How to Set a Wiper Insert



(a) **One Corner Type**	(b) **Two Corner Type**	(c) **Two Corner Type**
Replace normal insert.	Replace normal insert.	Use locator for wiper insert.

· Sub cutting edge length has to be longer than the feed per revolution.
* Too long sub cutting edge causes chattering.
· When the cutter diameter is large and feed per revolution is longer than the sub cutting edge of the wiper insert, use two or three wiper inserts.
· When using more than 1 wiper inserts, eliminate run-out of wiper inserts.
· Use a high hardness grade (high wear resistance) for wiper inserts.

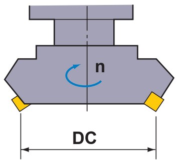
FORMULAE FOR FACE MILLING

■CUTTING SPEED (vc)

$$vc = \frac{\pi \cdot DC \cdot n}{1000} \ (m/min)$$

vc (m/min) : Cutting Speed
π (3.14) : Pi
DC (mm) : Cutter Diameter
n (min^{-1}) : Main Axis Spindle Speed

*Divide by 1000 to change to m from mm.



(Problem) What is the cutting speed when main axis spindle speed is 350min^{-1} and the cutter diameter is ϕ125 ?

(Answer) Substitute π=3.14, DC=125, n=350 into the formula.

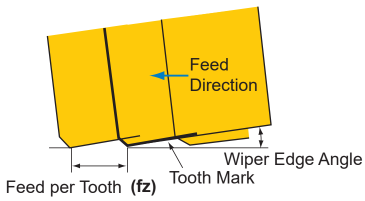
$$vc = \frac{\pi \cdot DC \cdot n}{1000} = \frac{3.14 \times 125 \times 350}{1000} = 137.4m/min$$

The cutting speed is 137.4m/min.

■FEED PER TOOTH (fz)

$$fz = \frac{vf}{z \cdot n} \ (mm/t.)$$

fz (mm/t.) : Feed per Tooth
vf (mm/min) : Table Feed per Min.
n (min^{-1}) : Main Axis Spindle Speed (Feed per Revolution **fr = z x fz**)
z : Insert Number



(Problem) What is the feed per tooth when the main axis spindle speed is 500min^{-1}, number of insert is 10, and table feed is 500mm/min ?

(Answer) Substitute the above figures into the formula.

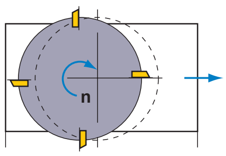
$$fz = \frac{vf}{z \times n} = \frac{500}{10 \times 500} = 0.1mm/t.$$

The answer is 0.1mm/t.

■TABLE FEED (vf)

$$vf = fz \cdot z \cdot n \ (mm/min)$$

vf (mm/min) : Table Feed per Min.
fz (mm/t.) : Feed per Tooth
n (min^{-1}) : Main Axis Spindle Speed
z : Insert Number



(Problem) What is the table feed when feed per tooth is 0.1mm/t., number of insert is 10, and main axis spindle speed is 500min^{-1}?

(Answer) Substitute the above figures into the formula.

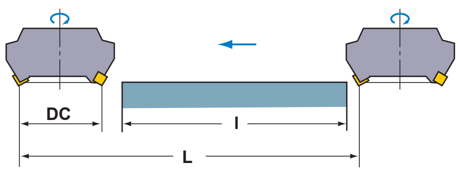
$$vf = fz \times z \times n = 0.1 \times 10 \times 500 = 500mm/min$$

The table feed is 500mm/min.

■CUTTING TIME (Tc)

$$Tc = \frac{L}{vf} \ (min)$$

Tc (min) : Cutting Time
vf (mm/min) : Table Feed per Min.
L (mm) : Total Table Feed Length (Workpiece Length: (**l**)+Cutter Diameter : (**DC**))



(Problem) What is the cutting time required for finishing 100mm width and 300mm length surface of a cast iron (JIS FC200) block when the cutter diameter is ϕ200mm, the number of inserts is 16, the cutting speed is 125m/min, and feed per tooth is 0.25mm. (spindle speed is 200min^{-1})

(Answer) Calculate table feed per min vf=0.25×16×200=800mm/min
Calculate total table feed length. L=300+200=500mm
Substitute the above answers into the formula.

$$Tc = \frac{500}{800} = 0.625 \ (min)$$

0.625×60=37.5 (sec). The answer is 37.5 sec.

■CUTTING POWER (Pc)

$$Pc = \frac{ap \cdot ae \cdot vf \cdot Kc}{60\times10^6\times\eta}$$

Pc (kW) : Actual Cutting Power
ae (mm) : Cutting Width
Kc (MPa) : Specific Cutting Force
ap (mm) : Depth of Cut
vf (mm/min) : Table Feed per Min.
η : (Machine Coefficient)

(Problem) What is the cutting power required for milling tool steel at a cutting speed of 80m/min. With depth of cut 2mm, cutting width 80mm, and table feed 280mm/min by ϕ250 cutter with 12 inserts. Machine coefficient 80%.

(Answer) First, calculate the spindle speed in order to obtain feed per tooth.

$$n = \frac{1000vc}{\pi DC} = \frac{1000\times80}{3.14\times250} = 101.91\text{min}^{-1}$$

Feed per Tooth $fz = \frac{vf}{z\times n} = \frac{280}{12\times101.9} = 0.228\text{mm/t.}$

Substitute the specific cutting force into the formula.

$$Pc = \frac{2\times80\times280\times1800}{60\times10^6\times0.8} = 1.68\text{ kW}$$

●Kc

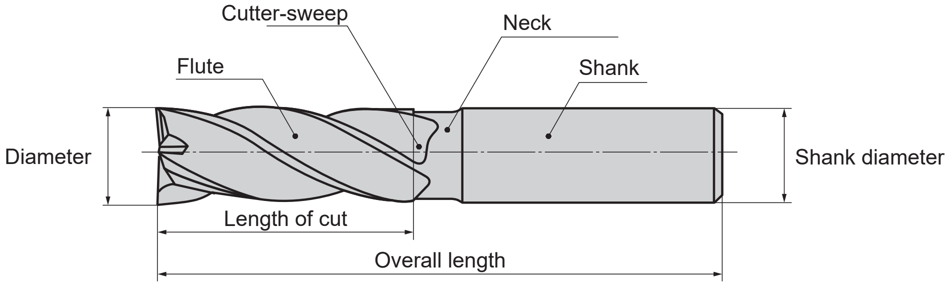
Workpiece Material	Tensile Strength (MPa) and Hardness	Specific Cutting Force Kc (MPa)				
		0.1mm/t.	0.2mm/t.	0.3mm/t.	0.4mm/t.	0.6mm/t.
Mild Steel	**520**	2200	1950	1820	1700	1580
Medium Steel	**620**	1980	1800	1730	1600	1570
Hard Steel	**720**	2520	2200	2040	1850	1740
Tool Steel	**670**	1980	1800	1730	1700	1600
Tool Steel	**770**	2030	1800	1750	1700	1580
Chrome Manganese Steel	**770**	2300	2000	1880	1750	1660
Chrome Manganese Steel	**630**	2750	2300	2060	1800	1780
Chrome Molybdenum Steel	**730**	2540	2250	2140	2000	1800
Chrome Molybdenum Steel	**600**	2180	2000	1860	1800	1670
Nickel Chrome Molybdenum Steel	**940**	2000	1800	1680	1600	1500
Nickel Chrome Molybdenum Steel	**352HB**	2100	1900	1760	1700	1530
Austenitic Stainless Steel	**155HB**	2030	1970	1900	1770	1710
Cast Iron	**520**	2800	2500	2320	2200	2040
Hard Cast Iron	**46HRC**	3000	2700	2500	2400	2200
Meehanite Cast Iron	**360**	2180	2000	1750	1600	1470
Grey Cast Iron	**200HB**	1750	1400	1240	1050	970
Brass	**500**	1150	950	800	700	630
Light Alloy (Al-Mg)	**160**	580	480	400	350	320
Light Alloy (Al-Si)	**200**	700	600	490	450	390
Light Alloy (Al-Zn-Mg-Cu)	**570**	880	840	840	810	720

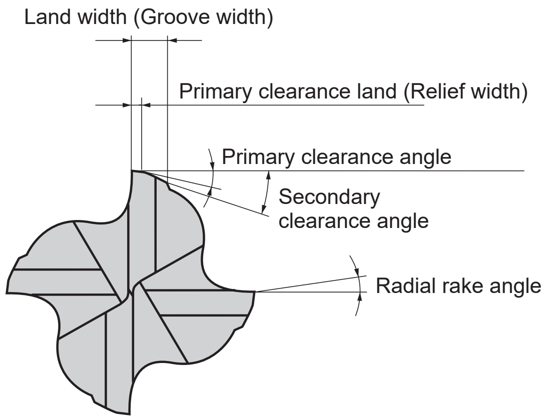
TROUBLE SHOOTING FOR END MILLING

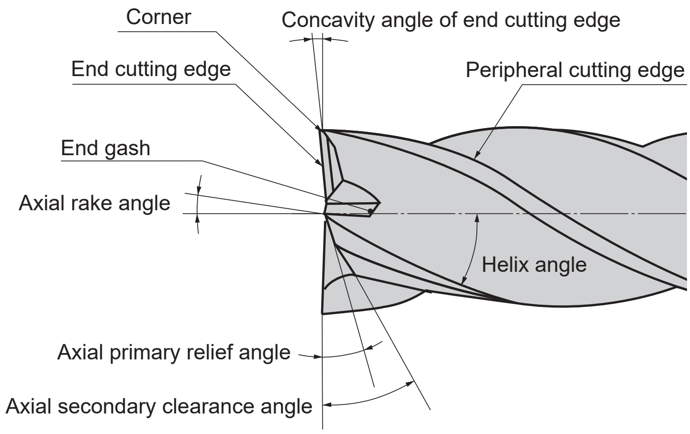
Trouble		Factors	Insert Grade Selection	Cutting Conditions										Style and Design of the Tool						Machine, Installation of Tool					
		Solution	Coated tool	Cutting speed	Feed	Depth of cut	Pick feed	Down cut	Use air blow	Coolant: Increase coolant quantity	Coolant: Do not use water-soluble cutting fluid	Coolant: Determine dry or wet cutting	Helix angle	Insert number	Concavity angle of end cutting edge	Tool diameter	Cutter rigidity	Wider chip pocket	Shorten tool overhang	Increase tool installation accuracy	Increase spindle collet run-out accuracy	Collet inspection and exchange	Increase chuck clamping power	Increase work clamping rigidity
				Up ↗ Down ↘	Up ↗ Down ↘	Up ↗ Down ↘	↘ Down						Up ↗ Larger Down ↘ Smaller	Up ↗ Larger Down ↘ Smaller	Up ↗ Larger Down ↘ Smaller	Up ↗ Larger Down ↘ Smaller								
Deterioration of Tool Life	Large peripheral cutting edge wear	Uncoated end mill is used	●																					
		A small number of cutting edges												●↗										
		Improper cutting conditions		●↘							●													
		Up cut milling is used						Down Cut																
	Severe chipping	Improper cutting conditions																						
		Fragile cutting edge															●							
		Insufficient clamping force																				●	●	
		Low clamping rigidity																	●	●	●	●	●	●
	Breakage during cutting	Improper cutting conditions				●↘																		
		Low end mill rigidity														●↗	●							
		Overhang longer than necessary				●↘													●					
		Chip jamming								●								●						
Deterioration of Surface Finish	Vibration during cutting	Improper cutting conditions		●↘	●↘																			
		Low end mill rigidity											●↗	●↗		●↗	●							
		Low clamping rigidity																	●	●	●	●	●	●
	Poor surface finish on walls	Large cutting edge wear	●																					
		Improper cutting conditions		●↘		●↘																		
		Chip packing.							●	●		● Wet												
	Poor surface finish on faces	The end cutting edge does not have a concave angle			●↘	●↘									●↗									
		Large pick feed					●↘																	
	Out of vertical	Large cutting edge wear	●																					
		Improper cutting conditions			●↘	●↘																		
		Lack of end mill rigidty											●↗	●↗		●↗	●							
	Poor dimensional accuracy	Improper cutting conditions		●↘	●↘	●↘																		
		Low clamping rigidity																	●	●	●	●	●	●
Burrs, Chipping, etc.	Burr or chipping occurs	Improper cutting conditions			●↘	●↘																		
		Large helix angle											●↘											
	Quick bur formation	Notch wear	●																					
		Improper cutting conditions		●↘	●↗																			
Poor Chip Dispersal	Chip packing	Metal removal too large			●↘	●↘																		
		Lack of chip pocket												●↘				●						

END MILL TERMINOLOGY

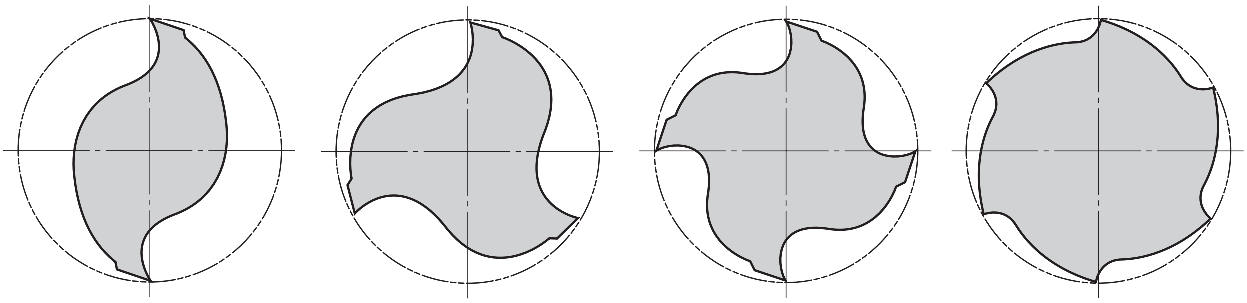
■END MILL TERMINOLOGY







■COMPARISON OF SECTIONAL SHAPE AREA OF CHIP POCKET



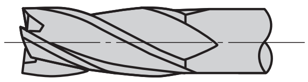
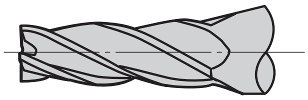
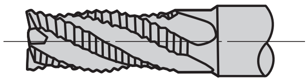
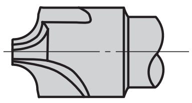
2-flutes 50% | 3-flutes 45% | 4-flutes 40% | 6-flutes 20%

■CHARACTERISTICS AND APPLICATIONS OF DIFFERENT-NUMBER-OF-FLUTE END MILLS

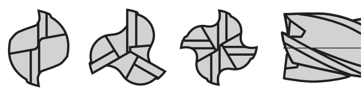
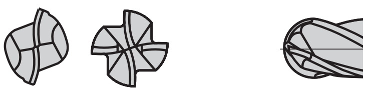
		2-flutes	3-flutes	4-flutes	6-flutes
Feature	Advantage	Chip disposability is excellent. Suitable for sinking. Low cutting resistance.	Chip disposability is excellent. Suitable for sinking.	High rigidity	High rigidity. Superior cutting edge durability.
	Fault	Low rigidity	Diameter is not easily measured.	Chip disposability is poor.	Chip disposability is poor.
Usage		Slotting, side milling, sinking etc. Wide range of use.	Slotting, side milling Heavy cutting, finishing	Shallow slotting, side milling Finishing	High Hardness Material Shallow slotting, side milling

TYPES AND SHAPES OF END MILL

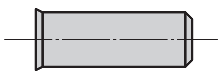
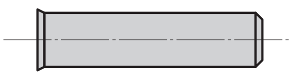
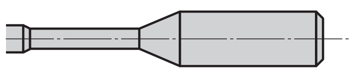
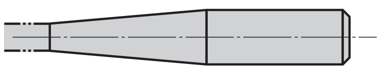
■Peripheral Cutting Edge

Kind	Shape	Feature
Ordinary Flute		Ordinary flute type is most generally used for the slotting, side milling, and the shoulder milling, etc. Can be used for roughing, semi-finishing, and the finishing.
Tapered Flute		A tapered fute is used for milling mould drafts and angled faces.
Roughing Flute		Because a roughing tooth has a wave-like form and produces small chips. Cutting resistance is low, and is suitable for roughing. Not suitable for finishing. The tooth face is re-grindable.
Formed Flute		A corner radius cutter is shown. An infinite range of form cutters can be produced.

■End Cutting Edge

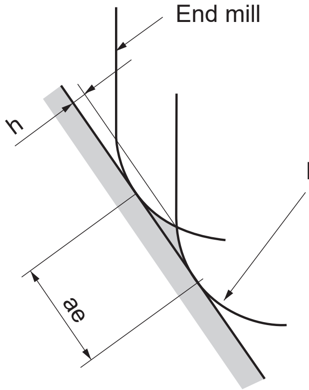
Kind	Shape	Feature
Square End (Centre With Hole)		This is generally used for slotting, side milling, and shoulder milling. Sinking is not possible. Grinding is centre supported, making re-grinding accurate.
Square End (Centre Cut)		It is generally used for slotting, side milling, and shoulder milling. Vertical cutting can be performed. Re-grinding is possible.
Ball End		Suitable for profile machining and pick feed milling.
End Radius		For corner radius milling and contouring. Efficient small corner radius milling due to large diameter and small corner radius.

