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

ISO13399 Property Symbols	Content
CWX	Cutting width maximum
CXD	Coolant exit diameter
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

LIST OF PROPERTY SYMBOLS COMPLYING WITH ISO13399

ISO13399 Property Symbols	Content
IIC	Insert interface code
INSL	Insert length
KAPR	Tool cutting edge angle
KCH	Corner chamfer angle
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

ISO13399 Property Symbols	Content
RER	Corner radius right hand
RMPX	Ramping angle maximum
RPMX	Rotational speed maximum
S	Insert thickness
S1	Insert thickness total
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 center 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

Up ↗ / Down ↘

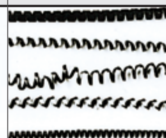
Trouble		Factors \ Solutions	Insert Grade Selection: Select a Harder Grade	Insert Grade Selection: Select a Tougher Grade	Insert Grade Selection: Select a Grade with Better Thermal Shock Resistance	Insert Grade Selection: Select a Grade with Better Adhesion Resistance	Cutting Conditions: Cutting Speed	Cutting Conditions: Feed Rate	Cutting Conditions: Depth of Cut	Cutting Conditions: Cutting Fluids: Do Not Use Water-soluble Cutting Fluid	Cutting Conditions: Cutting Fluids: Determine Dry or Wet Cutting	Style and Design of the Tool: Select Chip Breaker	Style and Design of the Tool: Rake Angle	Style and Design of the Tool: Corner Radius	Style and Design of the Tool: Lead Angle	Style and Design of the Tool: Honing Strengthens the Cutting Edge	Style and Design of the Tool: Class of Insert (Unground-Ground)	Style and Design of the Tool: Improve Tool Holder Rigidity	Machine and Installation of Tool: Installation of the Tool and Workpiece	Machine and Installation of Tool: Toolholder Overhang	Machine and Installation of Tool: Machine with Inadequate Horsepower and Rigidity
Short Tool Life	Rapid insert wear	Improper tool grade	●																		
		Improper cutting edge geometry										●	↗●	↗●	↗●	●↘					
		Improper cutting conditions					●↘	↗●			● Wet										
	Chipping and fracturing of cutting edge	Improper tool grade		●																	
		Improper cutting conditions						●↘	●↘												
		Lack of cutting edge strength										●		↗●		↗●					
		Thermal cracking			●		●↘	●↘	●↘	●	● Dry										
		Built-up edge				●	↗●	↗●		●	● Wet										
		Lack of rigidity																●	●	●	●
Worsening Dimensional Accuracy	Dimensional unevenness during machining	Improper insert tolerance															●				
		Large cutting resistance and cutting edge flank										●	●	●↘	●↘	●↘		●	●	●	●
	Machining accuracy not maintained adjustment is necessary each time	Improper tool grade	●																		
		Improper cutting conditions					●↘	↗●													
Poor Surface Finish	Worsening surface roughness	Welding occurs					↗●			●	● Wet										
		Improper cutting edge geometry										●		↗●							
		Vibration occurs					●↘	●↘	●↘									●	●	●	●
Heat Generation	Cutting heat creates deterioration in machining accuracy and tool life	Improper cutting conditions					●↘	●↘	●↘												
		Improper cutting edge geometry										●	↗●			●↘					

Trouble		Factors \ Solutions	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 Rate	Cutting Conditions: Depth of Cut	Cutting Conditions: Cutting Fluids: Do Not Use Water-soluble Cutting Fluid	Cutting Conditions: Cutting Fluids: Determine Dry or Wet Cutting	Style and Design of the Tool: Select Chip Breaker	Style and Design of the Tool: Rake Angle	Style and Design of the Tool: Corner Radius	Style and Design of the Tool: Lead Angle	Style and Design of the Tool: Honing Strengthens the Cutting Edge	Style and Design of the Tool: Class of Insert (Unground-Ground)	Style and Design of the Tool: Improve Tool Holder Rigidity	Machine and Installation of Tool: Installation of the Tool and Workpiece	Machine and Installation of Tool: Toolholder Overhang	Machine and Installation of Tool: Machine with Inadequate Horsepower and Rigidity
Burr / Chipping / Roughness	Burr (Steel, Aluminum alloy)	Notch wear occurs	●																		
		Improper cutting conditions					● ↘	↗ ●			● Wet										
		Improper cutting edge geometry										●	↗ ●	● ↘	● ↘	● ↘					
	Chipping (Cast iron)	Improper cutting conditions						● ↘	● ↘												
		Improper cutting edge geometry										●	↗ ●	↗ ●	↗ ●	● ↘					
		Vibration occurs																●	●	●	●
	Roughness (Mild steel)	Improper tool grade				●															
		Improper cutting conditions					↗ ●			●	● Wet										
		Improper cutting edge geometry										●	↗ ●			● ↘					
		Vibration occurs																●	●	●	●
Chip Control	Uncontrolled, continuous / tangled	Improper cutting conditions					● ↘	↗ ●	↗ ●		● Wet										
		Wide chip control range										●									
		Improper cutting edge geometry												● ↘	● ↘						
	Broken into short lengths and scatter	Improper cutting conditions						● ↘	● ↘		● Dry										
		Small chip control range										●									
		Improper cutting edge geometry												↗ ●	↗ ●						

(Cutting Conditions and Style and Design of the Tool: Up ↗ Down ↘)

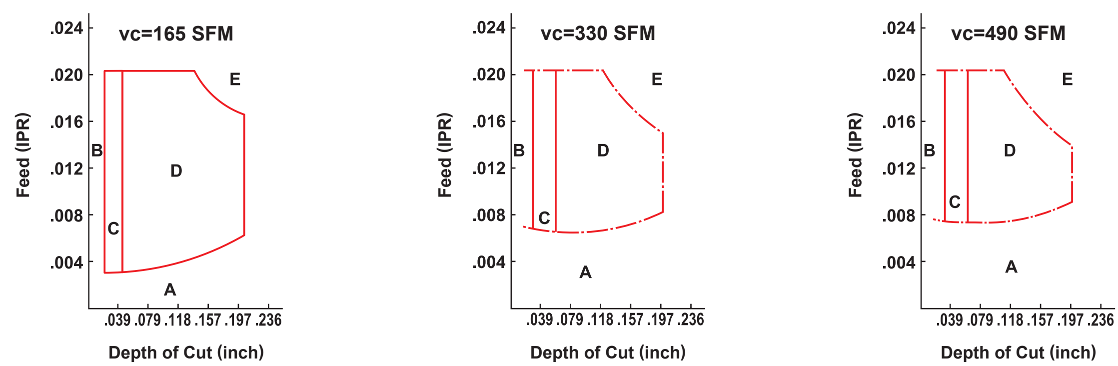
CHIP CONTROL FOR TURNING

■CHIP BREAKING CONDITIONS IN STEEL TURNING

Type	A Type	B Type	C Type	D Type	E Type
Small Depth of Cut d <.276"					
Large Depth of Cut d=.276"—.591"					
Curl Length l	No Curl	l≥2 inch	l≤2 inch 1—5 Curl	≒ 1 Curl	1 curl—half curl
Note	●Irregular continuous shape ●Tangle about 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

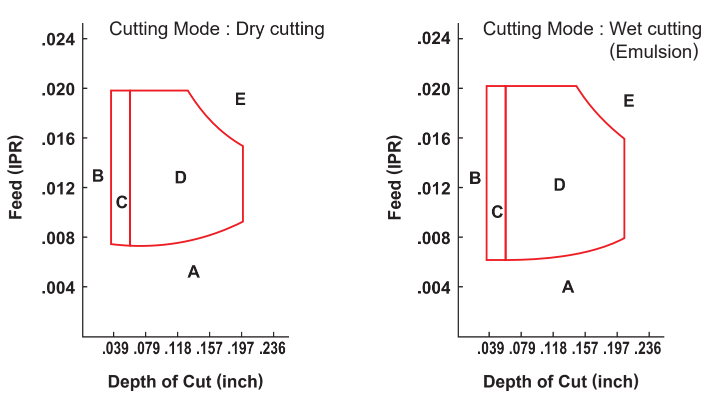
In general, when cutting speed increases, the chip control range tends to become narrower.



Workpiece : **AISI 1045 (180HB)**
Insert : **TNMG332**
Grade : **P10** Grade
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 : **AISI 1045**
Cutting Condition : **vc=330 SFM**

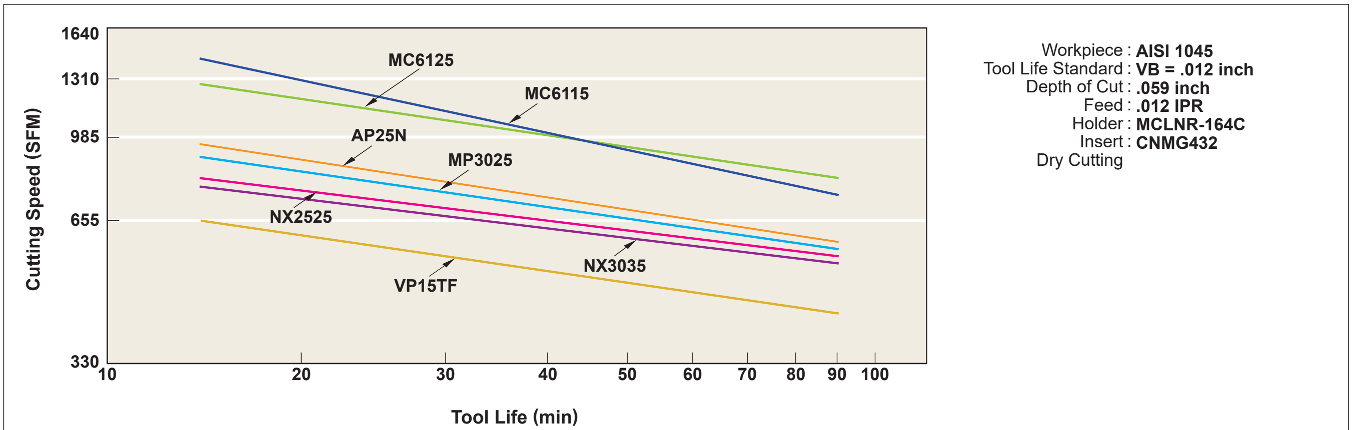
EFFECTS OF CUTTING CONDITIONS FOR TURNING

■EFFECTS OF CUTTING CONDITIONS

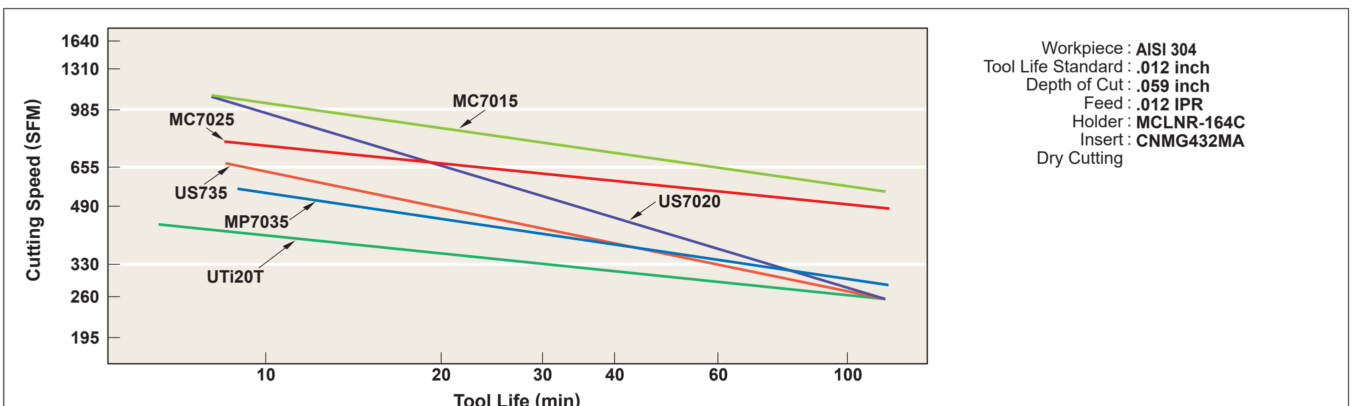
Ideal conditions for cutting are short cutting time, long tool life, and high cutting accuracy. In order to obtain these conditions, selection of efficient cutting conditions and tool, based on workpiece, hardness, shape and machine capability is necessary.

■CUTTING SPEED

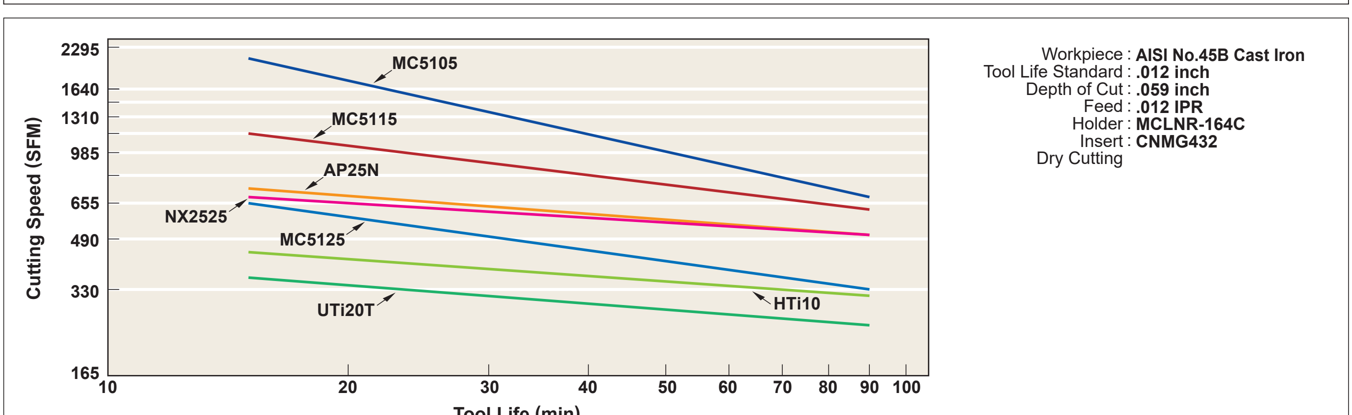
Cutting speed effects tool life greatly. Increasing cutting speed increases cutting temperature and results in shortening tool life. Cutting speed varies depending on the type and hardness of the workpiece. Selecting a tool grade suitable for the cutting speed is necessary.



P Class Grade Tool Life



M Class Grade Tool Life



K Class Grade Tool Life

●Effects of Cutting Speed

1. Increasing cutting speed by 20% decreases tool life to 1/2. Increasing cutting speed by 50% decreases tool life to 1/5.
2. Cutting at low cutting speed (65—130 SFM) tends to cause chattering. Thus, tool life is shortened.

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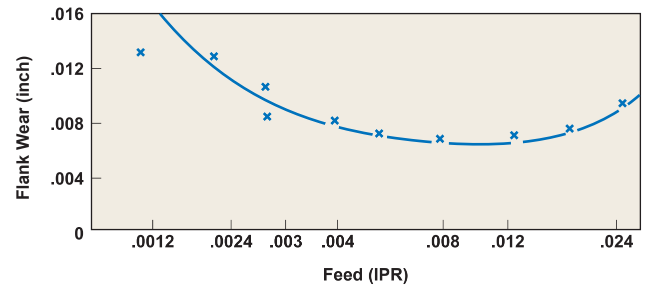
EFFECTS OF CUTTING CONDITIONS FOR TURNING

■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.



Cutting Conditions Workpiece : AISI 4340 Grade : P10
Insert : 0-0-5-5-35-35-0.3 mm
Depth of Cut ap=.040 inch Cutting Speed vc=660 SFM
Cutting Time Tc=10 min

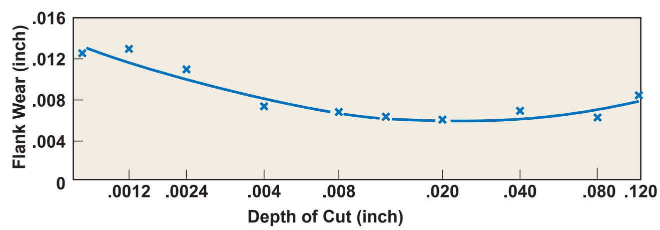
Feed and Flank Wear Relationship in Steel Turning

■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.

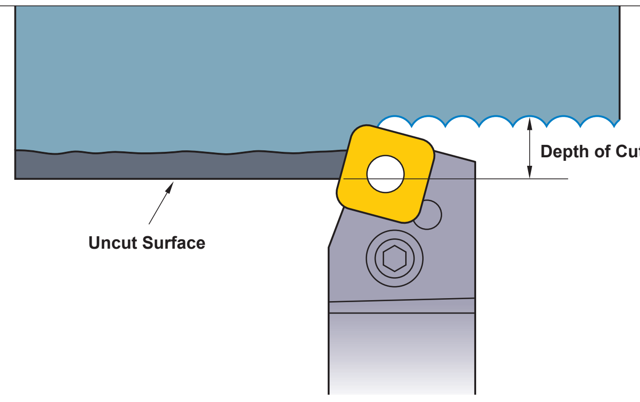
●Effects of Depth of Cut

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.



Cutting Conditions Workpiece : AISI 4340 Grade : P10
Insert : 0-0-5-5-35-35-0.3 mm
Feed f=.008 IPR Cutting Speed vc=660 SFM
Cutting Time Tc=10 min

Depth of Cut and Flank Wear Relationship in Steel Turning

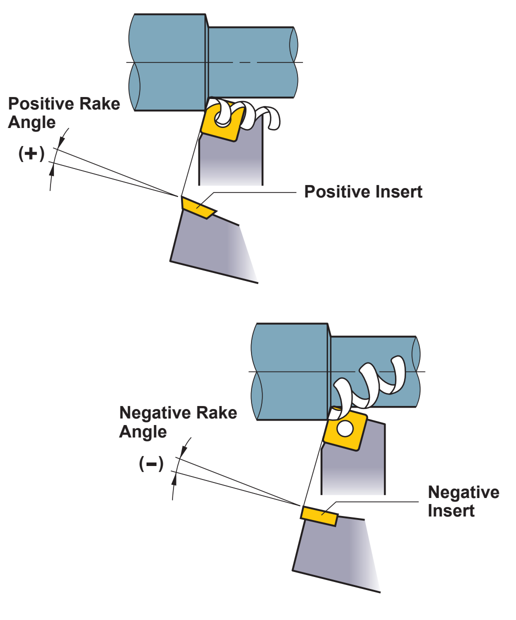


Roughing of Surface Layer that Includes Uncut Surface

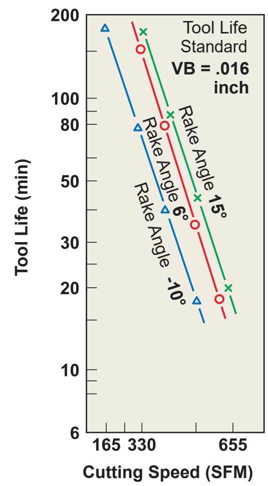
FUNCTION OF TOOL FEATURES FOR TURNING

■RAKE ANGLE

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

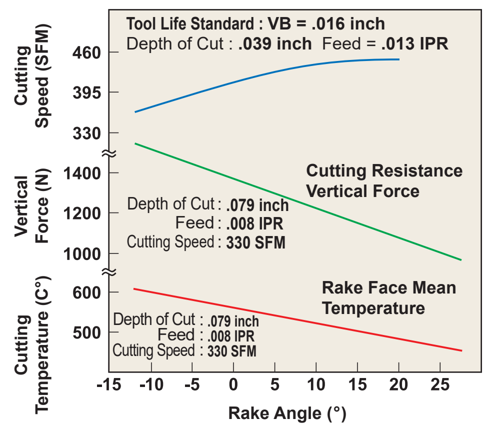


Chip Disposal and Rake Angle



Cutting Conditions
Grade : **P10**
Depth of Cut : **.039 inch**
Feed : **.013 IPR**
Workpiece : **Alloy steel**

Rake Angle and Tool Life



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

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

●Effects of Rake Angle

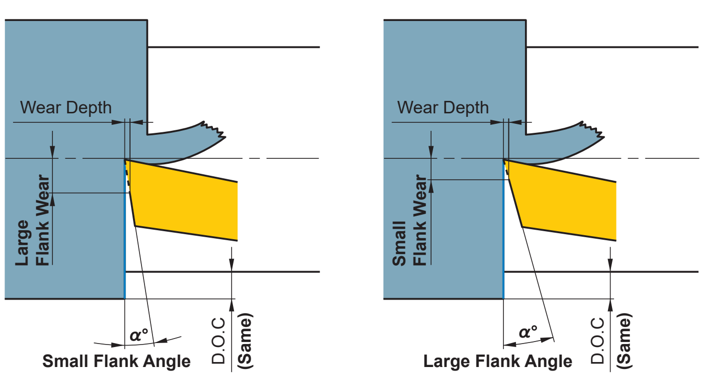
1. Increasing rake angle in the positive (+) direction improves sharpness.
2. Increasing rake angle by 1° in the positive (+) direction decreases cutting power by about 1%.
3. Increasing rake angle in the positive (+) direction lowers cutting edge strength and in the negative (-) direction increases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

When to Increase Rake Angle in the Negative (-) Direction
◯ Hard workpiece.
◯ When cutting edge strength is required such as in interrupted cutting and uncut surface cutting.

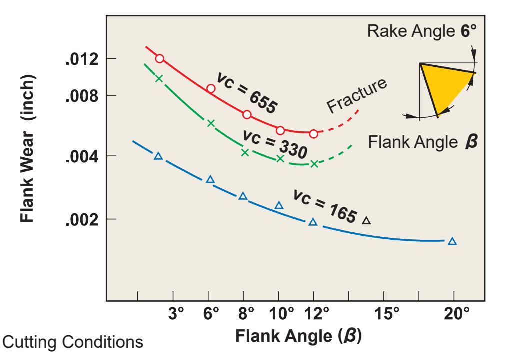
When to Increase Rake Angle in the Positive (+) Direction
◯ Soft workpieces.
◯ Workpiece is easily machined.
◯ When the workpiece or the machine have poor rigidity.

■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 : **Alloy steel (200HB)** Insert : **0-6-β-β-20-20-0.5 mm**
Grade : **P20** Feed : **.013 IPR**
Depth of Cut : **.039 inch** Cutting Time : **20 min**

Flank Angle and Flank Wear Relationship

●Effects of Flank Angle

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

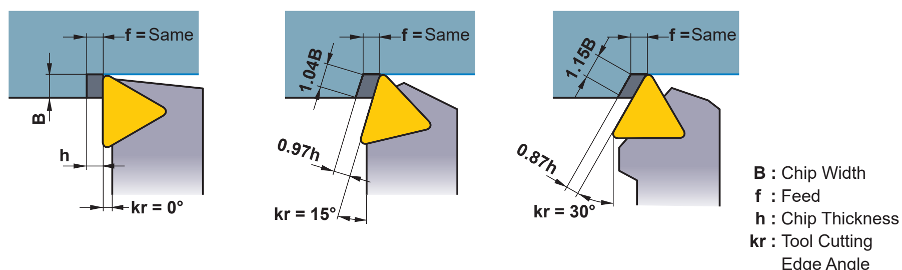
When to Decrease Flank Angle
◯ Hard workpiece.
◯ When cutting edge strength is required.