■Shank and Neck Parts

Kind	Shape	Feature
Standard (Straight Shank)		For general use.
Long Shank		For deep slotting and has a long shank, so that adjustment of the overhang is possible.
Long Neck		For deep slotting and small diameter end mills, also suitable for boring.
Taper Neck		For best performance in deep slotting and on mould drafts.

PITCH SELECTION OF PICK FEED

■PICK FEED MILLING (CONTOURING) WITH BALL NOSE END MILLS AND END MILLS WITH CORNER RADIUS



$$h = R \cdot \left[1 - \cos \left\{ \sin^{-1}\left(\frac{ae}{2R} \right) \right\} \right]$$

R : Radius of Ball Nose(RE), Corner Radius(RE)

ae : Pick Feed

h : Cusp Height

■CORNER R OF END MILLS AND CUSP HEIGHT BY PICK FEED

Unit : mm

ae / R	Pick Feed									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.5	0.003	0.010	0.023	0.042	0.067	0.100	–	–	–	–
1	0.001	0.005	0.011	0.020	0.032	0.046	0.063	0.083	0.107	–
1.5	0.001	0.003	0.008	0.013	0.021	0.030	0.041	0.054	0.069	0.086
2	0.001	0.003	0.006	0.010	0.016	0.023	0.031	0.040	0.051	0.064
2.5	0.001	0.002	0.005	0.008	0.013	0.018	0.025	0.032	0.041	0.051
3		0.002	0.004	0.007	0.010	0.015	0.020	0.027	0.034	0.042
4		0.001	0.003	0.005	0.008	0.011	0.015	0.020	0.025	0.031
5		0.001	0.002	0.004	0.006	0.009	0.012	0.016	0.020	0.025
6		0.001	0.002	0.003	0.005	0.008	0.010	0.013	0.017	0.021
8			0.001	0.003	0.004	0.006	0.008	0.010	0.013	0.016
10			0.001	0.002	0.003	0.005	0.006	0.008	0.010	0.013
12.5			0.001	0.002	0.003	0.004	0.005	0.006	0.008	0.010

ae / R	Pick Feed									
	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
0.5	–	–	–	–	–	–	–	–	–	–
1	–	–	–	–	–	–	–	–	–	–
1.5	0.104	–	–	–	–	–	–	–	–	–
2	0.077	0.092	0.109	–	–	–	–	–	–	–
2.5	0.061	0.073	0.086	0.100	–	–	–	–	–	–
3	0.051	0.061	0.071	0.083	0.095	0.109	–	–	–	–
4	0.038	0.045	0.053	0.062	0.071	0.081	0.091	0.103	–	–
5	0.030	0.036	0.042	0.049	0.057	0.064	0.073	0.082	0.091	0.101
6	0.025	0.030	0.035	0.041	0.047	0.054	0.061	0.068	0.076	0.084
8	0.019	0.023	0.026	0.031	0.035	0.040	0.045	0.051	0.057	0.063
10	0.015	0.018	0.021	0.025	0.028	0.032	0.036	0.041	0.045	0.050
12.5	0.012	0.014	0.017	0.020	0.023	0.026	0.029	0.032	0.036	0.040

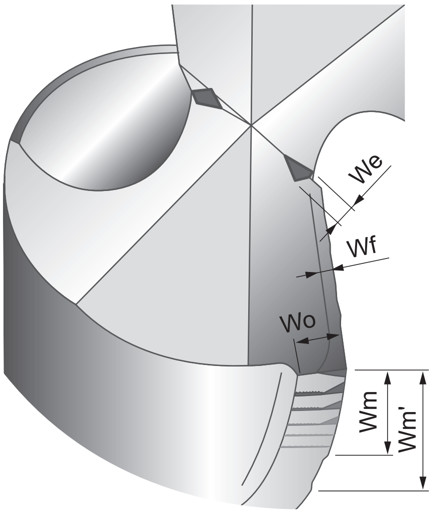
TROUBLE SHOOTING FOR DRILLING

Trouble		Factors \ Solution	Cutting Conditions									Style and Design of the Tool							Machine, Installation of Tool				
			Cutting speed (Up ↗ Down ↘)	Feed (Up ↗ Down ↘)	Lower feed at initial cutting	Lower feed when breaking through	Step feed	Increase accuracy of prep-hole and depth	Coolant: Increase oil ratio	Coolant: Increase volume	Coolant: Increase coolant pressure	Chisel width (Up ↗ Down ↘)	Honing width (Up ↗ Down ↘)	Core thickness (Up ↗ Down ↘)	Shorten flute length	Decrease lip height	Use internal coolant type drill	Change to a drill with X type thinning	Increase tool installation accuracy	Shorten tool overhang	Flat workpiece face	Increase work clamping rigidity	Reduce machine backlash and increase rigidity
Deterioration of Tool Life	Drill breakage	Lack of drill rigidity												●↗	●								
		Improper cutting conditions		●↘																			
		Large deflection of the tool holder																	●				●
		Workpiece face is inclined																			●		
	Large wear at the peripheral cutting edge and along the land	Improper cutting conditions	●↘																				
		An increase in temperature at the cutting point							●	●							●						
		Poor run-out accuracy																	●				
	Chipping of the peripheral cutting edge	Improper cutting conditions		●↘			●																
		Large deflection of the tool holder																	●				●
		chattering, vibration											●↘							●		●	●
	Chisel edge chipping	The chisel edge width is too wide										●↘											
		Poor entry			●																		
		Chattering, vibration											●↘							●		●	●
Deterioration of Hole Accuracy	Hole diameter increases	Lack of drill rigidity												●↗	●								
		Improper drill geometry														●							
	Hole diameter becomes smaller	An increase in temperature at the cutting point							●	●							●						
		Improper cutting conditions	●↘																				
		Improper drill geometry														●							
	Poor straightness	Lack of drill rigidity												●↗	●								
		Large deflection of the tool holder																	●				●
		Poor guiding properties						●															
	Poor hole positioning accuracy, roundness and surface finish	Lack of drill rigidity												●↗	●								
		Poor entry																●					
		Improper cutting conditions			●																		
		Large deflection of the tool holder																	●				●
Burrs	Burrs at the hole exit	Improper drill geometry											●↘										
		Improper cutting conditions				●																	
Poor Chip Dispersal	Long chips	Improper cutting conditions		●↗				●															
		Poor chip disposal								●	●			●↘			●						
	Chip jamming	Improper cutting conditions	●↘	●↘				●															
		Poor chip disposal								●	●			●↘			●						

DRILL WEAR AND CUTTING EDGE DAMAGE

■DRILL WEAR CONDITION

The table below shows a simple drawing depicting the wear of a drill's cutting edge. The generation and the amount of wear differ according to the workpiece materials and cutting conditions used. But generally, the peripheral wear is largest and determines a drill tool life. When regrinding, the flank wear at the point needs to be ground away completely. Therefore, if there is large wear more material needs to be ground away to renew the cutting edge.



We : **Chisel edge wear width**

Wf : **Flank Wear (The middle of the cutting edge)**

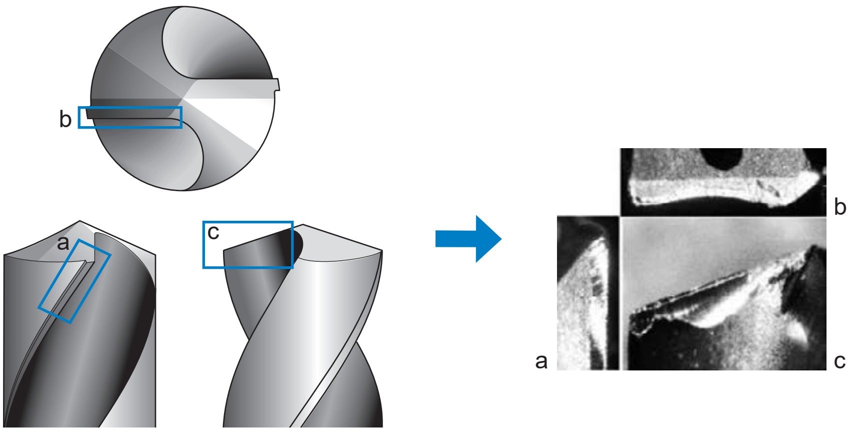
Wo : **Outer corner wear width**

Wm : **Margin wear width**

Wm' : **Margin wear width (Leading edge)**

■CUTTING EDGE DAMAGE

When drilling, the cutting edge of the drill can suffer from chipping, fracture and abnormal damage. In such cases, it is important to take a closer look at the damage, investigate the cause and take countermeasures.



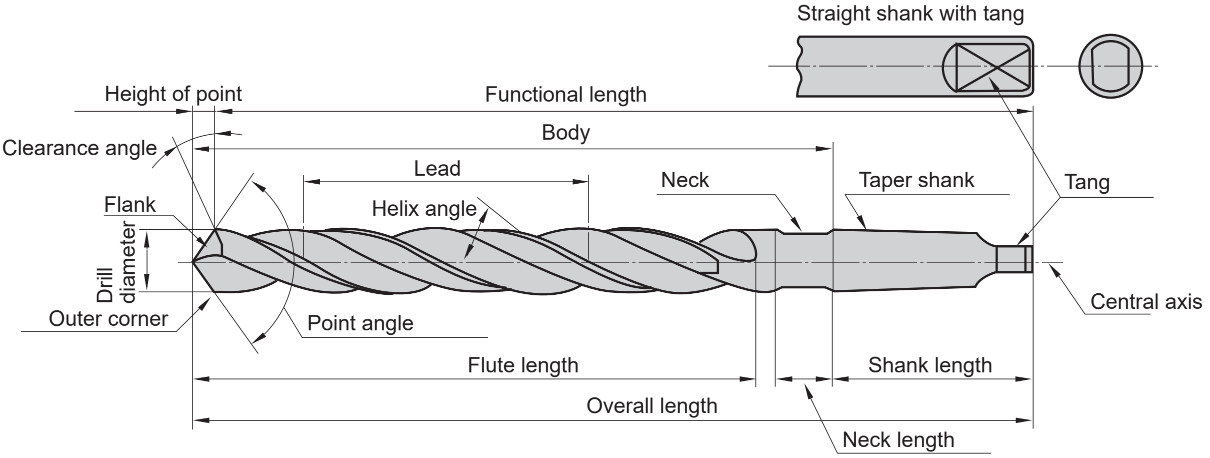
Cutting edge damage

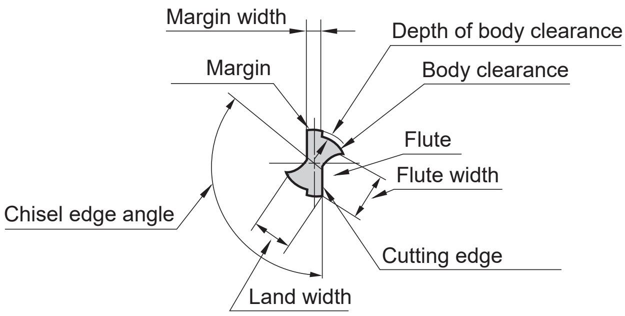
TECHNICAL DATA

Q

DRILL TERMINOLOGY AND CUTTING CHARACTERISTICS

■NAMES OF EACH PART OF A DRILL





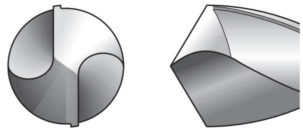
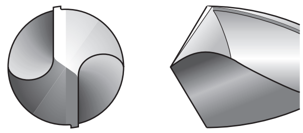
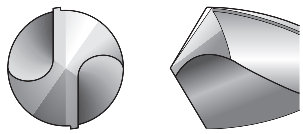
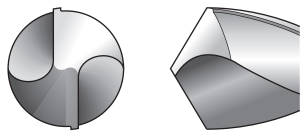
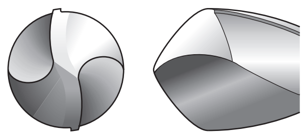
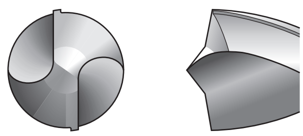
■SHAPE SPECIFICATION AND CUTTING CHARACTERISTICS

Helix Angle	Is the inclination of the flute with respect to the axial direction of a drill, which corresponds to the rake angle of a bit. The rake angle of a drill differs according to the position of the cutting edge, and it decreases greatly as the circumference approaches the centre.The chisel edge has a negative rake angle, crushing the work. **High-hardness material Small ◀·· Rake angle ··▶ Large Soft material** (Aluminium, etc.)
Flute Length	It is determined by depth of hole, bush length, and regrinding allowance. Since the influence on the tool life is great, it is necessary to minimize it as much as possible.
Point Angle	In general, the angle is 118° which is set differently to various applications. **Soft material with good machinability Small ◀·· Point angle ··▶ Large For hard material and high efficiency machining**
Web Thickness	It is an important element that determines the rigidity and chip raking performance of a drill. The web thickness is set according to applications. Small cutting resistance / Low rigidity / Good chip raking performance / Machinable material } **Thin ◀·· Web thickness ··▶ Thick** { Large cutting resistance / High rigidity / Poor chip raking performance / High-hardness material, cross hole drilling, etc.
Margin	The tip determines the drill diameter and functions as a drill guide during drilling. The margin width is determined in consideration of friction during hole drilled. **Poor guiding performance Small ◀·· Margin width ··▶ Large Good guiding performance**
Diameter Back Taper	To reduce friction with the inside of the drilled hole, the portion from the tip to the shank is tapered slightly. The degree is usually represented by the quantity of reduction in the diameter with respect to the flute length, which is approx. 0.04−0.1mm. It is set at a larger value for high efficiency drills and the workpiece material that allows drilled holes.

■CUTTING EDGE GEOMETRY AND ITS INFLUENCE

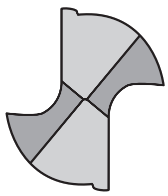
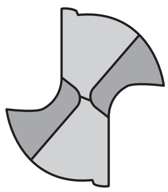
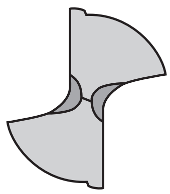
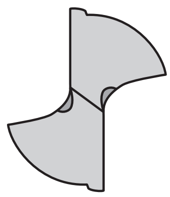
As shown in the table below, it is possible to select the most suitable cutting edge geometry for different applications. If the most suitable cutting edge geometry is selected then higher machining efficiency and higher hole accuracy can be obtained.

●Cutting Edge Shapes

Grinding Name	Shape	Features and Effect	Application
Conical		• The flank is conical and the clearance angle increases toward the centre of the drill.	• General Use
Flat		• The flank is flat. • Easy grinding.	• Mainly for small diameter drills.
Three Flank Angles		• As there is no chisel edge, the results are high centripetal force and small hole oversize. • Requires a special grinding machine. • Surface grinding of three sides.	• For drilling operations that require high hole accuracy and positioning accuracy.
Spiral Point		• To increase the clearance angle near the centre of the drill, conical grinding combined with irregular helix. • S type chisel edge with high centripetal force and machining accuracy.	• For drilling that requires high accuracy.
Radial Lip		• The cutting edge is ground radial with the aim of dispersing load. • High machining accuracy and finished surface roughness. • For through holes, small burrs on the base. • Requires a special grinding machine.	• Cast Iron, Aluminium Alloy • For cast iron plates. • Steel
Centre Point Drill		• This geometry has two-stage point angle for better concentricity and a reduction in shock when exiting the workpiece.	• For thin sheet drilling.

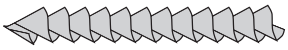
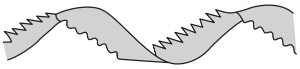
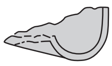
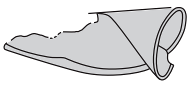
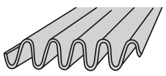
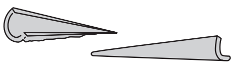
■WEB THINNING

The rake angle of the cutting edge of a drill reduces toward the centre, and it changes into a negative angle at the chisel edge. During drilling, the centre of a drill crushes the work, generating 50−70% of the cutting resistance. Web thinning is very effective for reduction in the cutting resistance of a drill, early removal of cut chips at the chisel edge, and better initial bite.

Shape	 **X type**	 **XR type**	 **S type**	 **N type**
Features	The thrust load substantially reduces, and the bite performance improves. This is effective when the web is thick.	The initial performance is slightly inferior to that of the X type, but the cutting edge is hard and the applicable range of work is wide.	Popular design, easy cutting type.	Effective when the web is comparatively thick.
Major Applications	General drilling and deep hole drilling.	Long life. General drilling and stainless steel drilling.	General drilling for steel, cast iron, and non-ferrous metal.	Deep hole drilling.