When to Increase Flank Angle
◯ Soft workpiece.
◯ Workpiece suffer from work hardening easily.

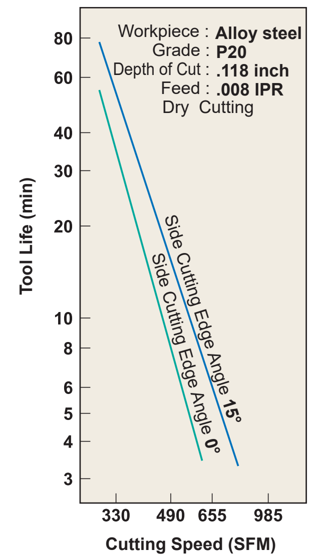
FUNCTION OF TOOL FEATURES FOR TURNING

■SIDE CUTTING EDGE ANGLE (LEAD ANGLE)

Side cutting edge angle lower impact load and effect feed force, back force, and chip thickness.



Side Cutting Edge Angle and Chip Thickness

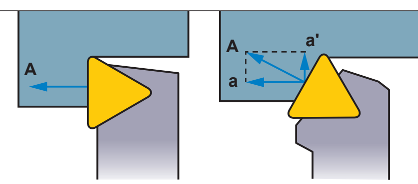


Side Cutting Edge and Tool Life

●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 workpiece 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	When to Increase Lead Angle
○Finishing with small depth of cut. ○Thin, long workpiece. ○When the machine has poor rigidity.	○Hard workpiece which produce high cutting temperature. ○When roughing a large diameter workpiece. ○When the machine has high rigidity.

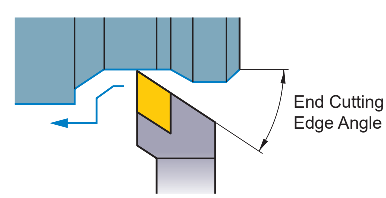


Receive force A.

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°.

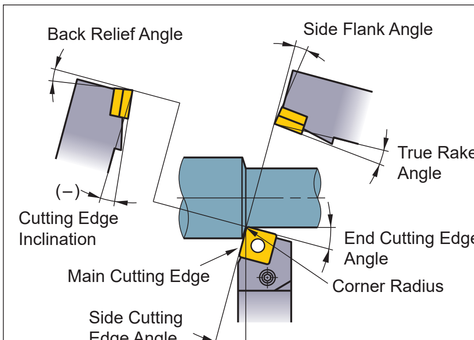


●Effects of End Cutting Edge Angle

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 in roughing and large angle in finishing are recommended.

■CUTTING EDGE INCLINATION

Cutting edge inclination indicates inclination of the rake face. In heavy cutting, the cutting edge receives extremely large shock at the beginning of cutting. 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.

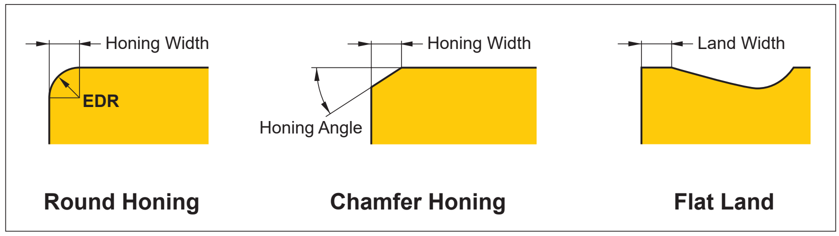


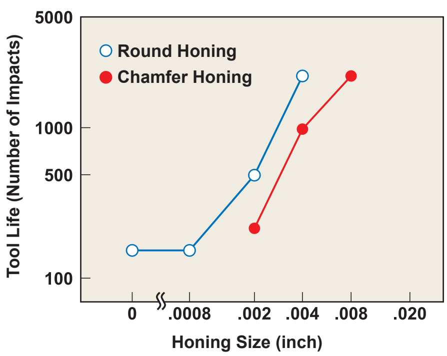
●Effects of Cutting Edge Inclination

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 back force of cutting resistance. Thus, chattering easily occurs.

■HONING AND LAND

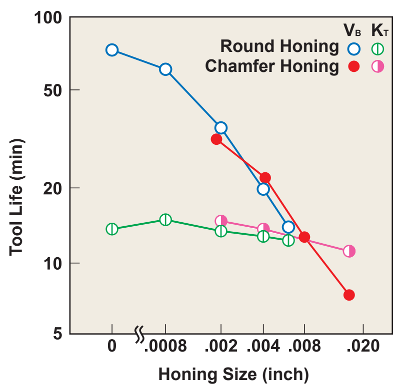
Honing and land are cutting edge shapes that maintain cutting edge strength.
Honing can be round or chamfer type. The optimal honing or / and land width is approximately 1/2 of the feed.
Land is the narrow flat area on the rake or flank face.





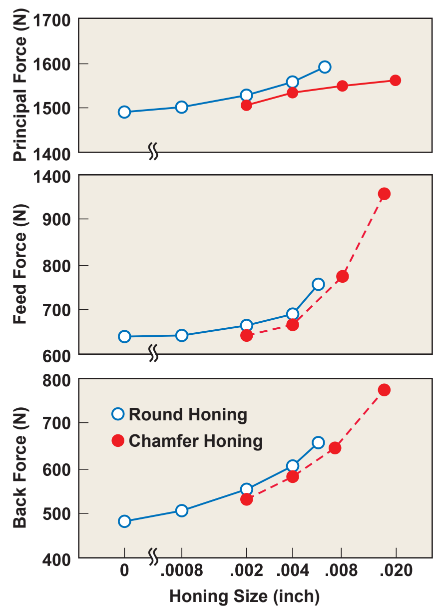
Workpiece : **Alloy steel (280HB)**
Grade : **P10**
Cutting Conditions : **vc=655 SFM ap=.059 inch f=.013 IPR**

Honing Size and Tool Life Due to Fracturing



Workpiece : **Alloy steel (220HB)**
Grade : **P10**
Cutting Conditions : **vc=525 SFM ap=.059 inch f=.018 IPR**

Honing Size and Tool Life Due to Wear



Workpiece : **Alloy steel (220HB)**
Grade : **P10**
Cutting Conditions : **vc=333 SFM ap=.059 inch f=.017 IPR**

Honing Size and Cutting Resistance

●Effects of Honing

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

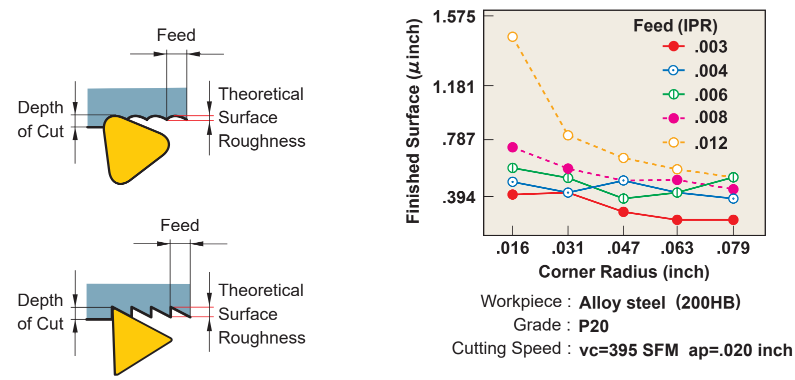
When to Decrease Honing Size	When to Increase Honing Size
◯ When finishing with small depth of cut and small feed. ◯ Soft workpiece. ◯ When the workpiece and the machine have poor rigidity.	◯ Hard workpiece. ◯ When the cutting edge strength is required such as for uncut surface cutting and interrupted cutting. ◯ When the machine has high rigidity.

*Cemented carbide, coated diamond, and indexable cermet inserts have round honing as standard.

FUNCTION OF TOOL FEATURES FOR TURNING

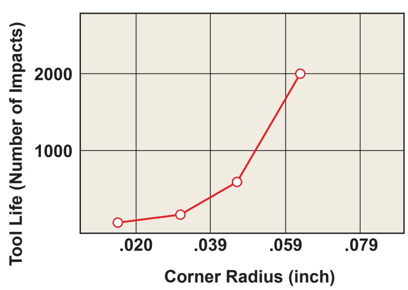
■CORNER RADIUS

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



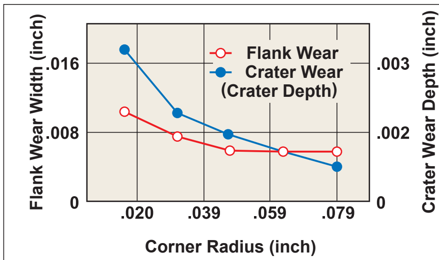
Workpiece : **Alloy steel (200HB)**
Grade : **P20**
Cutting Speed : **vc=395 SFM ap=.020 inch**

Corner Radius and Finished Surface



Workpiece : **Alloy steel (280HB)**
Grade : **P10**
Cutting Conditions : **vc=330 SFM ap=.079 inch f=.013 IPR**

Corner Radius Size and Tool Life Due to Fracturing



Workpiece : **Alloy steel (200HB)**
Grade : **P10**
Cutting Conditions : **vc=460 SFM ap=.079 inch f=.008 IPR Tc=10 min**

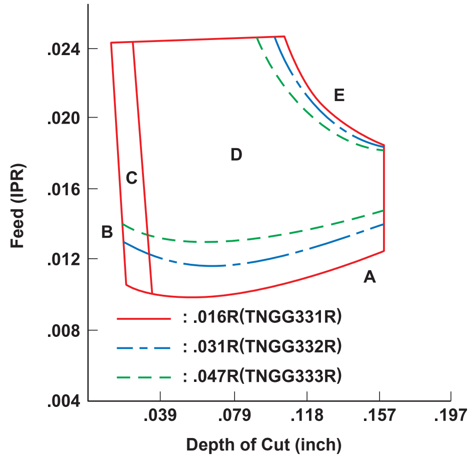
Corner Radius Size and Tool Wear

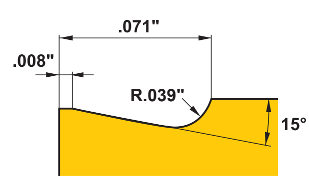
●Effects of Corner Radius

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 workpiece. ○When the machine has poor rigidity.	○When the cutting edge strength is required such as in interrupted 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 : **AISI 1045 (180HB)**
Insert : **TNGG331R**
TNGG332R
TNGG333R
(P10)
Holder : **ETJNR33K16**
(Side Cutting Edge angle 3°)
Cutting Speed : **vc=330 SFM**
Dry Cutting

Note 1) Please refer to page N008 for chip shapes (A, B, C, D, E).

FORMULAS FOR TURNING

CUTTING SPEED (vc)

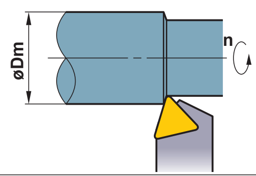
$vc = \dfrac{\pi \cdot Dm \cdot n}{12}$ (SFM)	vc (SFM) : Cutting Speed Dm (inch) : Workpiece Diameter π (3.14) : Pi n (min^{-1}) : Main Axis Spindle Speed

(Problem) What is the cutting speed when the main axis spindle speed is 700 min^{-1} and external diameter is ϕ2" ?

(Answer) Substitute π=3.14, Dm=2, n=700 into the formula.

$$vc = \frac{\pi \cdot Dm \cdot n}{12} = \frac{3.14 \times 2 \times 700}{12} = 365\ SFM$$

The answer is 365 SFM.



FEED (f)

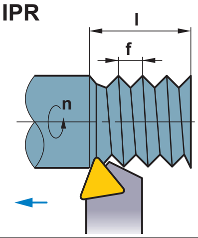
$f = \dfrac{I}{n}$ (IPR)	f (IPR) : Feed per Revolution I (IPM) : Cutting Length per Min. n (min^{-1}) : Main Axis Spindle Speed

(Problem) What is the feed per revolution when the main axis spindle speed is 500 min^{-1} and cutting length per minute is 4.72 IPM ?

(Answer) Substitute n=500, I=4.72 into the formula.

$$f = \frac{I}{n} = \frac{4.72}{500} = .009\ IPR$$

The answer is .009 IPR.



CUTTING TIME (Tc)

$Tc = \dfrac{Im}{I}$ (min)	Tc (min) : Cutting Time Im (inch) : Workpiece Length I (IPM) : Cutting Length per Min.

(Problem) What is the cutting time when 4 inch workpiece is machined at 1000 min^{-1} with feed= .008 IPR ?

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

$$I = f \times n = .008 \times 1000 = 8\ IPM$$

Substitute the answer above into the formula.

$$Tc = \frac{Im}{I} = \frac{4}{8} = 0.5\ min$$

0.5×60=30 (sec.)

The answer is 30 sec.

THEORETICAL FINISHED SURFACE ROUGHNESS (h)

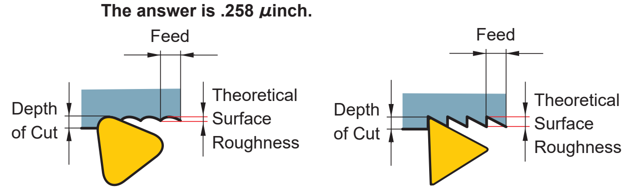
$h = \dfrac{f^2}{8RE} \times 1000$ (μinch)	h (μinch) : Finished Surface Roughness f (IPR) : Feed per Revolution RE (inch) : Insert Corner Radius

(Problem) What is the theoretical finished surface roughness when the insert corner radius is .031 inch and feed is .008 IPR ?

(Answer) Substitute f= .008 IPR, RE= .031 into the formula.

$$h = \frac{(.008)^2}{8 \times .031} \times 1000 = .258\ \mu inch$$

The answer is .258 μinch.

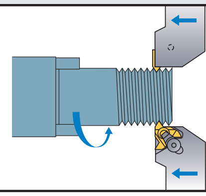
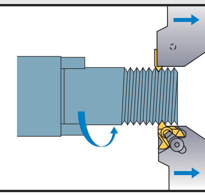
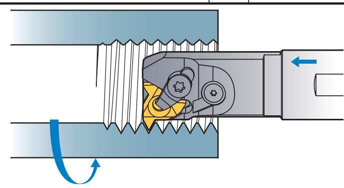
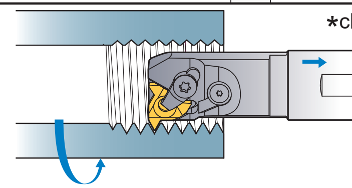


TROUBLE SHOOTING FOR THREADING

Problems	Observation	Causes	Solutions
Low thread precision.	Threads do not mesh with each other.	Incorrect tool installation.	Set the insert center height at 0".
			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 workpiece.	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 workpiece or tool clamping.	Re-check workpiece and tool clamping. (Chuck pressure, clamping allowance)
		Incorrect tool installation.	Set the insert center height at 0".
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 0" depth of cut. Depth of cut larger than .002" is recommended.
	Non-uniform wear of the right and left sides of the cutting edge.	The workpiece lead angle and the tool lead angle do not match.	Check the workpiece 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 workpiece deflection.
			Shorten tool overhang.
			Recheck workpiece 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 workpiece 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 supply is sufficient.
			Increase coolant pressure and volume.
		Cutting resistance too high.	Increase the number of passes and decrease the cutting resistance per pass.

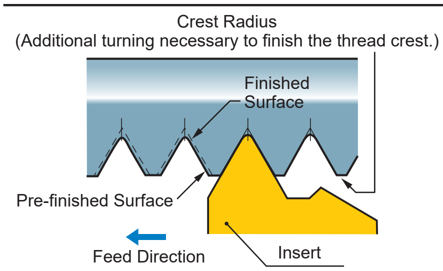
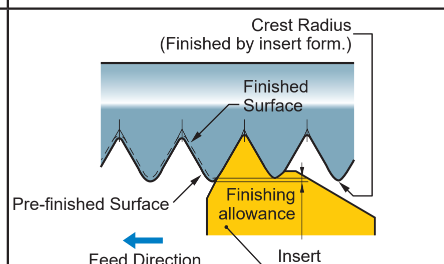
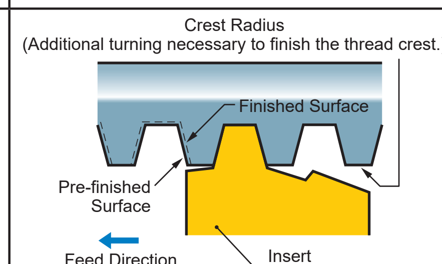
THREADING METHODS

THREADING METHODS

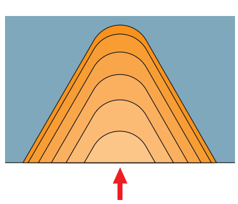
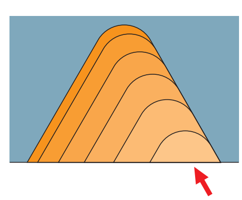
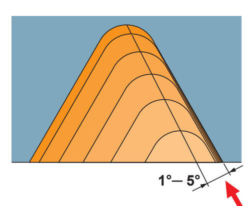
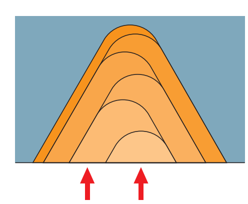
	Right Hand Thread	Left Hand Thread
EXTERNAL		 *change the shim
INTERNAL		 *change the shim

· Usually, threads are cut feeding the insert towards the chuck.
· When machining left hand threads, note that clamping rigidity is lowered due the application of back turning.
· When machining left hand threads, the lead angle is negative. Ensure an appropriate lead angle by changing the shim.

INSERT TYPES

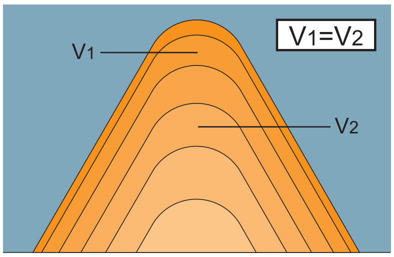
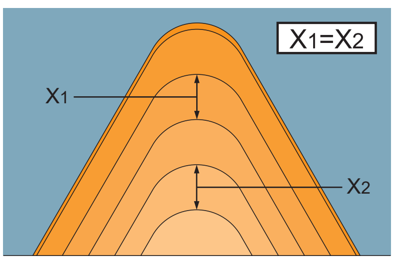
Partial Form	Full Form	Semi Full Form (Trapezoidal threads only)
● The same insert can be used for a range of pitches. ● Shorter tool life because the nose radius of the insert is smaller than that of a full form insert. ● Finishing with another operation may be necessary.	● No deburring needed after threading. ● Requires specific insert for each thread form and pitch.	● No de-burring needed after threading. ● Requires specific insert for each thread form and pitch. ● Finishing with another operation may be necessary.
		

INFEED METHODS

		 Radial Infeed	 Flank Infeed	 Modified Flank Infeed	 Incremental Infeed
Features	Advantages	● Easiest to use. (Standard program for threading) ● Wide application. (Cutting conditions easy to change.) ● Uniform wear of the right and left sides of the cutting edge.	● Relatively easy to use. (Semi-standard program for threading.) ● Reduced cutting force. ● Suitable for large pitch threads or materials that peel easily. ● Good chip discharge.	● Preventing flank wear on the right side of the cutting edge. ● Reduced cutting force. ● Good for large pitch or materials that peel easily. ● Good chip discharge.	● Uniform wear of the right and left sides of the cutting edge. ● Reduced cutting force. ● Good for large pitch or materials that peel easily.
	Disadvantages	● Difficult chip control. ● Subject to vibration in the later passes due to long cutting edge in contact with workpiece. ● Ineffective for large pitch threading. ● Heavy load on the nose radius.	● Large flank wear of the right side of a cutting edge. ● Relatively difficult to change cutting depth. (Re-programming necessary)	● Complex machining programming. ● Difficult to change cutting depth. (NC programming necessary)	● Complex machining programming. ● Difficult to change cutting depth. (Re-programming necessary) ● Chip control is difficult.

THREADING METHODS

THREADING DEPTH

	Features	
	Advantages	Disadvantages
 Fixed cut area	· Easy to use. (Standard program for threading.) · Superior resistance to vibration. (Constant cutting force.)	· Long chips generated during the final pass. · Complex calculation of cutting depth when changing the number of passes.
 Fixed cutting depth	· Reduced load on nose radius during the first half of the passes. · Easy chip control. (Optional setting of chip thickness) · Easy to calculate cutting depth when changing the number of passes. · Good chip control.	· Subject to vibration in the later stages of cutting. (Increased cutting force) · In some cases, changing the NC program is necessary.

* It is recommended to set the depth of cut of the final pass to .002-.001 inch
Large cutting depths can cause vibration, leading to a poor surface finish.

■ Formulas

●Formulas to calculate infeed for each pass in a reduced series.

$$\triangle ap_n = \frac{ap}{\sqrt{n_{ap}-1}} \times \sqrt{b}$$

$\triangle ap_n$: Depth of cut
n : Actual pass
ap : Total depth of cut
n_{ap} : Number of passes
b : 1st pass 0.3
2nd pass 2−1=1
3rd pass 3−1=2
·
·
nth pass

Example) External threading (ISO metric)
Pitch : 1.0 mm
ap : 0.6 mm
n_{ap} : 5

1st pass $\triangle ap_1 = \frac{0.60}{\sqrt{5-1}} \times \sqrt{0.3}$ = 0.16 → **0.16** ($\triangle ap_1$)

2nd pass $\triangle ap_2 = \frac{0.60}{\sqrt{5-1}} \times \sqrt{2-1}$ = 0.3 → **0.14** ($\triangle ap_2 - \triangle ap_1$)

3rd pass $\triangle ap_3 = \frac{0.60}{\sqrt{5-1}} \times \sqrt{3-1}$ = 0.42 → **0.12** ($\triangle ap_3 - \triangle ap_2$)

4th pass $\triangle ap_4 = \frac{0.60}{\sqrt{5-1}} \times \sqrt{4-1}$ = 0.52 → **0.1** ($\triangle ap_4 - \triangle ap_3$)

5th pass $\triangle ap_5 = \frac{0.60}{\sqrt{5-1}} \times \sqrt{5-1}$ = 0.6 → **0.08** ($\triangle ap_5 - \triangle ap_4$)

■ NC Program for Modified Flank Infeed

●Example:- M12×1.0 5 passes modified 1°-3° (mm)

External Threading	Internal Treading
G00 Z = 5.0	G00 Z = 5.0
X = 14.0	X = 10.0
G92 U−4.34 Z−13.0 F1.0	G92 U4.34 Z−13.0 F1.0
G00 W−0.07	G00 W−0.07
G92 U−4.64 Z−13.0 F1.0	G92 U4.64 Z−13.0 F1.0
G00 W−0.06	G00 W−0.05
G92 U−4.88 Z−13.0 F1.0	G92 U4.84 Z−13.0 F1.0
G00 W−0.05	G00 W−0.04
G92 U−5.08 Z−13.0 F1.0	G92 U5.02 Z−13.0 F1.0
G00 W−0.03	G00 W−0.03
G92 U−5.20 Z−13.0 F1.0	G92 U5.14 Z−13.0 F1.0
G00	G00

Selecting Cutting Conditions

		Priority					
		Tool life	Cutting force	Surface finish	Precision of thread	Chips discharge	Efficiency (Reduced passes)
Threading methods	Radial	○		○	○		○
	Flank	(△ : Modified)	○	(△ : Modified)		○	
Cutting depth	Fixed cutting depth					○	
	Fixed cut area	○	○	○	○		○

Note) · Tool life and surface finish accuracy can be increased by changing the threading method from flank infeed to modified flank infeed.
· Chip control can be improved by increasing the cutting depth in the later half of passes.