DRILL TERMINOLOGY AND CUTTING CHARACTERISTICS

■DRILLING CHIPS

Types of Chips	Shape	Features and Ease of Raking
Conical Spiral		Fan-shaped chips cut by the cutting edge are curved by the flute. Chips of this type are produced when the feeding rate of ductile material is small. If the chip breaks after several turns, the chip raking performance is satisfactory.
Long Pitch		The generated chip comes out without coiling. It will easily coil around the drill.
Fan		This is a chip broken by the restraint caused by the drill flute and the wall of a drilled hole. It is generated when the feed rate is high.
Segment		A conical spiral chip that is broken before the chip grows into the long-pitch shape by the restraint caused by the wall of the drilled hole due to the insufficiency of ductility. Excellent chip disposal and chip discharge.
Zigzag		A chip that is buckled and folded because of the shape of flute and the characteristics of the material. It easily causes chip packing at the flute.
Needle		Chips broken by vibration or broken when brittle material is curled with a small radius. The raking performance is satisfactory, but these chips can pack closely creating.

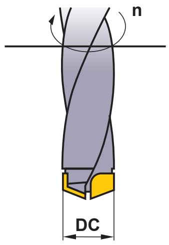
FORMULAE FOR DRILLING

■CUTTING SPEED (vc)

$$vc = \frac{\pi \cdot DC \cdot n}{1000} \ (m/min)$$

vc (m/min) : Cutting Speed	**DC (mm)** : Drill Diameter
π (3.14) : Pi	**n (min^{-1})** : Main Axis Spindle Speed

*Divide by 1,000 to change to m from mm.



(Problem) What is the cutting speed when main axis spindle speed is 1350min^{-1} and drill diameter is 12mm ?

(Answer) Substitute π=3.14, DC=12, n=1350 into the formula

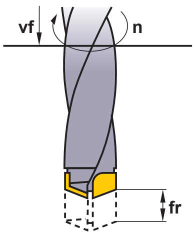
$$vc = \frac{\pi \cdot DC \cdot n}{1000} = \frac{3.14 \times 12 \times 1350}{1000} = 50.9m/min$$

The cutting speed is 50.9m/min.

■FEED OF THE MAIN SPINDLE (vf)

$$vf = fr \cdot n \ (mm/min)$$

vf (mm/min) : Feed Speed of the Main Spindle (Z axis)
fr (mm/rev) : Feed per Revolution
n (min^{-1}) : Main Axis Spindle Speed



(Problem) What is the spindle feed (vf) when the feed per revolution is 0.2mm/rev and main axis spindle speed is 1350min^{-1} ?

(Answer) Substitute fr=0.2, n=1350 into the formula

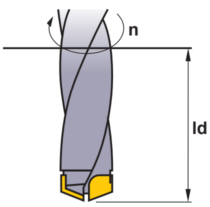
$$vf = fr \times n = 0.2 \times 1350 = 270mm/min$$

The spindle feed is 270mm/min.

■DRILLING TIME (Tc)

$$Tc = \frac{Id \cdot i}{n \cdot fr}$$

Tc (min) : Drilling Time
n (min^{-1}) : Spindle Speed
Id (mm) : Hole Depth
fr (mm/rev) : Feed per Revolution
i : Number of Holes



(Problem) What is the drilling time required for drilling a 30mm length hole in alloy steel (JIS SCM440) at a cutting speed of 50m/min and a feed 0.15mm/rev ?

(Answer) Spindle Speed $n = \frac{50 \times 1000}{15 \times 3.14} = 1061.57min^{-1}$

$$Tc = \frac{30 \times 1}{1061.57 \times 0.15} = 0.188$$

$$= 0.188 \times 60 \fallingdotseq 11.3 \ sec$$

METALLIC MATERIALS CROSS REFERENCE LIST

CARBON STEEL

Japan	Germany		U.K.		France	Italy	Spain	Sweden	USA	China
JIS	W-nr.	DIN	BS	EN	AFNOR	UNI	UNE	SS	AISI/SAE	GB
STKM 12A STKM 12C	1.0038	RSt.37-2	4360 40 C	–	E 24-2 Ne	–	–	1311	A570.36	15
–	1.0401	C15	080M15	–	CC12	C15, C16	F.111	1350	1015	15
–	1.0402	C22	050A20	2C	CC20	C20, C21	F.112	1450	1020	20
SUM22	1.0715	9SMn28	230M07	1A	S250	CF9SMn28	F.2111 11SMn28	1912	1213	Y15
SUM22L	1.0718	9SMnPb28	–	–	S250Pb	CF9SMnPb28	11SMnPb28	1914	12L13	–
–	1.0722	10SPb20	–	–	10PbF2	CF10Pb20	10SPb20	–	–	–
–	1.0736	9SMn36	240M07	1B	S300	CF9SMn36	12SMn35	–	1215	Y13
–	1.0737	9SMnPb36	–	–	S300Pb	CF9SMnPb36	12SMnP35	1926	12L14	–
S15C	1.1141	Ck15	080M15	32C	XC12	C16	C15K	1370	1015	15
S25C	1.1158	Ck25	–	–	–	–	–	–	1025	25
–	1.8900	StE380	4360 55 E	–	–	FeE390KG	–	2145	A572-60	–
–	1.0501	C35	060A35	–	CC35	C35	F.113	1550	1035	35
–	1.0503	C45	080M46	–	CC45	C45	F.114	1650	1045	45
–	1.0726	35S20	212M36	8M	35MF4	–	F210G	1957	1140	–
–	1.1157	40Mn4	150M36	15	35M5	–	–	–	1039	40Mn
SMn438(H)	1.1167	36Mn5	–	–	40M5	–	36Mn5	2120	1335	35Mn2
SCMn1	1.1170	28Mn6	150M28	14A	20M5	C28Mn	–	–	1330	30Mn
S35C	1.1183	Cf35	060A35	–	XC38TS	C36	–	1572	1035	35Mn
S45C	1.1191	Ck45	080M46	–	XC42	C45	C45K	1672	1045	Ck45
S50C	1.1213	C50	060A52	–	XC48TS	C53	–	1674	1050	50
–	1.0535	C55	070M55	9	–	C55	–	1655	1055	55
–	1.0601	C60	080A62	43D	CC55	C60	–	–	1060	60
S55C	1.1203	Ck55	070M55	–	XC55	C50	C55K	–	1055	55
S58C	1.1221	Ck60	080A62	43D	XC60	C60	–	1678	1060	60Mn
–	1.1274	Ck101	060A96	–	XC100	–	F.5117	1870	1095	–
SK3	1.1545	C105W1	BW1A	–	Y105	C36KU	F.5118	1880	W1	–
SUP4	1.1545	C105W1	BW2	–	Y120	C120KU	F.515	2900	W210	–

ALLOY STEEL

Japan	Germany		U.K.		France	Italy	Spain	Sweden	USA	China
JIS	W-nr.	DIN	BS	EN	AFNOR	UNI	UNE	SS	AISI/SAE	GB
SM400A, SM400B SM400C	1.0144	St.44.2	4360 43 C	–	E28-3	–	–	1412	A573-81	–
SM490A, SM490B SM490C	1.0570	St52-3	4360 50 B	–	E36-3	Fe52BFN Fe52CFN	–	2132	–	–
–	1.0841	St52-3	150M19	–	20MC5	Fe52	F.431	2172	5120	–
–	1.0904	55Si7	250A53	45	55S7	55Si8	56Si7	2085	9255	55Si2Mn
–	1.0961	60SiCr7	–	–	60SC7	60SiCr8	60SiCr8	–	9262	–
SUJ2	1.3505	100Cr6	534A99	31	100C6	100Cr6	F.131	2258	ASTM 52100	GCr15
–	1.5415	15Mo3	1501-240	–	15D3	16Mo3KW	16Mo3	2912	ASTM A204Gr.A	–
–	1.5423	16Mo5	1503-245-420	–	–	16Mo5	16Mo5	–	4520	–
–	1.5622	14Ni6	–	–	16N6	14Ni6	15Ni6	–	ASTM A350LF5	–
–	1.5662	X8Ni9	1501-509-510	–	–	X10Ni9	XBNi09	–	ASTM A353	–
SNC236	1.5710	36NiCr6	640A35	111A	35NC6	–	–	–	3135	–
SNC415(H)	1.5732	14NiCr10	–	–	14NC11	16NiCr11	15NiCr11	–	3415	–
SNC815(H)	1.5752	14NiCr14	655M13	36A	12NC15	–	–	–	3415, 3310	–
SNCM220(H)	1.6523	21NiCrMo2	805M20	362	20NCD2	20NiCrMo2	20NiCrMo2	2506	8620	–
SNCM240	1.6546	40NiCrMo22	311-Type 7	–	–	40NiCrMo2(KB)	40NiCrMo2	–	8740	–
–	1.6587	17CrNiMo6	820A16	–	18NCD6	–	14NiCrMo13	–	–	–
SCr415(H)	1.7015	15Cr3	523M15	–	12C3	–	–	–	5015	15Cr

Japan	Germany		U.K.		France	Italy	Spain	Sweden	USA	China
JIS	W-nr.	DIN	BS	EN	AFNOR	UNI	UNE	SS	AISI/SAE	GB
SCr440	1.7045	42Cr4	–	–	–	–	42Cr4	2245	5140	40Cr
SUP9(A)	1.7176	55Cr3	527A60	48	55C3	–	–	–	5155	20CrMn
SCM415(H)	1.7262	15CrMo5	–	–	12CD4	–	12CrMo4	2216	–	–
–	1.7335	13CrMo4 4	1501-620Gr27	–	15CD3.5 15CD4.5	14CrMo45	14CrMo45	–	ASTM A182 F11, F12	–
–	1.7380	10CrMo910	1501-622 Gr31, 45	–	12CD9 12CD10	12CrMo9 12CrMo10	TU.H	2218	ASTM A182 F.22	–
–	1.7715	14MoV63	1503-660-440	–	–	–	13MoCrV6	–	–	–
–	1.8523	39CrMoV13 9	897M39	40C	–	36CrMoV12	–	–	–	–
–	1.6511	36CrNiMo4	816M40	110	40NCD3	38NiCrMo4(KB)	35NiCrMo4	–	9840	–
–	1.6582	34CrNiMo6	817M40	24	35NCD6	35NiCrMo6(KB)	–	2541	4340	40CrNiMoA
SCr430(H)	1.7033	34Cr4	530A32	18B	32C4	34Cr4(KB)	35Cr4	–	5132	35Cr
SCr440(H)	1.7035	41Cr4	530M40	18	42C4	41Cr4	42Cr4	–	5140	40Cr
–	1.7131	16MnCr5	(527M20)	–	16MC5	16MnCr5	16MnCr5	2511	5115	18CrMn
SCM420 SCM430	1.7218	25CrMo4	1717CDS110 708M20	–	25CD4	25CrMo4(KB)	55Cr3	2225	4130	30CrMn
SCM432 SCCRM3	1.7220	34CrMo4	708A37	19B	35CD4	35CrMo4	34CrMo4	2234	4137 4135	35CrMo
SCM 440	1.7223	41CrMo4	708M40	19A	42CD4TS	41CrMo4	42CrMo4	2244	4140 4142	40CrMoA
SCM440(H)	1.7225	42CrMo4	708M40	19A	42CD4	42CrMo4	42CrMo4	2244	4140	42CrMo 42CrMnMo
–	1.7361	32CrMo12	722M24	40B	30CD12	32CrMo12	F.124.A	2240	–	–
SUP10	1.8159	50CrV4	735A50	47	50CV4	50CrV4	51CrV4	2230	6150	50CrVA
–	1.8509	41CrAlMo7	905M39	41B	40CAD6 40CAD2	41CrAlMo7	41CrAlMo7	2940	–	–
–	1.2067	100Cr6	BL3	–	Y100C6	–	100Cr6	–	L3	CrV, 9SiCr
SKS31 SKS2, SKS3	1.2419	105WCr6	–	–	105WC13	100WCr6 107WCr5KU	105WCr5	2140	–	CrWMo
SKT4	1.2713	55NiCrMoV6	BH224/5	–	55NCDV7	–	F.520.S	–	L6	5CrNiMo
–	1.5662	X8Ni9	1501-509	–	–	X10Ni9	XBNi09	–	ASTM A353	–
–	1.5680	12Ni19	–	–	Z18N5	–	–	–	2515	–
–	1.6657	14NiCrMo134	832M13	36C	–	15NiCrMo13	14NiCrMo131	–	–	–
SKD1	1.2080	X210Cr12	BD3	–	Z200C12	X210Cr13KU X250Cr12KU	X210Cr12	–	D3 ASTM D3	Cr12
SKD11	1.2601	X153CrMoV12	BD2	–	–	X160CrMoV12	–	–	D2	Cr12MoV
SKD12	1.2363	X100CrMoV5	BA2	–	Z100CDV5	X100CrMoV5	F.5227	2260	A2	Cr5Mo1V
SKD61	1.2344	X40CrMoV51 X40CrMoV51	BH13	–	Z40CDV5	X35CrMoV05KU X40CrMoV51KU	X40CrMoV5	2242	H13 ASTM H13	4Cr5MoSiV1
SKD2	1.2436	X210CrW12	–	–	–	X215CrW121KU	X210CrW12	2312	–	–
–	1.2542	45WCrV7	BS1	–	–	45WCrV8KU	45WCrSi8	2710	S1	–
SKD5	1.2581	X30WCrV93	BH21	–	Z30WCV9	X28W09KU	X30WCrV9	–	H21	30WCrV9
–	1.2601	X165CrMoV12	–	–	–	X165CrMoW12KU	X160CrMoV12	2310	–	–
SKS43	1.2833	100V1	BW2	–	Y1105V	–	–	–	W210	V
SKH3	1.3255	S 18-1-2-5	BT4	–	Z80WKCV	X78WCo1805KU	HS18-1-1-5	–	T4	W18Cr4VCo5
SKH2	1.3355	S 18-0-1	BT1	–	Z80WCV	X75W18KU	HS18-0-1	–	T1	–
SCMnH/1	1.3401	G-X120Mn12	Z120M12	–	Z120M12	XG120Mn12	X120MN12	–	–	–
SUH1	1.4718	X45CrSi93	401S45	52	Z45CS9	X45CrSi8	F.322	–	HW3	X45CrSi93
SUH3	1.3343	S6-5-2	4959BA2	–	Z40CSD10	15NiCrMo13	–	2715	D3	–
SKH9, SKH51	1.3343	S6/5/2	BM2	–	Z85WDCV	HS6-5-2-2	F.5603	2722	M2	–
–	1.3348	S 2-9-2	–	–	–	HS2-9-2	HS2-9-2	2782	M7	–
SKH55	1.3243	S6/5/2/5	BM35	–	6-5-2-5	HS6-5-2-5	F.5613	2723	M35	–

METALLIC MATERIALS CROSS REFERENCE LIST

■STAINLESS STEEL (FERRITIC,MARTENSITIC)

Japan	Germany		U.K.		France	Italy	Spain	Sweden	USA	China
JIS	W-nr.	DIN	BS	EN	AFNOR	UNI	UNE	SS	AISI/SAE	GB
SUS403	1.4000	X7Cr13	403S17	–	Z6C13	X6Cr13	F.3110	2301	403	OCr13 1Cr12
–	1.4001	X7Cr14	–	–	–	–	F.8401	–	–	–
SUS416	1.4005	X12CrS13	416S21	–	Z11CF13	X12CrS13	F.3411	2380	416	–
SUS410	1.4006	X10Cr13	410S21	56A	Z10C14	X12Cr13	F.3401	2302	410	1Cr13
SUS430	1.4016	X8Cr17	430S15	60	Z8C17	X8Cr17	F.3113	2320	430	1Cr17
SCS2	1.4027	G-X20Cr14	420C29	56B	Z20C13M	–	–	–	–	–
SUS420J2	1.4034	X46Cr13	420S45	56D	Z40CM Z38C13M	X40Cr14	F.3405	2304	–	4Cr13
–	1.4003	–	405S17	–	Z8CA12	X6CrAl13	–	–	405	–
–	1.4021	–	420S37	–	Z8CA12	X20Cr13	–	2303	420	–
SUS431	1.4057	X22CrNi17	431S29	57	Z15CNi6.02	X16CrNi16	F.3427	2321	431	1Cr17Ni2
SUS430F	1.4104	X12CrMoS17	–	–	Z10CF17	X10CrS17	F.3117	2383	430F	Y1Cr17
SUS434	1.4113	X6CrMo17	434S17	–	Z8CD17.01	X8CrMo17	–	2325	434	1Cr17Mo
SCS5	1.4313	X5CrNi134	425C11	–	Z4CND13.4M	(G)X6CrNi304	–	2385	CA6-NM	–
SUS405	1.4724	X10CrA113	403S17	–	Z10C13	X10CrA112	F.311	–	405	OCr13Al
SUS430	1.4742	X10CrA118	430S15	60	Z10CAS18	X8Cr17	F.3113	–	430	Cr17
SUH4	1.4747	X80CrNiSi20	443S65	59	Z80CSN20.02	X80CrSiNi20	F.320B	–	HNV6	–
SUH446	1.4762	X10CrA124	–	–	Z10CAS24	X16Cr26	–	2322	446	2Cr25N
SUH35	1.4871	X53CrMnNiN219	349S54	–	Z52CMN21.09	X53CrMnNiN219	–	–	EV8	5Cr2Mn9Ni4N
–	1.4521	X1CrMoTi182	–	–	–	–	–	2326	S44400	–
–	1.4922	X20CrMoV12-1	–	–	–	X20CrMoNi1201	–	2317	–	–
–	1.4542	–	–	–	Z7CNU17-04	–	–	–	630	–