Cutting depth and the number of passes

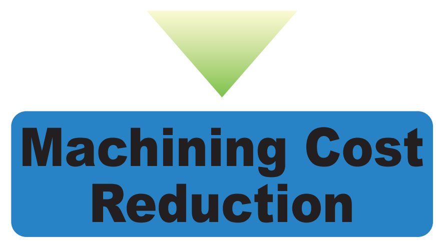
●Selection of the appropriate cutting depth and the right number of passes is vital for threading.

· For most threading, use a "threading cycle program," which has originally been installed on machines, and specify "total cutting depth" and "cutting depth in the first or final pass."

· Cutting depth and the number of passes are easy to change for the radial infeed method, thus making it easy to determine the appropriate cutting conditions.

Feature and benefits of Mitsubishi products

· Insert grades, specially produced for threading tools, ensure highly efficient cutting by enabling high-speed machining and a reduced number of passes.



Advice on improved threading

●Increasing tool life

· To prevent damage to the nose radius - Recommended method - Modified flank infeed.

· To have uniform flank wear on both sides of a cutting edge - Recommended method - Radial infeed

· To prevent crater wear - Recommended method - Flank infeed

●Preventing chip problems

· Change to flank or modified infeed.

· During radial infeed cutting, use an inverted holder and change the coolant supply to a downward direction.

· When using the radial infeed method, set the minimum cutting depth at around .008 inch to make the chips thicker.

· Tangled chips during internal threading can damage the insert. In these cases, pause slightly away from the start point and clear the chips with coolant before every pass.

· Change to M-class inserts with a 3-D chip breaker.

●To achieve highly efficient machining

· Increase cutting speed. (Dependant on the maximum revolution and rigidity of the machine.)

· Reduce the number of passes. (Reduce by 30-40%.)

· A reduced number of passes can improve chip discharge because of the thicker chips generated.

●Preventing vibration

· Change to flank or modified infeed.

· When using radial infeed, reduce cutting depth in the later half of passes and lower the cutting speed.

●Increased surface finish accuracy

· A final pass should be performed at the same depth of cut as the last regular pass.

· When using the flank infeed method, change to radial infeed only during the final pass.

TROUBLE SHOOTING FOR FACE MILLING

Trouble		Factors	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 Rate	Cutting Conditions: Depth of Cut	Cutting Conditions: Engage Angle	Cutting Conditions: Cutting Fluids: Do Not Use Water-soluble Cutting Fluid	Cutting Conditions: Cutting Fluids: Determine Dry or Wet Cutting	Style and Design of the Tool: Rake Angle	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: Decrease the 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: Run-out Accuracy	Style and Design of the Tool: Improve Cutter Rigidity	Machine and Installation of Tool: Installation of the Tool and Workpiece	Machine and Installation of Tool: Shorten Tool Overhang	Machine and Installation of Tool: Machine with Inadequate Horsepower and Rigidity
Short Tool Life	Rapid insert wear	Improper tool grade	●																					
		Improper cutting edge geometry											↗●	↗●	●↘					●				
		Improper cutting conditions					●↘					● Wet												
	Chipping and fracturing of cutting edge	Improper tool grade		●																				
		Improper cutting conditions						●↘	●↘															
		Lack of cutting edge strength													↗●									
		Thermal cracking occurs			●		●↘	●↘	●↘		●	● Dry												
		Built-up edge occurs				●	↗●	↗●			●	● Wet												
		Lack of rigidity																			●	●	●	●
Poor Surface Finish	Worsening surface roughness	Improper cutting conditions	●				●↘	●↘	●↘															
		Welding occurs				●	↗●				●	● Wet	↗●		●↘									
		Poor run-out accuracy																	●	●				
		Vibration occurs					●↘	●↘	●↘	↗●			↗●		●↘		●				●	●	●	●
	Not parallel or irregular surface	Workpiece bending						●↘	●↘				↗●	●↘	●↘		●					●		
		Tool clearance																			●	●	●	●
		Large back force											↗●	●↘	●↘		●							
Burr / Chipping	Burr	Chip thickness is too large					↗●	●↘	●↘															
		Cutter diameter is too large								↗●						●↘								
		Poor sharpness											↗●		●↘									
		A large corner angle												●↘										
	Chipping	Improper cutting conditions						●↘	●↘															
		Poor sharpness											↗●		●↘									
		Corner angle is too small												↗●										
		Vibration occurs					●↘	●↘	●↘	↗●			↗●		●↘		●				●	●	●	●
Chip Control	Poor chip disposal, chip jamming and chip packing	Welding occurs					↗●																	
		Chip thickness is too thin					↗●	↗●																
		Cutter diameter is too small														●↘								
		Poor chip disposal									●	● Wet					●	●						

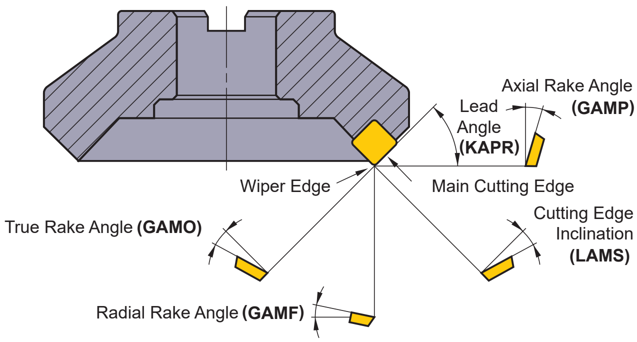
Cutting Conditions: Up ↗ / Down ↘ — Style and Design of the Tool: Up ↗ / Down ↘

TECHNICAL DATA

N

FUNCTION OF TOOL FEATURES FOR FACE MILLING

■FUNCTION OF EACH CUTTING EDGE ANGLE IN FACE MILLING

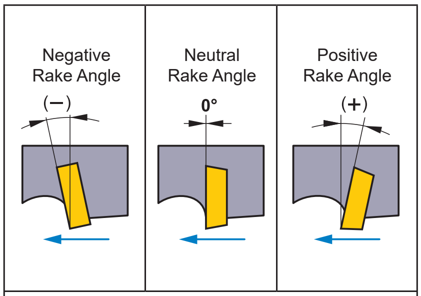


Each Cutting Edge Angle in Face Milling

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.

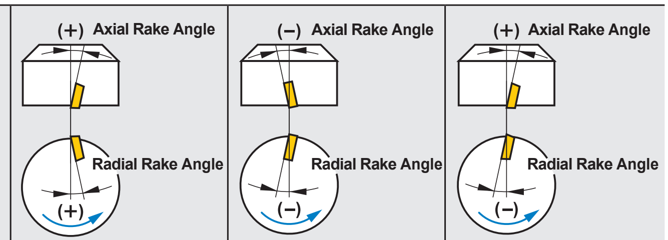
■STANDARD INSERTS

●Positive and Negative Rake Angle



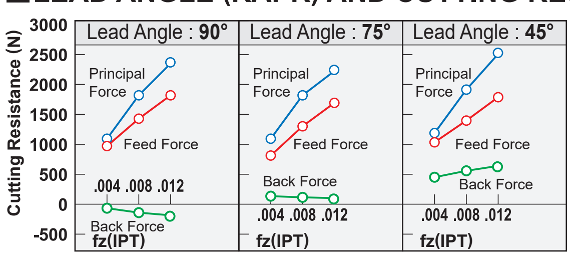
- Insert shape whose cutting edge precedes is a positive rake angle.
- Insert shape whose cutting edge follows is a negative rake angle.

●Standard Cutting Edge Shape



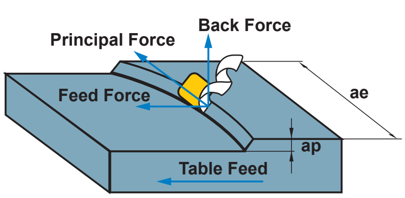
Standard Cutting Edge Combinations		Double Positive (DP Edge Type)	Double Negative (DN Edge Type)	Negative/Positive (NP Edge Type)
Axial Rake Angle (GAMP)		Positive (+)	Negative (−)	Positive (+)
Radial Rake Angel (GAMF)		Positive (+)	Negative (−)	Negative (−)
Insert Used		Positive Insert (One Sided Use)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

■LEAD ANGLE (KAPR) AND CUTTING RESISTANCE



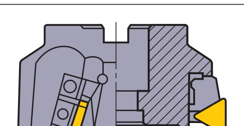
Workpiece : **Alloy Steel (281HB)**
Tool : **ø4" Single Insert**
Cutting Conditions : **vc=410 SFM ap=.157 inch ae=4.33 inch**

Cutting Resistance Comparison between Different Lead Angles



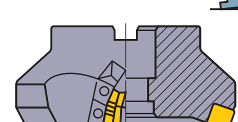
Three Cutting Resistance Forces in Milling

Lead Angle 90° Back force is in the minus direction. Lifts the workpiece when workpiece clamp rigidity is low.



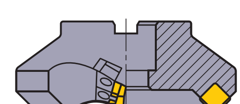
Lead Angle 90°

Lead Angle 75° Lead Angle 75° is recommended for face milling of workpiece with low rigidity such as thin workpiece.



Lead Angle 75°

Lead Angle 45° The largest back force. Bends thin workpiece and lowers cutting accuracy.
* Prevents workpiece edge chipping in cast iron cutting.



Lead Angle 45°

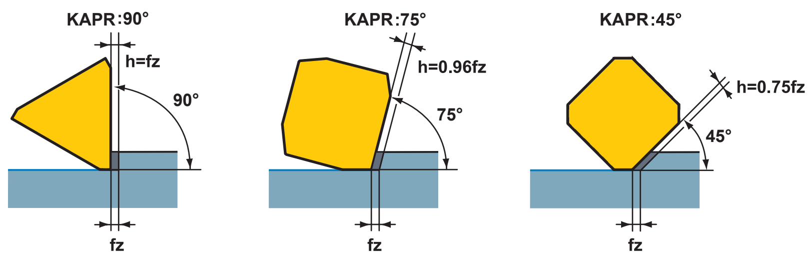
* Principal force: Force is in the opposite direction of face milling rotation.
* Back force: Force that pushes in the axial direction.
* Feed Force: Force is in the feed direction and is caused by table feed.

FUNCTION OF TOOL FEATURES FOR FACE MILLING

■LEAD ANGLE AND TOOL LIFE

●Lead Angle and Chip Thickness

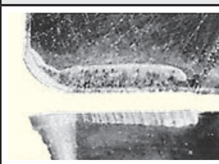
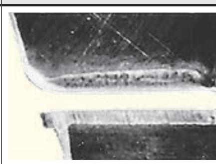
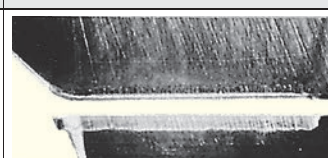
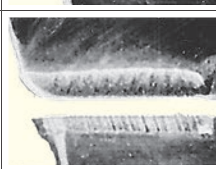
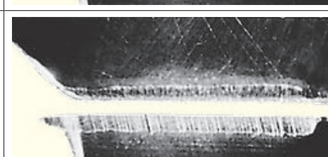
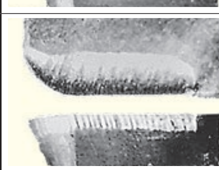
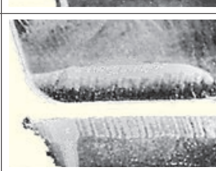
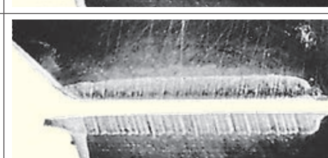
When the depth of cut and feed per tooth, fz, are fixed, the larger lead angle (KAPR) is, then the thinner chip thickness (h) becomes (for a 45° KAPR, it is approx. 75% that of a 0° KAPR). This can be seen in below. Therefore as the KAPR increases, the cutting resistance decreases resulting in longer 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

●Corner Angle and Crater Wear

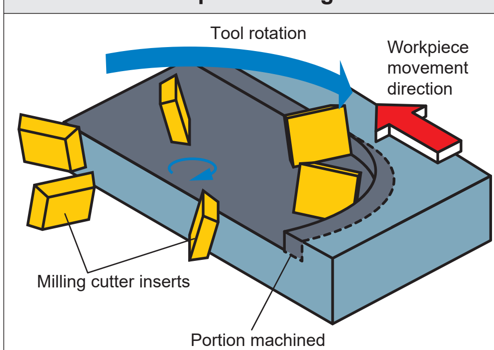
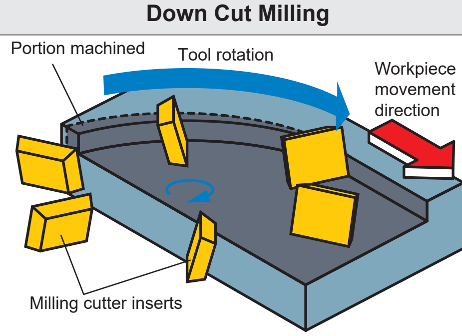
Below shows wear patterns for different lead angles. When comparing crater wear for 90° and 45° lead angles, it can be clearly seen that the crater wear for 90° lead angle is larger. This is because if the chip thickness is relatively large, the cutting resistance increases and so promotes crater wear. As the crater wear develops then cutting edge strength will reduce and lead to fracturing.

	90° Lead Angle	**75°** Lead Angle	**45°** Lead Angle
vc=330 SFM Tc=69 min			
vc=410 SFM Tc=55 min			
vc=525 SFM Tc=31 min			

Workpiece : **AISI 4340 (287HB)**
Tool : **DC=4.92 inch**
Insert : **M20**
Cutting Conditions : **ap=.118 inch**
ae=4.33 inch
fz=.008 IPT
Cutting Mode : Dry Cutting

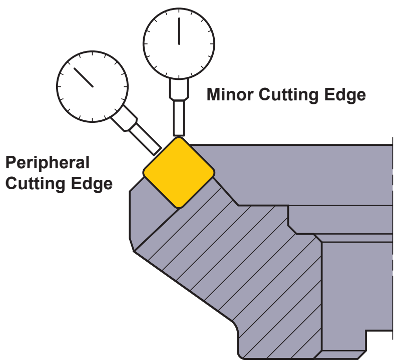
■UP CUT AND DOWN CUT MILLING

Which method to be used will depend on the machine and the face mill cutter that has been selected. Generally down cut machining offers longer tool life than up cut milling.

Up Cut Milling	Down Cut Milling
	

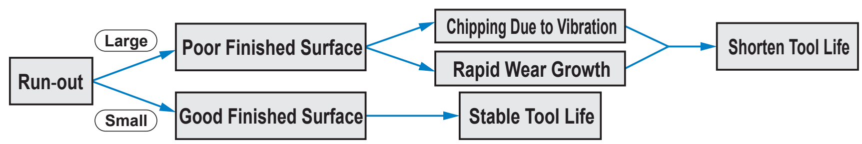
FINISHED SURFACE

Cutting Edge Run-out Accuracy

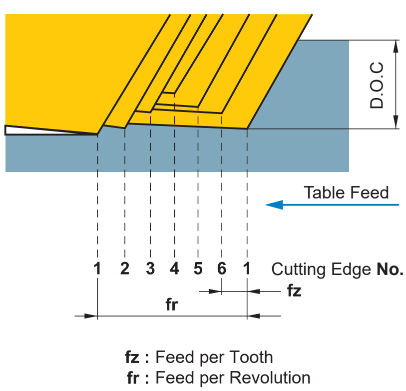


Cutting Edge Run-out and Accuracy in Face Milling

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

Usually the minor cutting edges are set parallel to the face of a milling cutter and theoretically the finished surface accuracy should be maintained, even if run-out accuracy is poor.

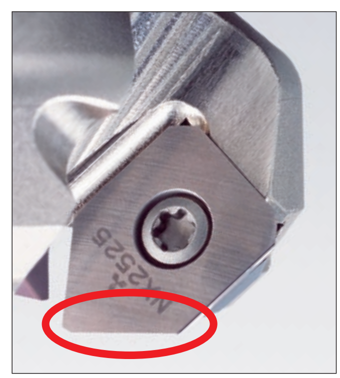
Actual Problems

- Cutting edge run-out.
- Minor cutting edge inclination.
- Cutter body accuracy.
- Spare parts accuracy.
- Welding, vibration, chattering.

Countermeasure

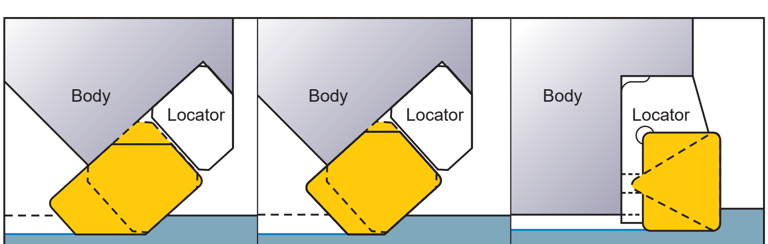
Wiper Insert

* Machine a surface that has already been machined by normal insert in order to produce smooth finished surface.



- Replace one normal insert with wiper insert.
- Wiper inserts are set to protrude by .0012 — .004 inch from the standard inserts.
  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.

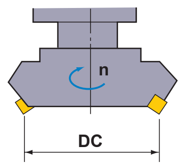
- Wiper edge length has to be longer than the feed per revolution.
* Too long wiper edge causes chattering.
- When the cutter diameter is large and feed per revolution is longer than the wiper edge, use two or three wiper inserts.
- When using two wiper inserts or more, eliminate run-out of wiper inserts.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

FORMULAS FOR FACE MILLING

CUTTING SPEED (vc)

$$vc = \frac{\pi \cdot DC \cdot n}{12} \text{ (SFM)}$$

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



(Problem) What is the cutting speed when main axis spindle speed is 350 min^{-1} and cutter diameter is ϕ5" ?

(Answer) Substitute π 3.14, DC=5", n=350 into the formula.

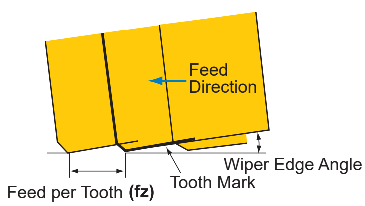
$$vc = \frac{\pi \cdot DC \cdot n}{12} = \frac{3.14 \times 5'' \times 350}{12} = 457.9 \text{ SFM}$$

The answer is 457.9 SFM.

FEED PER TOOTH (fz)

$$fz = \frac{vf}{z \cdot n} \text{ (IPT)}$$

fz (IPT) : Feed per Tooth
vf (IPM) : Table Feed per Min.
n (min^{-1}) : Main Axis Spindle Speed (Feed per Revolution fr=z×fz)
z : Insert Number



(Problem) What is the feed per tooth when the main axis spindle speed is 500 min^{-1}, insert number is 10, and table feed is 20 IPM ?

(Answer) Substitute the above figures into the formula.

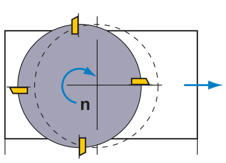
$$fz = \frac{Vf}{z \times n} = \frac{20}{10 \times 500} = .004 \text{ IPT}$$

The answer is .004 IPT.

TABLE FEED (vf)

$$vf = fz \cdot z \cdot n \text{ (IPM)}$$

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



(Problem) What is the table feed when feed per tooth is .004 IPT, with 10 inserts and main axis spindle speed is 500 min^{-1}?

(Answer) Substitute the above figures into the formula.

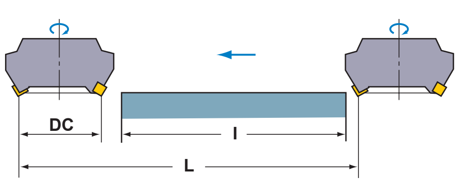
vf = fz×z×n = .004 IPT×10×500 = 20 IPM

The answer is 20 IPM.

CUTTING TIME (Tc)

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

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



(Problem) What is the cutting time required for finishing 4" width and 12" length surface of a cast iron (AISI No 30 B) block when cutter diameter is ϕ8", the number of inserts is 16, the cutting speed is 410 SFM, and feed per tooth is .01". (spindle speed is 200 min^{-1})

(Answer) Calculate table feed per min vf=.01×16×200=32 IPM
Calculate total table feed length. L=12+8=20 inch
Substitute the above answers into the formula.

$$Tc = \frac{20}{32} = 0.625 \text{ (min)}$$

0.625 × 60 = 37.5 (sec.)

The answer is 37.5 sec.

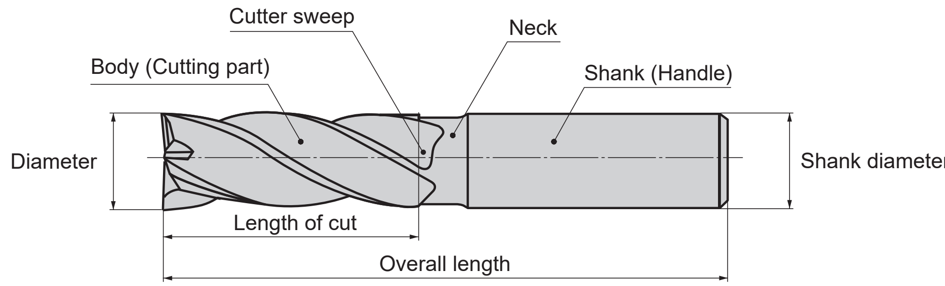
TROUBLE SHOOTING FOR END MILLING

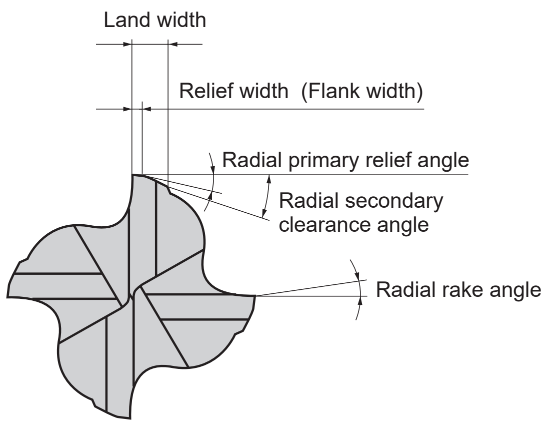
Solutions / Factors / Trouble — Up ↗ Down ↘