■STAINLESS STEEL (AUSTENITIC)

Japan	Germany		U.K.		France	Italy	Spain	Sweden	USA	China
JIS	W-nr.	DIN	BS	EN	AFNOR	UNI	UNE	SS	AISI/SAE	GB
SUS304L	1.4306	X2CrNi1911	304S11	–	Z2CN18.10	X2CrNi18.11	–	2352	304L	OCr19Ni10
SUS304	1.4350	X5CrNi189	304S11	58E	Z6CN18.09	X5CrNi1810	F.3551 F.3541 F.3504	2332	304	OCr18Ni9
SUS303	1.4305	X12CrNiS188	303S21	58M	Z10CNF18.09	X10CrNiS18.09	F.3508	2346	303	1Cr18Ni9MoZr
SUS304L	–	–	304C12	–	Z3CN19.10	–	–	2333	–	–
SCS19	1.4306	X2CrNi189	304S12	–	Z2CrNi1810	X2CrNi18.11	F.3503	2352	304L	–
SUS301	1.4310	X12CrNi177	–	–	Z12CN17.07	X12CrNi1707	F.3517	2331	301	Cr17Ni7
SUS304LN	1.4311	X2CrNiN1810	304S62	–	Z2CN18.10	–	–	2371	304LN	–
SUS316	1.4401	X5CrNiMo1810	316S16	58J	Z6CND17.11	X5CrNiMo1712	F.3543	2347	316	0Cr17Ni11Mo2
SCS13	1.4308	G-X6CrNi189	304C15	–	Z6CN18.10M	–	–	–	–	–
SCS14	1.4408	G-X6CrNiMo1810	316C16	–	–	–	F.8414	–	–	–
SCS22	1.4581	G-X5CrNiMoNb1810	318C17	–	Z4CNDNb1812M	XG8CrNiMo1811	–	–	–	–
SUS316LN	1.4429	X2CrNiMoN1813	–	–	Z2CND17.13	–	–	2375	316LN	OCr17Ni13Mo
–	1.4404	–	316S13	–	Z2CND17.12	X2CrNiMo1712	–	2348	316L	–
SCS16 SUS316L	1.4435	X2CrNiMo1812	316S13	–	Z2CND17.12	X2CrNiMo1712	–	2353	316L	OCr27Ni12Mo3
–	1.4436	–	316S13	–	Z6CND18-12-03	X8CrNiMo1713	–	2343, 2347	316	–
SUS317L	1.4438	X2CrNiMo1816	317S12	–	Z2CND19.15	X2CrNiMo1816	–	2367	317L	OOCr19Ni13Mo
–	1.4539	X1NiCrMo	–	–	Z6CNT18.10	–	–	2562	UNS V 0890A	–
SUS321	1.4541	X10CrNiTi189	321S12	58B	Z6CNT18.10	X6CrNiTi1811	F.3553 F.3523	2337	321	1Cr18NI9Ti
SUS347	1.4550	X10CrNiNb189	347S17	58F	Z6CNNb18.10	X6CrNiNb1811	F.3552 F.3524	2338	347	1Cr18Ni11Nb
–	1.4571	X10CrNiMoTi1810	320S17	58J	Z6CNDT17.12	X6CrNiMoTi1712	F.3535	2350	316Ti	Cr18Ni12Mo2T
–	1.4583	X10CrNiMoNb1812	–	–	Z6CNDNb1713B	X6CrNiMoNb1713	–	–	318	Cr17Ni12Mo3Mb

Japan	Germany		U.K.		France	Italy	Spain	Sweden	USA	China
JIS	W-nr.	DIN	BS	EN	AFNOR	UNI	UNE	SS	AISI/SAE	GB
SUH309	1.4828	X15CrNiSi2012	309S24	–	Z15CNS20.12	X6CrNi2520	–	–	309	1Cr23Ni13
SUH310	1.4845	X12CrNi2521	310S24	–	Z12CN2520	X6CrNi2520	F.331	2361	310S	OCr25Ni20
SCS17	1.4406	X10CrNi18.08	–	58C	Z1NCDU25.20	–	F.8414	2370	308	–
–	1.4418	X4CrNiMo165	–	–	Z6CND16-04-01	–	–	–	–	–
–	1.4568 1.4504	–	316S111	–	Z8CNA17-07	X2CrNiMo1712	–	–	17-7PH	–
–	1.4563	–	–	–	Z1NCDU31-27-03 Z1CNDU20-18-06AZ	–	–	2584 2378	NO8028 S31254	–
SUS321	1.4878	X12CrNiTi189	321S32	58B, 58C	Z6CNT18.12B	X6CrNiTi18 11	F.3523	–	321	1Cr18Ni9Ti

■HEAT RESISTANT STEELS

Japan	Germany		U.K.		France	Italy	Spain	Sweden	USA	China
JIS	W-nr.	DIN	BS	EN	AFNOR	UNI	UNE	SS	AISI/SAE	GB
SUH330	1.4864	X12NiCrSi3616	–	–	Z12NCS35.16	–	–	–	330	–
SCH15	1.4865	G-X40NiCrSi3818	330C11	–	–	XG50NiCr3919	–	–	HT, HT 50	–

■GRAY CAST IRON

Japan	Germany		U.K.		France	Italy	Spain	Sweden	USA	China
JIS	W-nr.	DIN	BS	EN	AFNOR	UNI	UNE	SS	AISI/SAE	GB
–	–	–	–	–	–	–	–	0100	–	–
FC100	–	GG 10	–	–	Ft 10 D	–	–	0110	No 20 B	–
FC150	0.6015	GG 15	Grade 150	–	Ft 15 D	G15	FG15	0115	No 25 B	HT150
FC200	0.6020	GG 20	Grade 220	–	Ft 20 D	G20	–	0120	No 30 B	HT200
FC250	0.6025	GG 25	Grade 260	–	Ft 25 D	G25	FG25	0125	No 35 B	HT250
–	–	–	–	–	–	–	–	–	No 40 B	–
FC300	0.6030	GG 30	Grade 300	–	Ft 30 D	G30	FG30	0130	No 45 B	HT300
FC350	0.6035	GG 35	Grade 350	–	Ft 35 D	G35	FG35	0135	No 50 B	HT350
–	0.6040	GG 40	Grade 400	–	Ft 40 D	–	–	0140	No 55 B	HT400
–	0.6660	GGL NiCr202	L-NiCuCr202	–	L-NC 202	–	–	0523	A436 Type 2	–

■DUCTILE CAST IRON

Japan	Germany		U.K.		France	Italy	Spain	Sweden	USA	China
JIS	W-nr.	DIN	BS	EN	AFNOR	UNI	UNE	SS	AISI/SAE	GB
FCD400	0.7040	GGG 40	SNG 420/12	–	FCS 400-12	GS 370-17	FGE 38-17	07 17-02	60-40-18	QT400-18
–	–	GGG 40.3	SNG 370/17	–	FGS 370-17	–	–	07 17-12	–	–
–	0.7033	GGG 35.3	–	–	–	–	–	07 17-15	–	–
FCD500	0.7050	GGG 50	SNG 500/7	–	FGS 500-7	GS 500	FGE 50-7	07 27-02	80-55-06	QT500-7
–	0.7660	GGG NiCr202	Grade S6	–	S-NC202	–	–	07 76	A43D2	–
–	–	GGG NiMn137	L-NiMn 137	–	L-MN 137	–	–	07 72	–	–
FCD600	–	GGG 60	SNG 600/3	–	FGS 600-3	–	–	07 32-03	–	QT600-3
FCD700	0.7070	GGG 70	SNG 700/2	–	FGS 700-2	GS 700-2	FGS 70-2	07 37-01	100-70-03	QT700-18

■MALLEABLE CAST IRON

Japan	Germany		U.K.		France	Italy	Spain	Sweden	USA	China
JIS	W-nr.	DIN	BS	EN	AFNOR	UNI	UNE	SS	AISI/SAE	GB
FCMB310	–	–	8 290/6	–	MN 32-8	–	–	08 14	–	–
FCMW330	–	GTS-35	B 340/12	–	MN 35-10	–	–	08 15	32510	–
FCMW370	0.8145	GTS-45	P 440/7	–	Mn 450	GMN45	–	08 52	40010	–
FCMP490	0.8155	GTS-55	P 510/4	–	MP 50-5	GMN55	–	08 54	50005	–
FCMP540	–	GTS-65	P 570/3	–	MP 60-3	–	–	08 58	70003	–
FCMP590	0.8165	GTS-65-02	P 570/3	–	Mn 650-3	GMN 65	–	08 56	A220-70003	–
FCMP690	–	GTS-70-02	P 690/2	–	Mn 700-2	GMN 70	–	08 62	A220-80002	–

DIE STEELS

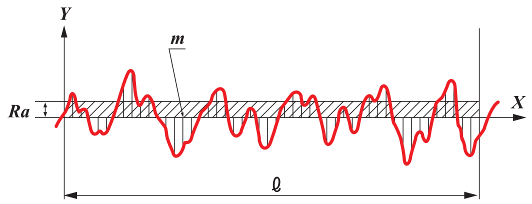
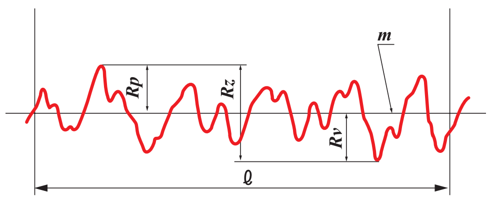
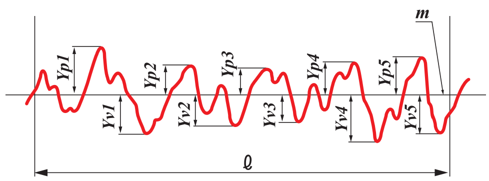
Classification	JIS (Others)	Aichi Steel Works	Uddeholm	Kobe Steel	Sumitomo Metal Industries	Daido Steel	Nippon Koshuha	Hitachi Metals	Mitsubishi Steel Manufacturing
Carbon Steel for Machine Structure	S50C	AUK1		KTSM2A	SD10	PDS1	KPM1		MT50C
	I			KTSM21	SD17	PXZ			
	S55C			KTSM22	SD21				
Alloy Steel for Machine Structure	SCM440	AUK11		KTSM3A	SD61	PDS3			
	I			KTSM31					
	SCM445		HOLDAX						
Carbon Tool Steel	SK3	SK3				YK3	K3	YC3	
Alloy Tool Steel (For Cold Working)	SKS3	SKS3				GOA	KS3	SGT	
	SKS31					GO31	K31		
	SKS93	SK301				YK30	K3M	YCS3	
	SKD1						KD1	CRD	
	SKD11	SKD11		KAD181		DC11	KD11	SLD	
	SKD11	AUD11				DC3	KD11V	SLD2	
	SKD11						KDQ		
	SKD12		RIGOR			DC12	KD12	SCD	
		SX4							
		SX44							
		SX105V					FH5		
		TCD							
						DC53	KD21	SLD8	
						PD613			
						GO4		ACD37	
						GO5		HMD5	
						GO40F		HPM2T	
								YSM	
								HPM31	
								HMD1	
							KDM5	HMD5	
							KD11S	ACD6	
								ACD8	
								ACD9	
Alloy Tool Steel (For Cold Working and Others)	(P20)		IMPAX	KTSM3M		PX5	KPM30	HPM2	MT24M
	(P20)							HPM7	
	(P21)			KTSM40EF		NAK55	KAP	HPM1	
				KTSM40E		NAK80	KAP2	HPM50	
						GLD2		CENA1	
Alloy Tool Steel (For Hot Working)	SKD4					DH4	KD4	YDC	
	SKD5					DH5	KD5	HDC	
	SKD6					DH6	KD6		
	SKD61	SKD61	Over M Suprem			DHA1	KDA	DAC	
	SKD61						MFA		
	SKD62	SKD62				DH62	KDB	DBC	
	SKT4					GFA	KTV	DM	
	SKD7					DH72	KDH1	YEM	
	(H10)					DH73			
	SKD8					DH41	KDF	MDC	
			QRO80M						
								YHD40	
						DH71			
						DH42			
						DH21			
							KDW		
							KDHM		
							AE31		
								YEM4	
								YHD50	
	SKT4	SKT4A						YHD26	
	6F4	MPH							
	SKT4								
						DH31	KDA1	DAC3	
							KDA5	DAC10	
								DAC40	
						GF78		DAC45	
						DH76		DAC55	
							TD3		
						DH2F	KDAS	FDAC	
								YHD3	
								MDC−K	
								YEM−K	

Classification	JIS (Others)	Aichi Steel Works	Uddeholm	Kobe Steel	Sumitomo Metal Industries	Daido Steel	Nippon Koshuha	Hitachi Metals	Mitsubishi Steel Manufacturing
High-Speed Tool Steel	SKH51					MH51	H51	YXM1	
	SKH55					MH55	HM35	YXM4	
	SKH57					MH57	MV10	XVC5	
						MH8	NK4	YXM60	
						MH24			
						MH7V1			
						MH64			
						VH54	HV2	XVC11	
							HM3	YXM7	
						MH85	KDMV	YXR3	
						MH88	HM9TL	YXR4	
								YXR7	
								YXR35	
Powder High-Speed Tool Steel			ASP23	KHA32		DEX20		HAP10	
			ASP30	KHA30		DEX40		HAP40	
				KHA3VN		DEX60		HAP50	
				KHA30N		DEX70		HAP63	
				KHA33N		DEX80		HAP72	
				KHA50					
				KHA77					
			ASP60	KHA60					
Stainless Steel	SUS403					GLD1			
	SUS420		STAVAX			S–STAR	KSP1	HPM38	
	SUS440C		ELMAX (Powder)	KAS440 (Powder)		SUS440C	KSP3		
	SUS420							SUS420	
	SUS630					NAK101	U630	PSL	
	(414)								
Maraging Steel						MAS1C	KMS18–20	YAG	DMG300
Heat Resistant Alloy								HRNC	

SURFACE ROUGHNESS

SURFACE ROUGHNESS

(From JIS B 0601-1994)

Type	Code	Determination	Determination Example (Figure)
Arithmetical 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 the 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):** $Ra=\frac{1}{\ell}\int_{0}^{\ell}\lvert f(x)\rvert dx$	
Maximum Height	Rz	**Rz shall be that only when the reference length is sampled from the roughness curve in the direction of the mean line, the distance between the top profile peak line and the bottom 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).** **Note) When finding Rz, a portion without an exceptionally high peak or low valley, which may be regarded as a flaw, is selected as the sampling length.** $Rz=Rp+Rv$	
Ten-Point Mean Roughness	RzJIS	**RzJIS shall be that only when 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 (Yp) and the depths of five deepest profile valleys (Yv) measured in the vertical magnification direction from the mean line of this sampled portion and this sum is expressed in micrometer (µm).** $Rz_{JIS}=\frac{(Yp1+Yp2+Yp3+Yp4+Yp5)+(Yv1+Yv2+Yv3+Yv4+Yv5)}{5}$	 *Yp1,Yp2,Yp3,Yp4,Yp5* : altitudes of the five highest profile peaks of the sampled portion corresponding to the reference length l. *Yv1,Yv2,Yv3,Yv4,Yv5* : altitudes of the five deepest profile valleys of the sampled portion corresponding to the reference length l.

■RELATIONSHIP BETWEEN ARITHMETICAL MEAN (Ra) AND CONVENTIONAL DESIGNATION (REFERENCE DATA)

Arithmetical Mean Roughness **Ra**		Max. Height **Rz**	Ten-Point Mean Roughness **RzJIS**	Sampling Length for **Rz • RzJIS** l (mm)	Conventional Finish Mark
Standard Series	Cutoff Value λc (mm)	Standard Series			
0.012 a	0.08	0.05s	0.05z	0.08	▽▽▽▽
0.025 a	0.25	0.1 s	0.1 z		
0.05 a		0.2 s	0.2 z	0.25	
0.1 a	0.8	0.4 s	0.4 z		
0.2 a		0.8 s	0.8 z	0.8	
0.4 a		1.6 s	1.6 z		▽▽▽
0.8 a		3.2 s	3.2 z		
1.6 a		6.3 s	6.3 z		
3.2 a	2.5	12.5 s	12.5 z	2.5	▽▽
6.3 a		25 s	25 z		
12.5 a	8	50 s	50 z		▽
25 a		100 s	100 z	8	
50 a		200 s	200 z		—
100 a	—	400 s	400 z	—	

*The correlation among the three is shown for convenience and is not exact.
*Ra: The evaluation length of Rz and RzJIS is the cutoff value and sampling length multiplied by 5, respectively.