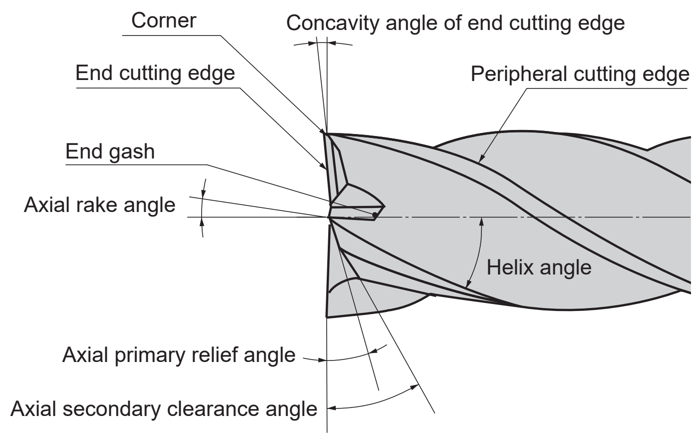
Trouble		Factors	Insert Grade Selection	Cutting Conditions									Style and Design of the Tool						Machine and Installation of Tool					
			Coated Tool	Cutting Speed	Feed Rate	Depth of Cut	Decrease Pick Feed Rate	Down Cut	Air Blow	Cutting Fluids: Increase Coolant Quantity	Cutting Fluids: Do Not Use Water-soluble Cutting Fluid	Cutting Fluids: Determine Dry or Wet Cutting	Helix Angle	Number of Flutes	Concavity Angle of End Cutting Edge	Tool Diameter	Improve End Mill Rigidity	Wider Chip Pocket	Shorten Tool Overhang	Tool Installation Accuracy	Spindle Collet Run-out Accuracy	Collet Inspection and Exchange	Increase Chuck Clamping Power	Machine Stability, Rigidity
Short Tool Life	Large wear at the peripheral cutting edge	Non-coated insert is used	●																					
		Not enough flutes												●↗										
		Improper cutting conditions		●↘							●													
		Up cut milling						Down Cut																
	Chipping	Improper cutting conditions																						
		Fragile cutting edge															●							
		Insufficient clamping force																				●	●	
		Poor clamping rigidity																	●	●	●	●	●	●
	Breakage during cutting	Improper cutting conditions				●↘																		
		Poor end mill rigidity														●↗	●							
		Overhang longer than necessary				●↘													●					
		Chip packing								●								●						
Poor Surface Finish	Vibration during cutting	Improper cutting conditions		●↘	●↘																			
		Poor end mill rigidity											●↗	●↗		●↗	●							
		Poor clamping rigidity																	●	●	●	●	●	●
	Poor wall surface roughness	Large cutting edge wear	●																					
		Improper cutting conditions		●↘		●↘																		
		Chip jamming							●	●		● Wet												
	Poor bottom surface roughness	The end cutting edge does not have a concave angle			●↘	●↘									●↗									
		Large pick feed					●																	
	Out of vertical	Large cutting edge wear	●																					
		Improper cutting conditions			●↘	●↘																		
		Poor end mill rigidity											●↗	●↗		●↗	●							
	Poor surface finish accuracy	Improper cutting conditions		●↘	●↘	●↘																		
		Poor clamping rigidity																	●	●	●	●	●	●
Burr / Chipping / Burrs	Burr, workpiece chipping	Improper cutting conditions			●↘	●↘																		
		Large helix angle											●↘											
	Quick burr formation	Notch wear occurs	●																					
		Improper cutting conditions		●↘	●↗																			
Chip Control	Chip packing	Metal removal too large			●↘	●↘																		
		Lack of flute chip space												●↘				●						

END MILL FEATURES AND SPECIFICATION

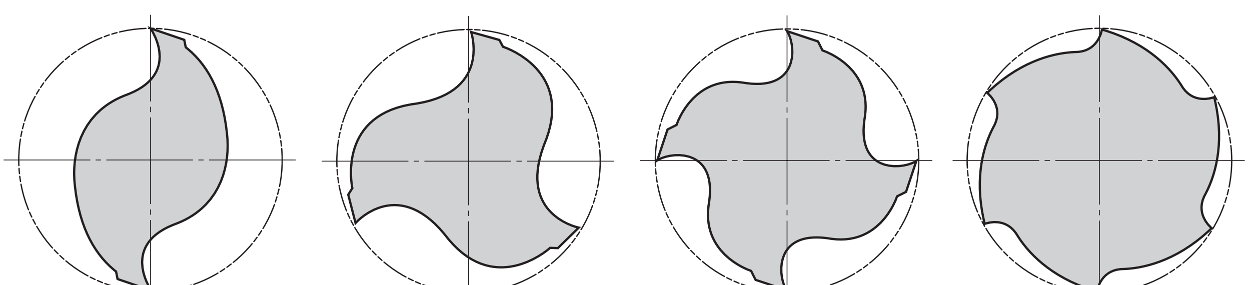
NOMENCLATURE







COMPARISON OF SECTIONAL AREA OF CHIP POCKET



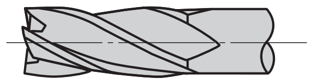
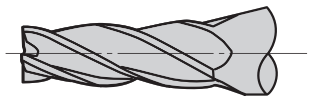
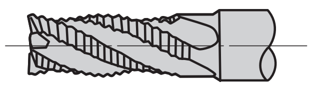
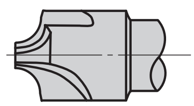
2-flutes	3-flutes	4-flutes	6-flutes
50%	45%	40%	20%

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

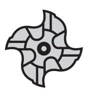
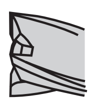
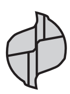
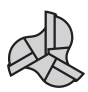
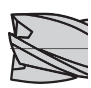
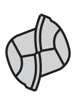
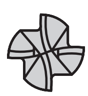
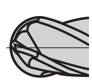
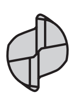
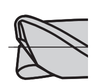
		2-flutes	3-flutes	4-flutes	6-flutes
Feature	Advantage	Effective chip disposal. Horizontal feed milling possible.	Effective chip disposal. Horizontal feed milling possible.	High rigidity.	High rigidity. Superior cutting edge durability.
	Fault	Low rigidity.	Diameter is not measured easily.	Chip disposal is poor.	Chip disposal is poor.
Usage		Various cutting modes including slotting, shoulder milling and drilling.	Slotting, shoulder milling Heavy cutting, finishing	Shallow slotting, shoulder milling Finishing	Machining hardened steels. Shallow slotting, shoulder milling.

END MILL TYPE AND GEOMETRY

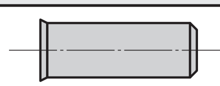
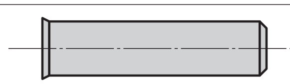
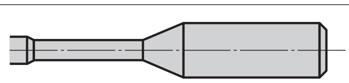
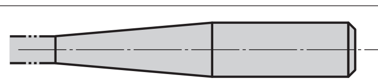
PERIPHERAL CUTTING EDGE

Type	Shape	Feature
Ordinary Flute		Regular flute geometry as shown is most commonly used for roughing and finishing of side milling, slotting and shoulder milling.
Tapered Flute		A tapered flute geometry is used for special applications such as mold drafts and for applying taper angles after conventional straight edged milling.
Roughing Flute		Roughing type geometry has a wave like edge form and breaks the material into small chips. Additionally the cutting resistance is low enabling high feed rates when roughing. The inside face of the flute is suitable for regrinding.
Formed Flute		Special form geometry as shown is used for producing corner radii on components. There are an infinite number of different geometry's that can be manufactured using such style of cutters.

END CUTTING EDGE

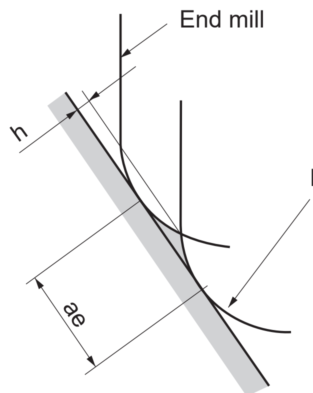
Type	Shape	Feature
Square End (With Center Hole)	 	Generally used for side milling, slotting and shoulder milling. Plunge cutting is not possible due to the center hole that is used to ensure accurate grinding and regrinding of the tool.
Square End (Center Cut)	   	Generally used for side milling, slotting and shoulder milling. Plunge cutting is possible and greater plunge cutting efficiency is obtained when using fewer flutes. Regrinding on the flank face can be done.
Ball End	  	Geometry completely suited for curved surface milling. At the extreme end point the chip pocket is very small leading to inefficient chip evacuation.
Corner Radius End	 	Used for radius profiling and corner radius milling. When pick feed milling an end mill with a large diameter and small corner radius can be efficiently used.

SHANK AND NECK PARTS

Type	Shape	Feature
Standard (Straight Shank)		Most widely used type.
Long Shank		Long shank type for deep pocket and shoulder applications.
Long Neck		Long neck geometry can be used for deep slotting and is also suitable for boring.
Taper Neck		Long taper neck features are best utilized on deep slotting and mold draft applications.

PITCH SELECTION OF PICK FEED

■PICK FEED MILLING (CONTOURING) WITH BALL NOSE END MILLS, 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 : inch

R \ ae	Pick Feed									
	.004	.008	.012	.016	.020	.024	.028	.031	.035	.039
0.5	.0001	.0004	.0009	.0017	.0026	.0039	—	—	—	—
1	.00004	.0002	.0004	.0008	.0016	.0018	.0025	.0033	.0042	—
1.5	.00004	.0001	.0003	.0005	.0008	.0012	.0016	.0021	.0027	.0034
2	.00004	.0001	.0002	.0004	.0006	.0009	.0012	.0016	.0020	.0025
2.5	.00004	.00007	.0002	.0003	.0005	.0007	.0010	.0013	.0016	.0020
3		.00007	.0002	.0003	.0004	.0006	.0008	.0011	.0013	.0017
4		.00004	.0001	.0002	.0003	.0004	.0006	.0008	.0010	.0012
5		.00004	.00007	.0002	.0002	.0004	.0005	.0006	.0008	.0010
6		.00004	.00007	.0001	.0002	.0003	.0004	.0005	.0007	.0008
8			.00004	.0001	.0002	.0002	.0003	.0004	.0005	.0006
10			.00004	.00007	.0001	.0002	.0002	.0003	.0004	.0005
12.5			.00004	.00007	.0001	.0002	.0002	.0002	.0003	.0004

R \ ae	Pick Feed									
	.043	.047	.051	.055	.059	.063	.067	.071	.075	.079
0.5	—	—	—	—	—	—	—	—	—	—
1	—	—	—	—	—	—	—	—	—	—
1.5	.0041	—	—	—	—	—	—	—	—	—
2	.0030	.0036	.0043	—	—	—	—	—	—	—
2.5	.0024	.0029	.0034	.0039	—	—	—	—	—	—
3	.0020	.0024	.0028	.0033	.0037	.0043	—	—	—	—
4	.0015	.0018	.0021	.0024	.0028	.0032	.0036	.0041	—	—
5	.0012	.0014	.0017	.0019	.0022	.0025	.0029	.0032	.0036	.0040
6	.0010	.0012	.0014	.0016	.0019	.0021	.0024	.0027	.0030	.0033
8	.0007	.0009	.0010	.0012	.0014	.0016	.0018	.0020	.0022	.0025
10	.0006	.0007	.0008	.0010	.0011	.0013	.0014	.0016	.0018	.0020
12.5	.0005	.0006	.0007	.0008	.0009	.0010	.0011	.0013	.0014	.0016