HARDNESS COMPARISON TABLE

HARDNESS CONVERSION NUMBERS OF STEEL

Brinell Hardness (HB) 10mm Ball, Load: 3,000 kgf		Vickers Hardness	Rockwell Hardness				Shore Hardness	Tensile Strength (Approx.)
Standard Ball	Tungsten Carbide Ball		A Scale, Load:60kgf, Diamond Point	B Scale, Load:100kgf, 1/16" Ball	C Scale, Load:150kgf, Diamond Point	D Scale, Load:100kgf, Diamond Point		Mpa
		(HV)	(HRA)	(HRB)	(HRC)	(HRD)	(HS)	
–	–	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
–	–	533	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

Brinell Hardness (HB) 10mm Ball, Load: 3,000 kgf		Vickers Hardness	Rockwell Hardness				Shore Hardness	Tensile Strength (Approx.)
Standard Ball	Tungsten Carbide Ball		A Scale, Load:60kgf, Diamond Point	B Scale, Load:100kgf, 1/16" Ball	C Scale, Load:150kgf, Diamond Point	D Scale, Load:100kgf, Diamond Point		Mpa
		(HV)	(HRA)	(HRB)	(HRC)	(HRD)	(HS)	
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	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 1) Above list is the same as that at AMS Metals Hand book with tensile strength in approximate metric value and Brinell hardness over a recommended range.

Note 2) 1MPa=1N/mm^2

Note 3) Figures in ( ) are rarely used and are included for reference. This list has been taken from JIS Handbook Steel I.

JIS FIT TOLERANCE TABLE (HOLE)

Classification of Standard Dimensions (mm)		Class of Geometrical Tolerance Zone of Holes															
>	≤	B10	C9	C10	D8	D9	D10	E7	E8	E9	F6	F7	F8	G6	G7	H6	H7
–	3	+180 +140	+85 +60	+100 +60	+34 +20	+45 +20	+60 +20	+24 +14	+28 +14	+39 +14	+12 +6	+16 +6	+20 +6	+8 +2	+12 +2	+6 0	+10 0
3	6	+188 +140	+100 +70	+118 +70	+48 +30	+60 +30	+78 +30	+32 +20	+38 +20	+50 +20	+18 +10	+22 +10	+28 +10	+12 +4	+16 +4	+8 0	+12 0
6	10	+208 +150	+116 +80	+138 +80	+62 +40	+76 +40	+98 +40	+40 +25	+47 +25	+61 +25	+22 +13	+28 +13	+35 +13	+14 +5	+20 +5	+9 0	+15 0
10	14	+220 +150	+138 +95	+165 +95	+77 +50	+93 +50	+120 +50	+50 +32	+59 +32	+75 +32	+27 +16	+34 +16	+43 +16	+17 +6	+24 +6	+11 0	+18 0
14	18																
18	24	+244 +160	+162 +110	+194 +110	+98 +65	+117 +65	+149 +65	+61 +40	+73 +40	+92 +40	+33 +20	+41 +20	+53 +20	+20 +7	+28 +7	+13 0	+21 0
24	30																
30	40	+270 +170	+182 +120	+220 +120	+119 +80	+142 +80	+180 +80	+75 +50	+89 +50	+112 +50	+41 +25	+50 +25	+64 +25	+25 +9	+34 +9	+16 0	+25 0
40	50	+280 +180	+192 +130	+230 +130													
50	65	+310 +190	+214 +140	+260 +140	+146 +100	+174 +100	+220 +100	+90 +60	+106 +60	+134 +60	+49 +30	+60 +30	+76 +30	+29 +10	+40 +10	+19 0	+30 0
65	80	+320 +200	+224 +150	+270 +150													
80	100	+360 +220	+257 +170	+310 +170	+174 +120	+207 +120	+260 +120	+107 +72	+126 +72	+159 +72	+58 +36	+71 +36	+90 +36	+34 +12	+47 +12	+22 0	+35 0
100	120	+380 +240	+267 +180	+320 +180													
120	140	+420 +260	+300 +200	+360 +200	+208 +145	+245 +145	+305 +145	+125 +85	+148 +85	+185 +85	+68 +43	+83 +43	+106 +43	+39 +14	+54 +14	+25 0	+40 0
140	160	+440 +280	+310 +210	+370 +210													
160	180	+470 +310	+330 +230	+390 +230													
180	200	+525 +340	+355 +240	+425 +240	+242 +170	+285 +170	+355 +170	+146 +100	+172 +100	+215 +100	+79 +50	+96 +50	+122 +50	+44 +15	+61 +15	+29 0	+46 0
200	225	+565 +380	+375 +260	+445 +260													
225	250	+605 +420	+395 +280	+465 +280													
250	280	+690 +480	+430 +300	+510 +300	+271 +190	+320 +190	+400 +190	+162 +110	+191 +110	+240 +110	+88 +56	+108 +56	+137 +56	+49 +17	+69 +17	+32 0	+52 0
280	315	+750 +540	+460 +330	+540 +330													
315	355	+830 +600	+500 +360	+590 +360	+299 +210	+350 +210	+440 +210	+182 +125	+214 +125	+265 +125	+98 +62	+119 +62	+151 +62	+54 +18	+75 +18	+36 0	+57 0
355	400	+910 +680	+540 +400	+630 +400													
400	450	+1010 +760	+595 +440	+690 +440	+327 +230	+385 +230	+480 +230	+198 +135	+232 +135	+290 +135	+108 +68	+131 +68	+165 +68	+60 +20	+83 +20	+40 0	+63 0
450	500	+1090 +840	+635 +480	+730 +480													

Note) Values shown in the upper portion of respective lines are upper dimensional tolerance, while values shown in the lower portion of respective lines are lower dimensional tolerance.

Units : μm

Class of Geometrical Tolerance Zone of Holes																	
H8	H9	H10	JS6	JS7	K6	K7	M6	M7	N6	N7	P6	P7	R7	S7	T7	U7	X7
+14 0	+25 0	+40 0	±3	±5	0 −6	0 −10	−2 −8	−2 −12	−4 −10	−4 −14	−6 −12	−6 −16	−10 −20	−14 −24	—	−18 −28	−20 −30
+18 0	+30 0	+48 0	±4	±6	+2 −6	+3 −9	−1 −9	0 −12	−5 −13	−4 −16	−9 −17	−8 −20	−11 −23	−15 −27	—	−19 −31	−24 −36
+22 0	+36 0	+58 0	±4.5	±7	+2 −7	+5 −10	−3 −12	0 −15	−7 −16	−4 −19	−12 −21	−9 −24	−13 −28	−17 −32	—	−22 −37	−28 −43
+27 0	+43 0	+70 0	±5.5	±9	+2 −9	+6 −12	−4 −15	0 −18	−9 −20	−5 −23	−15 −26	−11 −29	−16 −34	−21 −39	—	−26 −44	−33 −51 −38 −56
+33 0	+52 0	+84 0	±6.5	±10	+2 −11	+6 −15	−4 −17	0 −21	−11 −24	−7 −28	−18 −31	−14 −35	−20 −41	−27 −48	— −33 −54	−33 −54 −40 −61	−46 −67 −56 −77
+39 0	+62 0	+100 0	±8	±12	+3 −13	+7 −18	−4 −20	0 −25	−12 −28	−8 −33	−21 −37	−17 −42	−25 −50	−34 −59	−39 −64 −45 −70	−51 −76 −61 −86	—
+46 0	+74 0	+120 0	±9.5	±15	+4 −15	+9 −21	−5 −24	0 −30	−14 −33	−9 −39	−26 −45	−21 −51	−30 −60 −32 −62	−42 −72 −48 −78	−55 −85 −64 −94	−76 −106 −91 −121	—
+54 0	+87 0	+140 0	±11	±17	+4 −18	+10 −25	−6 −28	0 −35	−16 −38	−10 −45	−30 −52	−24 −59	−38 −73 −41 −76	−58 −93 −66 −101	−78 −113 −91 −126	−111 −146 −131 −166	—
+63 0	+100 0	+160 0	±12.5	±20	+4 −21	+12 −28	−8 −33	0 −40	−20 −45	−12 −52	−36 −61	−28 −68	−48 −88 −50 −90 −53 −93	−77 −117 −85 −125 −93 −133	−107 −147 −119 −159 −131 −171	—	—
+72 0	+115 0	+185 0	±14.5	±23	+5 −24	+13 −33	−8 −37	0 −46	−22 −51	−14 −60	−41 −70	−33 −79	−60 −106 −63 −109 −67 −113	−105 −151 −113 −159 −123 −169	—	—	—
+81 0	+130 0	+210 0	±16	±26	+5 −27	+16 −36	−9 −41	0 −52	−25 −57	−14 −66	−47 −79	−36 −88	−74 −126 −78 −130	—	—	—	—
+89 0	+140 0	+230 0	±18	±28	+7 −29	+17 −40	−10 −46	0 −57	−26 −62	−16 −73	−51 −87	−41 −98	−87 −144 −93 −150	—	—	—	—
+97 0	+155 0	+250 0	±20	±31	+8 −32	+18 −45	−10 −50	0 −63	−27 −67	−17 −80	−55 −95	−45 −108	−103 −166 −109 −172	—	—	—	—

JIS FIT TOLERANCE TABLE (SHAFTS)

Classification of Standard Dimensions (mm)		Class of Geometrical Tolerance Zone of Shafts														
>	≤	b9	c9	d8	d9	e7	e8	e9	f6	f7	f8	g5	g6	h5	h6	h7
–	3	−140 −165	−60 −85	−20 −34	−20 −45	−14 −24	−14 −28	−14 −39	−6 −12	−6 −16	−6 −20	−2 −6	−2 −8	0 −4	0 −6	0 −10
3	6	−140 −170	−70 −100	−30 −48	−30 −60	−20 −32	−20 −38	−20 −50	−10 −18	−10 −22	−10 −28	−4 −9	−4 −12	0 −5	0 −8	0 −12
6	10	−150 −186	−80 −116	−40 −62	−40 −76	−25 −40	−25 −47	−25 −61	−13 −22	−13 −28	−13 −35	−5 −11	−5 −14	0 −6	0 −9	0 −15
10	14	−150 −193	−95 −138	−50 −77	−50 −93	−32 −50	−32 −59	−32 −75	−16 −27	−16 −34	−16 −43	−6 −14	−6 −17	0 −8	0 −11	0 −18
14	18															
18	24	−160 −212	−110 −162	−65 −98	−65 −117	−40 −61	−40 −73	−40 −92	−20 −33	−20 −41	−20 −53	−7 −16	−7 −20	0 −9	0 −13	0 −21
24	30															
30	40	−170 −232	−120 −182	−80 −119	−80 −142	−50 −75	−50 −89	−50 −112	−25 −41	−25 −50	−25 −64	−9 −20	−9 −25	0 −11	0 −16	0 −25
40	50	−180 −242	−130 −192													
50	65	−190 −264	−140 −214	−100 −146	−100 −174	−60 −90	−60 −106	−60 −134	−30 −49	−30 −60	−30 −76	−10 −23	−10 −29	0 −13	0 −19	0 −30
65	80	−200 −274	−150 −224													
80	100	−220 −307	−170 −257	−120 −174	−120 −207	−72 −107	−72 −126	−72 −159	−36 −58	−36 −71	−36 −90	−12 −27	−12 −34	0 −15	0 −22	0 −35
100	120	−240 −327	−180 −267													
120	140	−260 −360	−200 −300	−145 −208	−145 −245	−85 −125	−85 −148	−85 −185	−43 −68	−43 −83	−43 −106	−14 −32	−14 −39	0 −18	0 −25	0 −40
140	160	−280 −380	−210 −310													
160	180	−310 −410	−230 −330													
180	200	−340 −455	−240 −355	−170 −242	−170 −285	−100 −146	−100 −172	−100 −215	−50 −79	−50 −96	−50 −122	−15 −35	−15 −44	0 −20	0 −29	0 −46
200	225	−380 −495	−260 −375													
225	250	−420 −535	−280 −395													
250	280	−480 −610	−300 −430	−190 −271	−190 −320	−110 −162	−110 −191	−110 −240	−56 −88	−56 −108	−56 −137	−17 −40	−17 −49	0 −23	0 −32	0 −52
280	315	−540 −670	−330 −460													
315	355	−600 −740	−360 −500	−210 −299	−210 −350	−125 −182	−125 −214	−125 −265	−62 −98	−62 −119	−62 −151	−18 −43	−18 −54	0 −25	0 −36	0 −57
355	400	−680 −820	−400 −540													
400	450	−760 −915	−440 −595	−230 −327	−230 −385	−135 −198	−135 −232	−135 −290	−68 −108	−68 −131	−68 −165	−20 −47	−20 −60	0 −27	0 −40	0 −63
450	500	−840 −995	−480 −635													

Note) Values shown in the upper portion of respective lines are upper dimensional tolerance, while values shown in the lower portion of respective lines are lower dimensional tolerance.

Units : μm

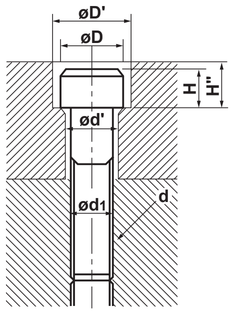
Class of Geometrical Tolerance Zone of Shafts															
h8	**h9**	**js5**	**js6**	**js7**	**k5**	**k6**	**m5**	**m6**	**n6**	**p6**	**r6**	**s6**	**t6**	**u6**	**x6**
0 −14	0 −25	±2	±3	±5	+4 0	+6 0	+6 +2	+8 +2	+10 +4	+12 +6	+16 +10	+20 +14	—	+24 +18	+26 +20
0 −18	0 −30	±2.5	±4	±6	+6 +1	+9 +1	+9 +4	+12 +4	+16 +8	+20 +12	+23 +15	+27 +19	—	+31 +23	+36 +28
0 −22	0 −36	±3	±4.5	±7	+7 +1	+10 +1	+12 +6	+15 +6	+19 +10	+24 +15	+28 +19	+32 +23	—	+37 +28	+43 +34
0 −27	0 −43	±4	±5.5	±9	+9 +1	+12 +1	+15 +7	+18 +7	+23 +12	+29 +18	+34 +23	+39 +28	—	+44 +33	+51 +40 +56 +45
0 −33	0 −52	±4.5	±6.5	±10	+11 +2	+15 +2	+17 +8	+21 +8	+28 +15	+35 +22	+41 +28	+48 +35	— +54 +41	+54 +41 +61 +48	+67 +54 +77 +64
0 −39	0 −62	±5.5	±8	±12	+13 +2	+18 +2	+20 +9	+25 +9	+33 +17	+42 +26	+50 +34	+59 +43	+64 +48 +70 +54	+76 +60 +86 +70	—
0 −46	0 −74	±6.5	±9.5	±15	+15 +2	+21 +2	+24 +11	+30 +11	+39 +20	+51 +32	+60 +41 +62 +43	+72 +53 +78 +59	+85 +66 +94 +75	+106 +87 +121 +102	—
0 −54	0 −87	±7.5	±11	±17	+18 +3	+25 +3	+28 +13	+35 +13	+45 +23	+59 +37	+73 +51 +76 +54	+93 +71 +101 +79	+113 +91 +126 +104	+146 +124 +166 +144	—
0 −63	0 −100	±9	±12.5	±20	+21 +3	+28 +3	+33 +15	+40 +15	+52 +27	+68 +43	+88 +63 +90 +65 +93 +68	+117 +92 +125 +100 +133 +108	+147 +122 +159 +134 +171 +146	—	—
0 −72	0 −115	±10	±14.5	±23	+24 +4	+33 +4	+37 +17	+46 +17	+60 +31	+79 +50	+106 +77 +109 +80 +113 +84	+151 +122 +159 +130 +169 +140	—	—	—
0 −81	0 −130	±11.5	±16	±26	+27 +4	+36 +4	+43 +20	+52 +20	+66 +34	+88 +56	+126 +94 +130 +98	—	—	—	—
0 −89	0 −140	±12.5	±18	±28	+29 +4	+40 +4	+46 +21	+57 +21	+73 +37	+98 +62	+144 +108 +150 +114	—	—	—	—
0 −97	0 −155	±13.5	±20	±31	+32 +5	+45 +5	+50 +23	+63 +23	+80 +40	+108 +68	+166 +126 +172 +132	—	—	—	—

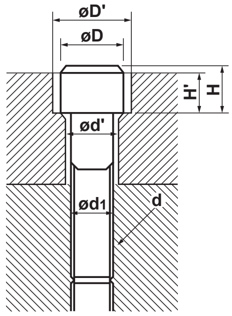
HEXAGON SOCKET HEAD BOLT HOLE SIZE

DIMENSIONS OF COUNTERBORING FOR HEXAGON SOCKET HEAD CAP SCREW AND BOLT HOLE

Unit : mm

Nominal dimensions of thread d	M3	M4	M5	M6	M8	M10	M12	M14	M16	M18	M20	M22	M24	M27	M30
d_1	3	4	5	6	8	10	12	14	16	18	20	22	24	27	30
d'	3.4	4.5	5.5	6.6	9	11	14	16	18	20	22	24	26	30	33
D	5.5	7	8.5	10	13	16	18	21	24	27	30	33	36	40	45
D'	6.5	8	9.5	11	14	17.5	20	23	26	29	32	35	39	43	48
H	3	4	5	6	8	10	12	14	16	18	20	22	24	27	30
H'	2.7	3.6	4.6	5.5	7.4	9.2	11	12.8	14.5	16.5	18.5	20.5	22.5	25	28
H"	3.3	4.4	5.4	6.5	8.6	10.8	13	15.2	17.5	19.5	21.5	23.5	25.5	29	32





TAPER STANDARD

Fig.1
Bolt Grip Taper

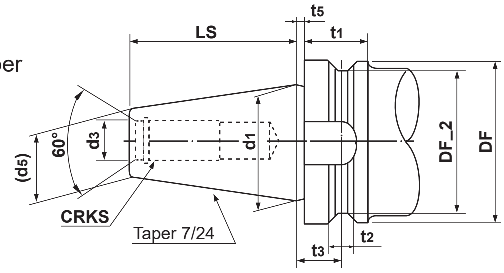
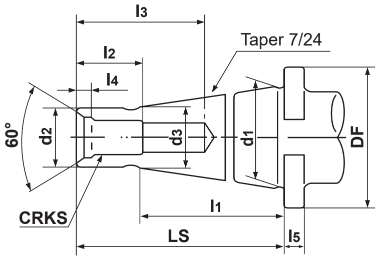


Fig.2
National Taper



●**Table 1 Bolt Grip Taper (Fig.1)**

Bearing Number	DF	DF_2	t_1	t_2	t_3	t_5	d_1	d_3	LS	CRKS	d_5
BT35	53	43	20	10	13.0	2	38.1	13	56.5	M12×1.75	21.62
BT40	63	53	25	10	16.6	2	44.45	17	65.4	M16×2	25.3
BT45	85	73	30	12	21.2	3	57.15	21	82.8	M20×25	33.1
BT50	100	85	35	15	23.2	3	69.85	25	101.8	M24×3	40.1
BT60	155	135	45	20	28.2	3	107.95	31	161.8	M30×3.5	60.7

●**Table 2 National Taper (Fig.2)**

Bearing Number	d_1	d_2	LS	l_1	CRKS		l_2	l_3	d_3	l_4	DF	l_5
					Metric Screw	Wit Screw						
NT30	31.75	17.4	70	50	M12	W 1/2	24	50	16.5	6	50	8
NT40	44.45	25.3	95	67	M16	W 5/8	30	70	24	7	63	10
NT50	69.85	39.6	130	105	M24	W 1	45	90	38	11	100	13
NT60	107.95	60.2	210	165	M30	W 1 1/4	56	110	58	12	170	15

Fig.3
Morse Taper
(Shank with Tongue)

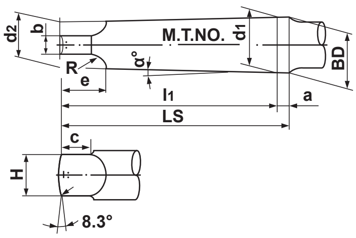
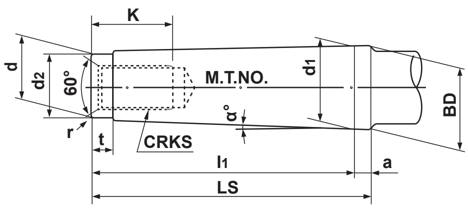


Fig.4
Morse Taper
(Shank with Screw)



●**Table 3 Shank with Tongue (Fig.3)**

Morse Taper Number	α°	d_1	a	BD	d_2	H	l_1	LS	b	c	e	R	r
0	1°29′27″	9.045	3	9.201	6.104	6	56.5	59.5	3.9	6.5	10.5	4	1
1	1°25′43″	12.065	3.5	12.240	8.972	8.7	62.0	65.5	5.2	8.5	13.5	5	1.2
2	1°25′50″	17.780	5	18.030	14.034	13.5	75.0	80.0	6.3	10	16	6	1.6
3	1°26′16″	23.825	5	24.076	19.107	18.5	94.0	99	7.9	13	20	7	2
4	1°29′15″	31.267	6.5	31.605	25.164	24.5	117.5	124	11.9	16	24	8	2.5
5	1°30′26″	44.399	6.5	44.741	36.531	35.7	149.5	156	15.9	19	29	10	3
6	1°29′36″	63.348	8	63.765	52.399	51.0	210.0	218	19	27	40	13	4
7	1°29′22″	83.058	10	83.578	68.185	66.8	286.0	296	28.6	35	54	19	5

●**Table 4 Shank with Screw (Fig.4)**

Morse Taper Number	α°	d_1	a	BD	d	d_2	l_1	LS	t	r	CRKS	K
0	1°29′27″	9.045	3	9.201	6.442	6	50	53	4	0.2	–	–
1	1°25′43″	12.065	3.5	12.240	9.396	9	53.5	57	5	0.2	M6	16
2	1°25′50″	17.780	5	18.030	14.583	14	64	69	5	0.2	M10	24
3	1°26′16″	23.825	5	24.076	19.759	19	81	86	7	0.6	M12	28
4	1°29′15″	31.267	6.5	31.605	25.943	25	102.5	109	9	1.0	M16	32
5	1°30′26″	44.399	6.5	44.741	37.584	35.7	129.5	136	9	2.5	M20	40
6	1°29′36″	63.348	8	63.765	53.859	51	182	190	12	4.0	M24	50
7	1°29′22″	83.058	10	83.578	70.052	65	250	260	18.5	5.0	M33	80

INTERNATIONAL SYSTEM OF UNITS

■UNIT CONVERSION TABLE for EASIER CHANGE into SI UNITS (Bold type Indicates SI unit)

●Pressure

Pa	**kPa**	**MPa**	bar	kgf/cm^2	atm	mmH2O	mmHg or Torr
1	1×10^{-3}	1×10^{-6}	1×10^{-5}	1.01972×10^{-5}	9.86923×10^{-6}	1.01972×10^{-1}	7.50062×10^{-3}
1×10^{3}	1	1×10^{-3}	1×10^{-2}	1.01972×10^{-2}	9.86923×10^{-3}	1.01972×10^{2}	7.50062
1×10^{6}	1×10^{3}	1	1×10	1.01972×10	9.86923	1.01972×10^{5}	7.50062×10^{3}
1×10^{5}	1×10^{2}	1×10^{-1}	1	1.01972	9.86923×10^{-1}	1.01972×10^{4}	7.50062×10^{2}
9.80665×10^{4}	9.80665×10	9.80665×10^{-2}	9.80665×10^{-1}	1	9.67841×10^{-1}	1×10^{4}	7.35559×10^{2}
1.01325×10^{5}	1.01325×10^{2}	1.01325×10^{-1}	1.01325	1.03323	1	1.03323×10^{4}	7.60000×10^{2}
9.80665	9.80665×10^{-3}	9.80665×10^{-6}	9.80665×10^{-5}	1×10^{-4}	9.67841×10^{-5}	1	7.35559×10^{-2}
1.33322×10^{2}	1.33322×10^{-1}	1.33322×10^{-4}	1.33322×10^{-3}	1.35951×10^{-3}	1.31579×10^{-3}	1.35951×10	1

Note 1) 1Pa=1N/m^2

●Force

N	dyn	kgf
1	1×10^{5}	1.01972×10^{-1}
1×10^{-5}	1	1.01972×10^{-6}
9.80665	9.80665×10^{5}	1

●Stress

Pa	**MPa** or **N/mm^2**	kgf/mm^2	kgf/cm^2
1	1×10^{-6}	1.01972×10^{-7}	1.01972×10^{-5}
1×10^{6}	1	1.01972×10^{-1}	1.01972×10
9.80665×10^{6}	9.80665	1	1×10^{2}
9.80665×10^{4}	9.80665×10^{-2}	1×10^{-2}	1

Note 1) 1Pa=1N/m^2

●Work / Energy / Quantity of Heat

J	kW•h	kgf•m	kcal
1	2.77778×10^{-7}	1.01972×10^{-1}	2.38889×10^{-4}
3.600 ×10^{6}	1	3.67098×10^{5}	8.6000 ×10^{2}
9.80665	2.72407×10^{-6}	1	2.34270×10^{-3}
4.18605×10^{3}	1.16279×10^{-3}	4.26858×10^{2}	1

Note 1) 1J=1W•s, 1J=1N•m
1cal=4.18605J
(By the law of weights and measures)

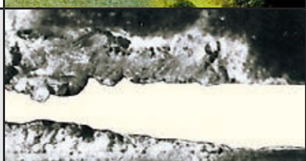
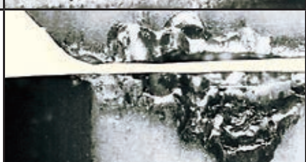
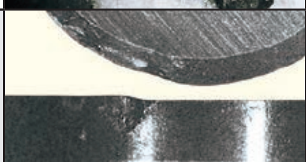
●Power (Rate of Production / Motive Power) /Heat Flow Rate

W	kgf•m/s	PS	kcal/h
1	1.01972×10^{-1}	1.35962×10^{-3}	8.6000 ×10^{-1}
9.80665	1	1.33333×10^{-2}	8.43371
7.355 ×10^{2}	7.5 ×10	1	6.32529×10^{2}
1.16279	1.18572×10^{-1}	1.58095×10^{-3}	1

Note 1) 1W=1J/s, PS:French horse power
1PS=0.7355kW
(By the enforcement act for the law of weights and measures)
1cal=4.18605J

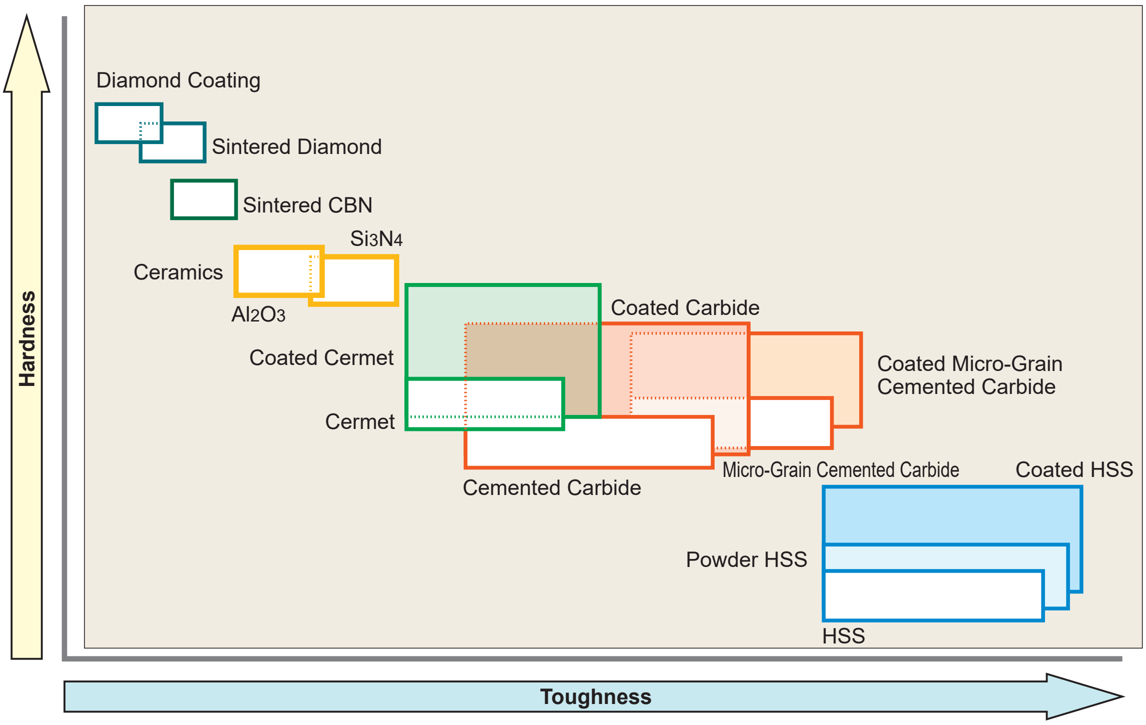
TOOL WEAR AND DAMAGE

CAUSES AND COUNTERMEASURES

Tool Damage Form		Cause	Countermeasure
Flank Wear		• Tool grade is too soft. • Cutting speed is too high. • Flank angle is too small. • Feed rate is extremely low.	• Tool grade with high wear resistance. • Lower cutting speed. • Increase flank angle. • Increase feed rate.
Crater Wear		• Tool grade is too soft. • Cutting speed is too high. • Feed rate is too high.	• Tool grade with high wear resistance. • Lower cutting speed. • Lower feed rate.
Chipping		• Tool grade is too hard. • Feed rate is too high. • Lack of cutting edge strength. • Lack of shank or holder rigidity.	• Tool grade with high toughness. • Lower feed rate. • Increase honing. (Round honing is to be changed to chamfer honing.) • Use large shank size.
Fracture		• Tool grade is too hard. • Feed rate is too high. • Lack of cutting edge strength. • Lack of shank or holder rigidity.	• Tool grade with high toughness. • Lower feed rate. • Increase honing. (Round honing is to be changed to chamfer honing.) • Use large shank size.
Plastic Deformation		• Tool grade is too soft. • Cutting speed is too high. • Depth of cut and feed rate are too large. • Cutting temperature is high.	• Tool grade with high wear resistance. • Lower cutting speed. • Decrease depth of cut and feed rate. • Tool grade with high thermal conductivity.
Thermal Cracks		• Expansion or shrinkage due to cutting heat. • Tool grade is too hard. *Especially in milling.	• Dry cutting. (For wet cutting, flood workpiece with cutting fluid) • Tool grade with high toughness.
Notching		• Hard surfaces such as uncut surfaces, chilled parts and machining hardened layer. • Friction caused by jagged shape chips. (Caused by small vibration)	• Tool grade with high wear resistance. • Increase rake angle to improve sharpness.
Welding		• Cutting speed is low. • Poor sharpness. • Unsuitable grade.	• Increase cutting speed. (For JIS S45C, cutting speed 80m/min.) • Increase rake angle. • Tool grade with low affinity. (Coated grade, cermet grade)
Flaking		• Cutting edge welding and adhesion. • Poor chip disposal.	• Increase rake angle to improve sharpness. • Enlarge chip pocket.
Flank Wear Fracture *Damage for polycrystallines		• Damage due to the lack of strength of a curved cutting edge.	• Increase honing. • Tool grade with high toughness.
Crater Wear Fracture *Damage for polycrystallines		• Tool grade is too soft. • Cutting resistance is too high and causes high cutting heat.	• Decrease honing. • Tool grade with high wear resistance.

CUTTING TOOL MATERIALS

The table below shows the relationship between various tool materials, in relation with hardness on a vertical axis and toughness on a horizontal axis. Today, cemented carbide, coated carbide and TiC-TiN-based cermet are key tool materials in the market. This is because they have the best balance of hardness and toughness.



GRADE CHARACTERISTICS

Hard Materials	Hardness (HV)	Energy Formation (kcal/g·atom)	Solubility in Iron (%.1250℃)	Thermal Conductivity (W/m·k)	Thermal Expansion (x 10^{-6}/k)*	Tool Material
Diamond	>9000	–	Highly Soluble	2100	3.1	Sintered Diamond
CBN	>4500	–	–	1300	4.7	Sintered CBN
Si_3N_4	1600	–	–	100	3.4	Ceramics
Al_2O_3	2100	-100	≒0	29	7.8	Ceramics Cemented Carbide
TiC	3200	-35	< 0.5	21	7.4	Cermet Coated Carbide
TiN	2500	-50	–	29	9.4	Cermet Coated Carbide
TaC	1800	-40	0.5	21	6.3	Cemented Carbide
WC	2100	-10	7	121	5.2	Cemented Carbide

*1W/m•K=2.39×10^{-3}cal/cm•sec•℃

GRADE CHAIN

For Cutting Tools

Cemented Carbide
- **P** Steel: UTi20T
- **M** Stainless Steel: UTi20T
- **K** Cast Iron: HTi05T, HTi10, UTi20T
- **N** Non-Ferrous: HTi10, TF15
- **S** Heat Resistant Alloy Ti Alloy: MT9005, RT9010, MT9015, TF15

Coated Carbide
- **P** Steel: UE6105 (CVD), UE6110 (CVD), MC6015 (CVD), MC6115 NEW (CVD), MS6015 (PVD), UE6020 (CVD), MC6025 (CVD), MP6120 (PVD), MC6125 NEW (CVD), MC6035 (CVD), UH6400 (CVD), FH7020 (CVD), VP15TF (PVD), MP6130 (PVD), VP10RT (PVD), VP20RT (PVD), VP30RT (PVD), VP20MF (PVD), UP20M (PVD)
- **M** Stainless Steel: MC7015 (CVD), US7020 (CVD), MC7020 (CVD), MC7025 (CVD), MS7025 NEW (PVD), MS9025 (PVD), F7030 (CVD), VP15TF (PVD), MP7030 (PVD), MP7130 (PVD), MP7035 (PVD), US735 (CVD), MP7140 (PVD), VP10RT (PVD), VP20RT (PVD), VP30RT (PVD), VP20MF (PVD), UP20M (PVD), VP20M (PVD)
- **K** Cast Iron: UC5105 (CVD), MC5005 (CVD), UC5115 (CVD), MH515 (CVD), MC5015 (CVD), MY5015 (CVD), MC520 NEW (CVD), MC5020 (CVD), VP15TF (PVD), VP10RT (PVD), VP20RT (PVD)
- **N** Non-Ferrous: LC15TF (DLC)
- **S** Heat Resistant Alloy Ti Alloy: US905 (CVD), MP9005 (PVD), VP05RT (PVD), VP10RT (PVD), VP20RT (PVD), MP9015 (PVD), VP15TF (PVD), MP9120 (PVD), MP9025 (PVD), MS9025 (PVD), MP9030 (PVD), MP9130 (PVD), MP9140 (PVD), VP30RT (PVD)
- **H** Hardened Materials: MP8010 (PVD), VP15TF (PVD)

Cermet
- **P** Steel: NX2525, NX3035, MX3020, MX3030, NX4545
- **M** Stainless Steel: NX2525, MX3020, MX3030, NX4545
- **K** Cast Iron: NX2525, MX3020, MX3030

Coated Cermet
- **P** Steel: AP25N (PVD), VP25N (PVD), MP3025 (PVD), VP45N (PVD)
- **M** Stainless Steel: AP25N (PVD), VP25N (PVD)
- **K** Cast Iron: AP25N (PVD), VP25N (PVD)

Polycrystallines (PCD/CBN)
- **N** Non-Ferrous Non-Metal: MD205, MD220, MD230, MD2030
- Sintered Alloy: MB4120
- **K** Cast Iron: MB710, BC5110 NEW (PVD), MB730, MBS140, BC5030 (PVD), MB4120
- **H** Hardened Materials: BC8105 (PVD), MB8110, BC8110 (PVD), BC8210 NEW (PVD), MB8120, BC8120 (PVD), BC8220 NEW (PVD), MB8130, BC8130 (PVD)

Micro-Grain Cemented Carbide
- Steel Cast Iron: SF10, MF07, MF10, TF15, MF20, MF30

GRADES COMPARISON TABLE

CEMENTED CARBIDE

	ISO Classification	ISO Symbol	MITSUBISHI MATERIALS	Sumitomo Electric	Tungaloy	Kyocera	Dijet	MOLDINO	Sandvik	Kennametal	Seco Tools	Iscar
Turning	P	P01										
		P10		ST10P	TH10			WS10				IC70
		P20	UTi20T	ST20E	KS20			EX35				IC70 IC50M
		P30	UTi20T	A30 A30N	UX30 KS15F			EX35				IC50M IC54
		P40		ST40E	TX40			EX35				IC54
	M	M10		EH510	TH10			WA10B		KU10 K313 K68	890	IC07
		M20	UTi20T	EH520	KS20			EX35		KU10 K313 K68	HX 883	IC07 IC08 IC20
		M30	UTi20T	A30 A30N	UX30			EX35				IC08 IC20 IC28
		M40			TU40							IC28
	K	K01	HTi05T	H1 H2	KS05F			WH01 WH05		KU10 K313 K68		
		K10	HTi10	EH510	TH10	KW10 GW15	KT9	WH10		KU10 K313 K68	890	IC20
		K20	UTi20T	G10E H10E EH520	KS15F KS20	GW25	KT9	WH20	H13A	KU10 K313 K68	HX	IC20
		K30	UTi20T	G10E H10E							883	
	N	N01		H1 H2	KS05F	GW05 KW10			H10			
		N10	HTi10	EH510	TH10	KW10 GW15	KT9	WH10	H10 HBA	KU10 K313 K68	890	IC08 IC20
		N20		G10E EH520	KS15F		KT9	WH20	H10 HBA	KU10 K313 K68	HX KX	IC08 IC20
		N30									883	
	S	S01	MT9005			SW05						
		S10	MT9005 RT9010 MT9015	EH510	KS05F TH10	SW10		WH13S	H10A H10F H13A	KU10 K313 K68	HX 883	IC07 IC08
		S20	RT9010 TF15	EH520	KS15F KS20	SW25				KU10 K313 K68	883	IC07 IC08
		S30	TF15									
Milling	P	P10										
		P20	UTi20T	A30N				EX35		K125M		IC50M IC28
		P30	UTi20T	A30N	UX30			EX35	SM30	GX		IC50M IC28
		P40						EX35				IC28
	M	M10										
		M20	UTi20T	A30N				EX35				IC08 IC20
		M30	UTi20T	A30N				EX35	SM30			IC08 IC28
		M40										IC28
	K	K01	HTi05T							K115M,K313		
		K10	HTi10	G10E	TH10	KW10 GW25	KT9	WH10		K115M K313		IC20
		K20	UTi20T	G10E		GW25	FZ15	WH20	H13A		HX	IC20
		K30	UTi20T									

Note 1) The chart above is based on data from various publications and not authorized by each individual company.

MICRO-GRAIN

	ISO Classification	ISO Symbol	MITSUBISHI MATERIALS	Sumitomo Electric	Tungaloy	Kyocera	Dijet	MOLDINO	Sandvik	Kennametal	Seco Tools
Cutting Tools	Z	Z01	SF10 MF07 MF10	F0	F MD05F MD1508		FZ05 FB05 FB10	NM08	PN90 6UF,H3F 8UF,H6F		
		Z10	HTi10 MF20	XF1 F1 AFU	MD10 MD0508 MD07F	FW30	FZ10 FZ15 FB15	NM10 NM12 NM15	H10F		890
		Z20	TF15 MF30	AF0 SF2 AF1	EM10 MD20 G1F		FZ15 FB15 FB20	BRM20 EF20N	H15F		890 883
		Z30		A1 CC			FZ20 FB20	NM25 NM40			883

CERMET

	ISO Classification	ISO Symbol	MITSUBISHI MATERIALS	Sumitomo Electric	Tungaloy	Kyocera	Dijet	MOLDINO	Sandvik	Kennametal	Seco Tools	Iscar
Turning	P	P01	AP25N* VP25N*	T1000A	NS520 GT720*	CCX* TN610 PV710* PV30*						IC20N IC520N*
		P10	NX2525 AP25N* VP25N*	T1500A T1500Z*	NS520 NS9530 GT9530* AT9530*	CCX* TN60 TN610 PV710* TN620 PV720*	CX75	CZ25*	CT5015 GC1525*	KT315 KT125	TP1020 TP1030* CM CMP*	IC20N IC520N* IC530N*
		P20	NX2525 AP25N* VP25N* NX3035 MP3025*	T1500A T1500Z* T2500A T2500Z* T3000Z*	NS9530 GT9530* AT9530*	TN60 TN620 PV720* TN6020	CX75 PX90*	CH550	GC1525*	KT325 KT1120 KT5020*	TP1020 TP1030*	IC20N IC520N* IC30N IC530N* IC75T
		P30	MP3025* VP45N*	T3000Z*		PV730* PV90*	PX90*					IC75T
	M	M10	NX2525 AP25N* VP25N*	T1000A T1500Z*		TN60 TN620 PV720* TN6020		CZ25*	GC1525*	KT125	TP1020 TP1030* CM CMP*	
		M20	NX2525 AP25N* VP25N*	T1500A T1500Z*		TN90 TN6020 TN620 PV720* PV90*		CH550				
		M30				PV730*						
	K	K01	NX2525 AP25N*	T1000A	NS520 GT720*	CCX* PV7005*						
		K10	NX2525 AP25N*		NS520 NS9530 GT9530*	CCX* PV7005* TN60		CZ25*	CT5015	KT325 KT125		
		K20	NX2525 AP25N*					CH550				
Milling	P	P10	NX2525			TN620M TN60	CX75	MZ1000*			C15M	IC30N
		P20	MX3020 NX2525	T250A T2500A		TN100M TN620M TN60	CX75 CX90	CH550 CH7030 MZ1000*	CT530	KT530M HT7 KT605M	C15M MP1020	IC30N
		P30	MX3030 NX4545	T4500A	NS740		CX90	CH7035				IC30N
	M	M10	NX2525			TN60						IC30N
		M20	MX3020 NX2525	T250A T2500A		TN100M	CX75		CT530	KT530M HT7 KT605M	C15M	IC30N
		M30	MX3030 NX4545	T4500A								
	K	K01										
		K10	NX2525			TN60	CX75					
		K20	NX2525				CX75			KT530M HT7		

*Coated Cermet

Note 1) The chart above is based on data from various publications and not authorized by each individual company.

GRADES COMPARISON TABLE

CVD COATED GRADE

	ISO Classification	ISO Symbol	MITSUBISHI MATERIALS	Sumitomo Electric	Tungaloy	Kyocera	Dijet	MOLDINO	Sandvik	Kennametal	Seco Tools	Iscar
Turning	P	P01	**MC6115** **UE6105**	AC810P AC8015P	T9105 T9205	CA510 CA5505	JC110V	HG8010	GC4305 GC4415	KCP05B KCP05	TP0501 TP1501	IC9150 IC8150 IC428
		P10	**MC6115** **UE6105** **MC6015** **UE6110** **MY5015** **MC6125**	AC810P AC8020P	T9205 T9105 T9115 T9215	CA510 CA5505 CA515 CA5515	JC110V JC215V	HG8010 HG8025 GM8020	GC4315 GC4325 GC4415	KCP10B KCP10 KCP25	TP1501 TP2501	IC9150 IC8150 IC8250
		P20	**MC6115** **MC6015** **UE6110** **MC6125** **MC6025** **UE6020** **MY5015**	AC8020P AC820P AC2000 AC8025P	T9115 T9125 T9215 T9225	CA025P CA515 CA5515 CA525 CA5525 CR9025	JC110V JC215V	HG8025 GM8020 GM25	GC4315 GC4325 GC4425	KCP25B KCP30B KCP25	TP2501	IC8250 IC9250 IC8350
		P30	**MC6125** **MC6025** **UE6020** **MC6035** **UH6400**	AC6030M AC8035P AC830P AC630M	T9125 T9135 T9225 T9235	CA025P CA525 CA5525 CA530 CA5535 CR9025	JC215V JC325V	GM25 GM8035	GC4325 GC4335 GC4425	KCP30B KCP30	TP3501	IC8350 IC9250 IC9350
		P40	**MC6035** **UH6400**	AC6030M AC8035P AC630M AC830P	T9135 T9235	CA530 CA5535	JC325V	GM8035 GX30	GC4335	KCP40 KCP40B	TP3501 TP40	IC9350
	M	M10	**MC7015** **US7020**	AC610M AC6020M	T6120 T6215	CA6515			GC2015 GC2220	KCM15B KCM15	TM1501 TM2000	IC6015 IC8250
		M20	**MC7015** **US7020** **MC7025**	AC6020M AC610M AC6030M AC630M	T6120 T6215	CA6515 CA6525		HG8025 GM25	GC2015 GC2220	KCM15 KCM25B KCP40B	TM2000 TM2501	IC8150 IC6015
		M30	**MC7025** **US735**	AC6030M AC630M	T6130	CA6525		GM8035 GX30	GC2025	KCM35B KCP40	TM4000 TM3501	IC8250 IC6025
		M40	**US735**	AC6030M AC630M				GX30	GC2025	KCM35B	TM4000 TM3501	IC6025
	K	K01	**MC5005** **UC5105**	AC405K AC410K AC4010K	T505 T515 T5105	CA4505 CA4010 CA310	JC050W JC105V	HX3505	GC3205 GC3210	KCK05B KCK05	TK0501 TH1500	IC5005
		K10	**MC5015** **MH515** **UC5115** **MY5015**	AC405K AC4010K AC410K AC4015K AC415K	T515 T5115	CA315 CA4515 CA4010 CA4115		HX3515 HG8010	GC3205 GC3210	KCK15B KCK15 KCK20 KC9315 KCK20B	TK0501 TK1501	IC5005 IC5010 IC428
		K20	**MC5015** **MH515** **UC5115** **UE6110** **MY5015**	AC4015K AC415K AC420K AC8025P	T5115 T5125	CA320 CA4515 CA4115 CA4120		HG8025 GM8020	GC3225	KCK20B KCK20 KCPK05	TK1501	IC5010 IC8150
		K30	**UE6110**	AC8025P	T5125			HG8025 GM8020	GC3225	KCPK05		
	S	S01	**MV9005** **US905**			CA6515 CA6525		HS9105 HS9115	S05F S205			
Milling	P	P10	**MV1020**	ACP2000 XCU2500 ACP100							MP1501	IC5400
		P20	**MV1020** **MC7020** **F7030**	ACP2000 ACP3000 XCU2500 ACP100	T3130 T3225			GX2140 GF30	GC4220		MP1501 MP2501 T25M	IC5500
		P30	**MV1020** **MC7020** **F7030**	ACP3000 XCU2500 ACP100	T3130 T3225			GX2140 GX2160 GF30	GC4330 GC4230	KCPK30 KC930M	MP1501 MP2501 TM25 T350	IC5500
		P40						GX2030 GX2160	GC4340 GC4240	KC935M KC530M	MM4500 T350M	
	M	M10		XCU2500								
		M20	**MC7020** **F7030**	ACP100 ACM200 XCU2500	T3130 T3225	CA6535		AX2040 GX2140		KC925M	MP2501 MS2500 T25M T350M	
		M30	**MV1020** **MC7020** **F7030**	ACP100 XCU2500 ACM200	T3130 T3225	CA6535		AX2040 GX2140 GX2160 GX30	GC2040	KC930M	MP2501 T25M T350M	IC5820
		M40						GX2160		KC930M KC935M	MM4500 T350M	
	K	K01										
		K10	**MV1020** **MC520** **MC5020**	XCK2000 ACK200	T1215 T1115	CA420M	JC605W	GX2120				
		K20	**MV1020** **MC520** **MC5020**	ACK200 XCK2500 XCK2000 ACK200	T1115		JC605W	GX2120	GC3220 GC3330 K20W	KC915M	MP1501	IC5100
		K30							GC3330 GC3040	KC920M KC925M KCPK30 KC930M KC935M	MP1501	IC5100 DT7150

Note 1) The chart above is based on data from various publications and not authorized by each individual company.

PVD COATED GRADE

	ISO Classification	ISO Symbol	MITSUBISHI MATERIALS	Sumitomo Electric	Tungaloy	Kyocera	Dijet	MOLDINO	Sandvik	Kennametal	Seco Tools	Iscar
Turning	P	P01										
		P10	VP10MF MS6015		AH710	PR1705 PR930 PR1025 PR1115 PR1225 PR1725			GC1125	KCU10 KT315 KC5010 KC5510 KU10T KTP10	CP200 TS2000	IC250 IC507 IC570 IC807 IC907 IC908
		P20	VP10RT VP20RT VP15TF VP20MF MS6015		AH725 AH120 J740 SH730 SH725	PR930 PR1025 PR1725 PR1115 PR1225 PR1425 PR1535		IP2000	GC1525 GC1125 GC15	KT315 KCS10 KCU10 KC5025 KC5525 KU25T KTP10	TS2500	IC1007 IC250 IC308 IC507 IC807 IC808 IC907 IC908 IC1008 IC1028 IC3028
		P30	VP10RT VP20RT VP15TF VP20MF MS7025	AC1030U AC530U	AH725 AH120 SH730 GH730 GH130 AH740 J740 SH725 AH7025	PR1025 PR1725 PR1225 PR1425 PR1535 PR1625		IP3000	GC1125	KCU25 KC5525 KU25T	CP500	IC228 IC250 IC328 IC330 IC354 IC528 IC1008 IC1028 IC3028
		P40			AH740	PR1535					CP500 CP600	IC228 IC328 IC528 IC928 IC1008 IC1028 IC3028
	M	M01				PR1725	JC5003				CP200 TS2000	
		M10	VP10MF		AH8005 AH630	PR1025 PR1225 PR930 PR1725	JC5003 JC8015 JC5015	IP050S	GC1525 GC1115 GC15 GC1125 GC1105	KCS10 KCU10 KC5010	CP200 TS2000 TS2500	IC354 IC507 IC520 IC807 IC907 IC1007 IC5080T
		M20	VP10RT VP20RT VP15TF VP20MF MS7025 MS9025	AC1030U AC530U AC6040M	AH725 AH120 SH730 AH630 SH725 AH8015 AH7025	PR1025 PR1225 PR930 PR1535 PR1725	JC5015 JC8015 JC5118	IP100S	GC1525 GC1115 GC15 GC1125	KCU25 KC5025 KCU10 KC5010 KCS10	TS2500 CP500 CP600	IC354 IC808 IC908 IC1008 IC1028 IC3028 IC5080T
		M30	VP10RT VP20RT VP15TF VP20M VP20MF MS7025 MP7035	AC530U AC1030U AC6040M	AH725 AH120 SH730 J740 AH645 SH725	PR1025 PR1725 PR1535 PR1225	JC5118		GC1125 GC2035	KC5025 KCU25	CP500 CP600	IC228 IC250 IC328 IC330 IC1008 IC1028 IC9080T
		M40	MP7035	AC530U AC6040M AC1030U	AH645	PR1535 PR1225			GC2035		CP600	IC328 IC928 IC1008 IC1028 IC3028 IC9080T
	K	K01										
		K10		AC510U	GH110 AH110				GC15	KCU10 KCS10 KC5010 KC5510	CP200 TS2000	IC350 IC910 IC1008
		K20	VP10RT VP20RT VP15TF	AC1030U AC530U	AH7025 AH120					KCU15 KCU25	CP200 TS2000 TS2500	IC228 IC350 IC808 IC830 IC908 IC1007 IC1008
		K30	VP10RT VP20RT VP15TF		AH120 GH130					KCU25 KC5525	CP500	IC228 IC350 IC808 IC830 IC908 IC928 IC1007 IC1008
	S	S01	MP9005 VP05RT	AC510U AC5005S AC5015S	AH8005	PR005S PR015S	JC5003 JC8015 JC5015	JP9105			TH1000	IC507 IC804 IC807 IC907 IC5080T
		S10	MP9005 MP9015 VP10RT	AC5005S AC510U AC520U AC5015S AC5025S	AH8005 AH8015	PR005S PR015S	JC5003 JC5015 JC8015	JP9115	GC1105	KCU10 KC5010 KCS10	CP200 TS2000 TS2050 TS2500 TH1000	IC507 IC806 IC807 IC903 IC5080T
		S20	MP9015 MT9015	AC520U AC5015S AC5025S	AH7025 AH8015	PR015S PR1535	JC5015 JC5118		GC1105 GC1115 GC1125 GC15	KCU10 KCU25 KC5025 KCS10 KC5010	TS2000 TS2500 CP200	IC228 IC300 IC328 IC808 IC908 IC928 IC3028 IC806 IC9080T
		S30	MS9025 MP9025 VP15TF VP20RT	AC1030U	AH630 AH7025	PR015S PR1535	JC5118		GC1125	KCU25 KC5025	CP600	IC928 IC830
Milling	P	P01			AH710 AH110		JC8003	ATH80D JP4105				IC903
		P10		ACU2500	AH120 AH725	PR830 PR1225	JC8003 JC8015 JC5015 JC5118	PN15M PN215 PCA12M JP4115	GC1010 GC1130	KC505M KC715M KC510M KC515M		IC808 IC810 IC900 IC903 IC908 IC910 IC950 IC380

Note 1) The chart above is based on data from various publications and not authorized by each individual company.

TECHNICAL DATA

Q

GRADES COMPARISON TABLE

PVD COATED GRADE

	ISO Classification	ISO Symbol	MITSUBISHI MATERIALS	Sumitomo Electric	Tungaloy	Kyocera	Dijet	MOLDINO	Sandvik	Kennametal	Seco Tools	Iscar
Milling	P	P20	MP6120 VP15TF	ACU2500 ACP200	AH3225 AH725 AH120 GH330 AH9030 AH3135	PR830 PR1225 PR1230 PR1525	JC5015 JC8015 JC5118	CY9020 JP4120 CY150	GC1010 GC1030 GC1130 GC2030	KC522M KC525M KC527M KC610M KC620M KC635M KC715M KC720M KC730M	F25M MP3000	IC808 IC810 IC830 IC900 IC908 IC910 IC928 IC950 IC1008 IC380
		P30	MP6120 VP15TF MP6130 VP30RT	ACU2500 ACP200 ACP300 ACP3000	AH120 AH130 AH6030 AH725 AH3225 AH3135 AH9130	PR1230 PR1525	JC8050 JC5040 JC5118	JS4045 CY250 CY250V CY25 HC844	GC1010 GC1030 GC2030 GC1130	KC735M KC725M KC530M KC537M	F25M MP3000 F30M MP2050	IC830 IC845 IC900 IC928 IC950 IC1008 IC380
		P40	VP30RT	ACP300	AH140	PR1525	JC8050 JC5040	JS4060 PTH30E PTH40H JS4060	GC2030 GC1030 GC1130	KC735M KC537M	F40M T60M	IC830 IC928 IC1008
	M	M01						PN08M PN208				IC907
		M10		ACU2500 ACM100	AH725	PR1225		PN15M PN215	GC1025 GC1030 GC1010 GC1130	KC715M KC515M		IC903
		M20	VP15TF MP7130 MP7030 VP20RT	ACU2500	AH725 AH3135 AH6030 AH130 AH3225 AH9130	PR830 PR1225 PR1525	JC5015 JC5118 JC8015	JP4120	GC1025 GC1030 GC1040 GC2030 S30T	KC610M KC635M KC730M KC720M KC522M KC525M	F25M MP3000	IC808 IC830 IC900 IC908 IC928 IC380 IC1008
		M30	VP15TF MP7130 MP7030 VP20RT MP7140 VP30RT	ACP300 ACM300 ACK300	AH130 AH9130 AH3135	PR830 PR1225 PR1525 PR1535	JC5015 JC8015 JC8050 JC5118	JS4045 CY250	S30T GC1040 GC2030	KC537M KC725M KC735M KC530M	F30M F40M MP3000 MP2050	IC328 IC330 IC380 IC830 IC882 IC928 IC1008 IC380
		M40	MP7140 VP30RT	ACM300	AH140	PR1525 PR1535	JC8050	PTH30E PTH40H JM4160			F40M MP2050	IC328 IC330 IC882 IC1008
	K	K01	MP8010		AH110		JC8003	ATH80D ATH08M TH308				IC380 IC900
		K10	MP8010	ACU2500 ACK3000	AH110 AH120	PR1210 PR1510	JC8015	ATH10E TH315 CY100H	GC1010	KC514M KC515M KC527M KC635M	MK2050	IC810 IC900 IC910 IC380
		K20	VP15TF VP20RT	ACU2500 ACK300 ACK3000	AH120 AH9130 AH9030	PR1210 PR1510	JC5015 JC8015	CY150 JP4120 CY9020 PTH13S	GC1010 GC1020	KC514M KC610M KC520M KC620M KC524M	MK2000 MK2050	IC810 IC910 IC928 IC950
		K30	VP15TF VP20RT	ACK300 ACK3000			JC5080 JC5015 JC8015	CY250 JS4045	GC1020	KC522M KC725M KC524M KC735M KC537M	MK2050	IC808 IC830 IC908 IC928 IC1008
	S	S01			AH110 AH710	PR905 PR1210	JC8003 JC8015 JC5118	PN08M PN208				IC907 IC908 IC808 IC903
		S10	MP9120 VP15TF	ACM100 ACU2500	AH120 AH725	PR1210 PR1535	JC8003 JC5015 JC8015 JC5118	JS1025 JP4120	GC1130 GC1010 GC1030 GC2030	KC510M	MS2050	IC903 IC907 IC908 IC840 IC910 IC808
		S20	MP9120 VP15TF MP9130 MP9030	ACK300 ACP300 ACU2500	AH725 AH6030 AH130	PR1210 PR1535	JC8015 JC5015 JC8050 JC5118	PTH30H	S30T GC2030 GC1030 GC1130	KC522M KC525M	MS2050 MP2050	IC300 IC908 IC808 IC900 IC830 IC928 IC328 IC330 IC840 IC882 IC380
		S30		ACM300	AH130	PR1535	JC8050 JC5118	JM4160	GC2030 GC1040	KC725M	MS2050 F40M KCSM40	IC830 IC882 IC928
	H	H01	MP8010 VP05HT		AH110 AH710		JC8003					IC903
		H10	VP15TF VP10H		AH110 AH120 AH710		JC6102 JC8008	JP4105 TH303 TH308 PTH08M ATH08M ATH80D	GC1130 GC1010 GC1030	KC505M KC510M	MH1000 F15M	IC900 IC808 IC907
		H20	VP15TF		AH120 AH725 AH9030		JC8015 JC5118	JP4115 TH315	GC1030 GC1130	KC635M	F15M	IC900 IC808 IC908 IC380
		H30						JP4120			MP3000 F30M	IC380 IC900 IC1008

Note 1) The chart above is based on data from various publications and not authorized by each individual company.

CBN

	ISO Classification	ISO Symbol	MITSUBISHI MATERIALS	Sumitomo Electric	Tungaloy	Kyocera	Dijet	Sandvik	Seco Tools
Turning	H	H01	**BC8105 BC8110 MB8110**	BNC100 BNX10 BN1000 BNC2010	BXM10 BX310	KBN05M KBN10M KBN510		CB7105	CBN060K
		H10	**BC8110 BC8210 BC8120 BC8220 MB8110 MB8120**	BNC160 BNX20 BN2000 BNC2020	BXM10 BX330 BX530	KBN05M KBN25M KBN525	JBN300	CB7115 CB7015	CBN010
		H20	**BC8210 BC8120 BC8220 MB8120**	BNC200 BNX25 BN250 BNC2020	BXM20 BXA20 BX360	KBN525 KBN05M KBN25M	JBN245	CB7125 CB7025 CB20	CBN150 CBN160C
		H30	**BC8130 MB8130**	BNC300 BN350	BXC50 BX380	KBN35M		CB7135 CB7525	CBN150 CBN160C
	S	S01	**MB730**	BN700 BN7000	M714B				CBN170
		S10		BNS8125	BX470, BX480				
		S20							
		S30							
	K	K01	**MB710 BC5110 MB5015**	BN500 BNC500	BX870 BX930 BX910				
		K10	**MB730 MB4120**	BN700 BN7500 BN7000	BX470 BX480	KBN60M	JBN795	CB7525	
		K20	**MB730 MB4120**	BN700 BN7000	BX480	KBN60M	JBN500		CBN200
		K30	**BC5030 MBS140**	BNS800 BNC8115, BNC8125	BX90S BXC90	KBN900		CB7925	CBN300 CBN400C CBN500
	Sintered Alloy		**MB4120**	BN7500 BN7000 BNC7115	BX470 BX480	KBN570 KBN70M			CBN200

PCD

	ISO Classification	ISO Symbol	MITSUBISHI MATERIALS	Sumitomo Electric	Tungaloy	Kyocera	Dijet	Sandvik	Seco Tools
Turning	N	N01	**MD205***	DA90	DX180 DX160	KPD001	JDA30 JDA735	CD05	PCD05
		N10	**MD220**	DA150	DX140	KPD010		CD10	PCD10
		N20	**MD220**	DA2200	DX120		JDA715		PCD20
		N30	**MD230* MD2030**	DA1000	DX110	KPD230	JDA10		PCD30 PCD30M

* Non stock, produced to order only.

Note 1) The chart above is based on data from various publications and not authorized by each individual company.

INSERT CHIP BREAKER COMPARISON TABLE

NEGATIVE INSERT TYPE

ISO Classifi-cation	Cutting Mode	MITSUBISHI MATERIALS	Sumitomo Electric	Tungaloy	Kyocera	Dijet	MOLDINO	Sandvik	Kennametal	Seco Tools	Walter	TaeguTec
P	Finish	FH, FP FY, FS	FA, FB FL	01* TF, 11 ZF	GP, PP, VF XP, XP-T, XF		FE	LC	FF	FF1, FF2	FP5	FA FX
	Light	LP SA, SH	SU LU, FE SX, SE	PS NS, 27 TSF, AS, TQ	PQ HQ, CQ	PF UR, UA, UT	BE B, BH, CE	XF PF MF	K LF, FN	MF2	MP3, FV5	FM FG
	Light (Mild Steel)	SY		17	XQ, XS							FC
	Light (With Wiper)	SW	LUW, SEW	FW, SW AFW, ASW	WF WP, WQ			WL, WF	FW	W-FF2 W-MF2	FW5, NF	WS
	Medium	MP MA MH	GU UG GE, UX	PM, NM, ZM TA, TM, AM, 28 DM, 33, 37, 38	PG, CJ, GS PS, HS PT	PG UB	CT, AB AH, AR AY, AE	PM QM, XM XMR	MP, P MN	MF3 MF5, M3 M5	MP5, MV5 MU5	PC, MP, FT MT
	Medium (With Wiper)	MW	GUW		WE			WMX, WM WR	MW, RW	W-M6, W-M3 W-MF5	MW5, NM	WT
	Rough	RP GH Std.	MU, MX, ME UZ	TH, THS Std.	PH GT Std.	UD GG	RE Y	PR, HM Std.	RN, RP	M6, MR6, MR7	RP5, RP7 RV5	RT Std.
	Heavy	HZ HL, HM, HX HV	MP HG, HP HU, HW, HF	TRS, 57 TU TUS, 65	PX	UC	HX HE, H	QR, PR HR, MR	MR, RP RM RH	R4, R5 R57, RR6, R7 R68, RR9	NRF HU5 NRR	RX, RH HD, HY, HT HZ, EH
M	Finish Light	SH, LM	SU, EF	SS	MQ, SK*		MP, AB, BH	XF, MF	FF, FP LF*	FF1, FF2 MF1	FM5	SF
	Medium	MS, GM MM, MA ES	EX, EG, UP GU HM	SA, SF SM S	MS, MU TK ST	SF, SZ SG	PV, DE, SE AH	MM QM, XM K	MS, MP UP	MF3 MF4 MF5, M3	MM5, RM5 MU5	ML EM, MM VF
	Heavy	GH, RM HL, HZ	EM, MU MP	TH, SH			AE	MR MR	MR, RP	M5, M6, R6 R56, RR6, R7 R8,PR9	HU5	
K	Finish Light	LK, MA		CF	KQ		VA, AH	KF	FN	MF2 M3, M4	MK5	FG
	Medium	MK, GK Std.	UZ, GZ, UX	CM Std.	KG, Std., C	PG	V, AE	KM	RP,UN	M5	RK5, MV7	MC
	Rough	RK			KH. GC, PH	GG	RE	KR, KRR		MR7	RK7 RV7	KT
	Heavy	Flat Top	Flat Top	CH, Flat Top	ZS, Flat Top	Flat Top	Flat Top		Flat Top	MR9 Flat Top	Flat Top	
S	Finish	FJ*	EF		MQ, SK*			SF	FS*, FF	MF1	FM5	FA
	Light	LS,MJ,MJ*	SU*	HRF				SGF*	LF*, MS, FN	MF3	NFT MS3	EA, SF
	Medium	MS MA	EG, EX, UP	HRM, 28 SA, HMM	SQ MS, MU, TK		VI	NGP*, SM QM	UP, P, NGP*	M1 M3	NMS, NMT MU5	
	Heavy	RS, GJ	MU		SG, SX			SR, SMR	RP	MR3 MR4	NRS, NRT HU5	ET

*Peripheral ground type insert.

Note 1) The chart above is based on data from various publications and not authorized by each individual company.

7°POSITIVE INSERT TYPE

ISO Classifi-cation	Cutting Mode	MITSUBISHI MATERIALS	Sumitomo Electric	Tungaloy	Kyocera	Dijet	MOLDINO	Sandvik	Kennametal	Seco Tools	Walter	TaeguTec
P	Finish	SMG*	FC*, SC*	JS*, 01*	CF*,CK* GQ*,GF* SKS*, SK*			UM*	LF*		FP2*	SA*
	Finish Light	FP, FV LP, SV	FB, FP, LU LB, SU	PF, PSF PS, PSS, TSF	GP, PP, VF XP		JQ	PF, UF	UF, 11 LF, FP	FF1 F1, MF2	PF4, FP4	FA, FX FG
	Light (With Wiper)	SW	LUW, SDW		WP			WF	FW	W-F1	PF	
	Medium	MV MP, Std.	GU MU	TM, 23 PM, 24	HQ, MF* XQ, GK	FT	JE	PM, UM PR, UR	MF, MP	M3 F2, M5	FP6, MP4 RP4	PC MT
	Medium (With Wiper)	MW		SW				WM	MW	W-MF2 W-M3	PM	WT
M	Finish | Light	FM LM	FC*,SI* LU LB, SU	PF, PSF PS, PSS	CF*,CK* GQ*,GF* MQ*,SK*		MP	MF, UF	LF, UF FP	F1, F2 MF2	FM2* FM4	FA FG
	Medium	MM Std.	GU, MU	PM	HQ, GK			MM, UM MR, UR	MP	M3 M5	FM6 MM4, RM4	PC MT
K	Medium	MK, Std. Flat Top	MU, Flat Top*	Flat Top, CM	Flat Top*			KF, KM, UM, KR	Flat Top	F1, M3, M5	FK6, MK4 RK4, RK6	MT
N	Medium	AZ*	AG* AW*	AL*	AP* AH*	ASF*,ALU* ACB*		AL*	HP*	AL*	FN2*, PM2* MN2*	FL*
S	Finish Light	FS*, LS* FS-P*, LS-P* FJ* LS, MS	SI* GU	Std.	CF*, CK* GQ*, GF* SK*, MQ			UM* UF, MF UM, MM	LF* HP*		FM2* FM4, FM6 MM4, RM4	SA*, FA, FG PC, MT

*Peripheral ground type insert.

Note 1) The chart above is based on data from various publications and not authorized by each individual company.

11°POSITIVE INSERT TYPE

ISO Classifi-cation	Cutting Mode	MITSUBISHI MATERIALS	Sumitomo Electric	Tungaloy	Kyocera	Dijet	MOLDINO	Sandvik	Kennametal	Seco Tools	Walter	TaeguTec
P	Finish Light	FV, SMG* SV	SI, FK. FB LU, LUW, LB SU,SF	01* PF, PSF PS, PSS, TSF	PP, GP, GF* SKS*, CF*, CK* PF*, XP		JQ	PF	UF, FP FW, LF		FP4	FG PC
	Medium	MV	GU, MU, US	PM TM, 23 24	HQ XQ	BM	JE	PM, UM	MF MP, MW		MP4	
M	Finish | Light	SMG* SV	SU	SS* PF, PS	GF*, CK* PF*, GP, CF* SKS*		MP	MF	HP* LF		FM4	PC
	Medium	MV	GU, MU, US	PM, Std.	HQ			MM			MM4	

*Peripheral ground type insert.

Note 1) The chart above is based on data from various publications and not authorized by each individual company.

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