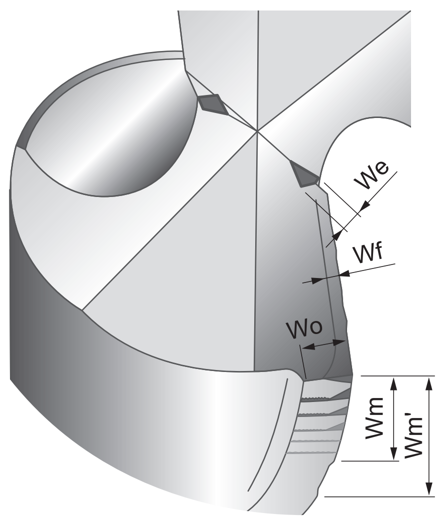
TROUBLE SHOOTING FOR DRILLING

Trouble		Factors \ Solutions	Cutting Conditions									Style and Design of the Tool							Machine and Installation of Tool				
									Cutting Fluids														
			Cutting Speed	Feed Rate	Lower the Feed at Initial Entry	Lower the Feed when Exiting	Step Feed	Increase the Accuracy and the Depth of the Pre-hole	Increase Oil Ratio	Increase Volume	Increase Coolant Pressure	Chisel Width	Honing Width	Core Thickness	Shorten the Flute Length	Decrease the Lip Height	Use a Drill with Coolant Holes	Change to a Drill with X Type Thinning	Tool Installation Accuracy	Shorten Tool Overhang	Flatten the Workpiece Face	Workpiece Installation Accuracy	Machine Stability, Rigidity
			Up ↗ / Down ↘	Up ↗ / Down ↘								Large ↗ / Small ↘	Large ↗ / Small ↘	Large ↗ / Small ↘									
Short 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	Improper cutting conditions	● ↘																				
		Increase in temp. at 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 large										● ↘											
		Poor entry			●																		
		Chattering, vibration											● ↘							●		●	●
Poor Hole Accuracy	Hole diameter increases	Lack of drill rigidity												● ↗	●								
		Improper drill geometry														●							
	Hole diameter becomes smaller	Increase in temp. at 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																	●				●
Burr	Burrs at the hole exit	Improper drill geometry											● ↘										
		Improper cutting conditions				●																	
Chip Control	Long chips	Improper cutting conditions		● ↗				●															
		Poor chip disposal								●	●			● ↘			●						
	Chip packing	Improper cutting conditions	● ↘	● ↘				●															
		Poor chip disposal								●	●			● ↘			●						

DRILL WEAR CONDITION AND CUTTING EDGE DAMAGE

■DRILL WEAR CONDITION

The diagram 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 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 width (The middle of the cutting edge)

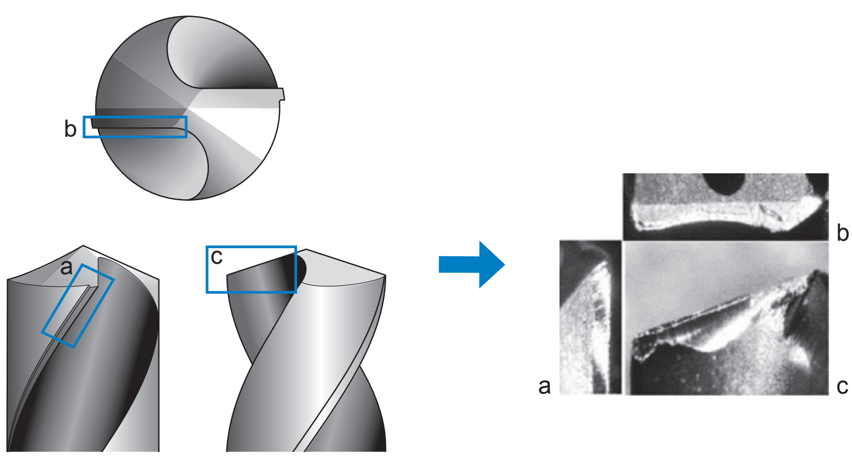
Wo : Outer corner wear width

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.

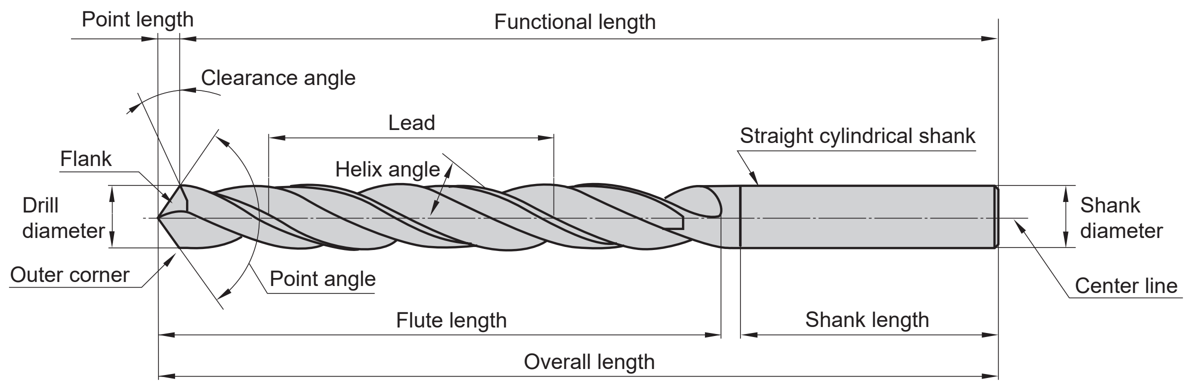


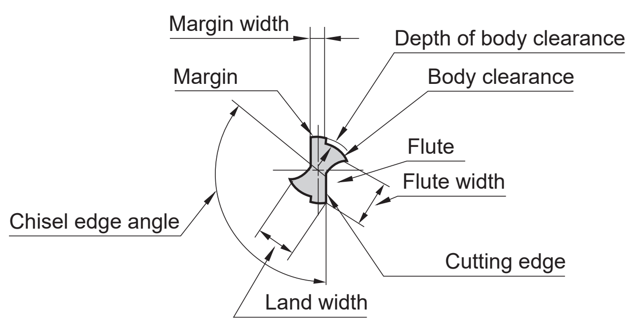
TECHNICAL DATA

N

DRILL TERMINOLOGY AND CUTTING CHARACTERISTICS

NAMES OF EACH PART OF A DRILL





SHAPE SPECIFICATION AND CUTTING CHARACTERISTICS

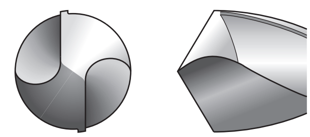
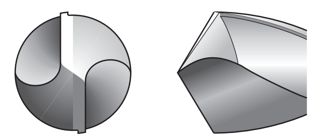
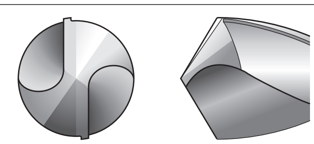
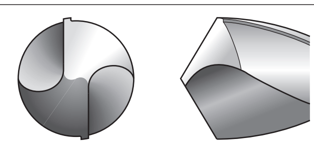
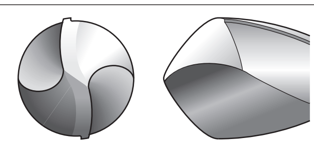
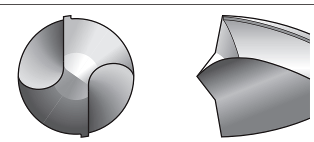
Helix Angle	Is the inclination of the flute with respect to the axial direction of a drill, which corresponds to the rake angle. The rake angle of a drill differs according to the position along the cutting edge. The rake angle is largest at the periphery and smallest towards the center of the cutting edge. The chisel edge has a negative rake angle, crushing the work. **High-hardness material Small ◀·· Rake Angle ··▶ Large Soft material** (Aluminum, etc.)
Flute Length	It is determined by depth of hole, guide 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° for high speed steel drills and 130ー140° for carbide drills. **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 disposal performance of a drill. The web thickness is set according to applications. Low cutting resistance, Low rigidity, Good chip disposal performance, Machinable material } **Thin ◀·· Web thickness ··▶ Thick** { Large cutting resistance, High rigidity, Poor chip disposal, High-hardness material, cross hole drilling, etc.
Margin	The margin determines the drill diameter and functions as a drill guide during drilling. The margin width is decided taking into consideration the friction within the hole to be 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 point 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. .0016"ー.016"/4".

DRILL TERMINOLOGY AND CUTTING CHARACTERISTICS

CUTTING EDGE GEOMETRY AND ITS INFLUENCE

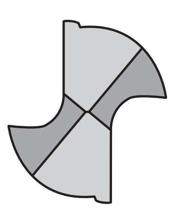
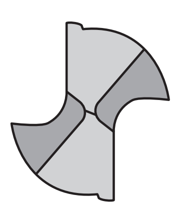
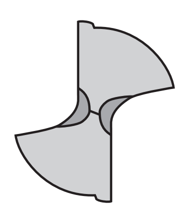
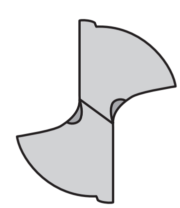
As shown in table below, it is possible to select the most suitable cutting edge geometry for different applications. If the most suitable cutting edge geometry is selected then higher machining efficiency and higher hole accuracy can be obtained.

Typical Cutting Edge Geometries

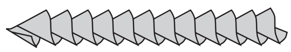
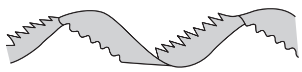
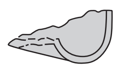
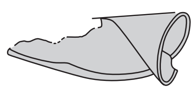
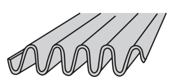
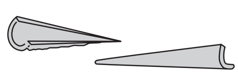
Grinding Name	Geometry	Features and Effect	Use
Conical		• The flank is conical and the clearance angle increases toward the center of the drill.	• For general use.
Flat		• The flank is flat and facilitates cutting.	• Mainly for small diameter drills.
Three Rake Angles		• As there is no chisel edge, the results are high centripetal force and small hole oversize. • Requires a special grinding machine. • Requires grinding of three sides.	• For drilling operations that require high hole accuracy and positioning accuracy.
Spiral Point		• To increase the clearance angle near the center 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.	• For cast iron and light alloy. • For cast iron plates. • Steel
Center 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 center, and it changes into a negative angle at the chisel edge. During drilling, the center 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.

Geometry	 **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 tough and the applicable range of workpieces is wide.	Popular design, easy cutting type.	Effective when the web is comparatively thick.
Major Applications	General drilling and deep hole drilling.	General drilling and stainless steel drilling.	General drilling for steel, cast iron, and non-ferrous metal.	Deep hole drilling.

DRILLING CHIPS

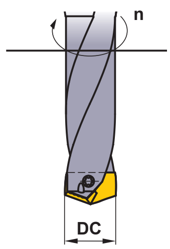
Types of Chips	Geometry	Features and Ease of Raking
Conical Spiral		Fan-shaped chips cut by the cutting edge are curved by the flute. Chips of this type are produced when the feeding rate of ductile material is small. If the chip breaks after several turns, the chip raking performance is satisfactory.
Long Pitch		Long pitch chips exit without coiling and will 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 in 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 become closely packed jams.

FORMULAS FOR DRILLING

CUTTING SPEED (vc)

$$vc = \frac{\pi \cdot DC \cdot n}{12} \text{ (SFM)}$$

vc (SFM)	: Cutting Speed	**DC(inch)**	: Drill Diameter
π (3.14)	: Circular Constant	**n (min^{-1})**	: Rotational Speed of the Main Spindle



(Problem) What is the cutting speed when main axis spindle speed is 1350 min^{-1} and drill diameter is .500 inch ?

(Answer) Substitute π=3.14, DC=.500 inch, n=1350 into the formula

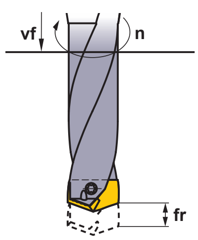
$$vc = \frac{\pi \cdot DC \cdot n}{12} = \frac{3.14 \times .500 \times 1350}{12} = 176.6 \text{ SFM}$$

The answer is 176.6 SFM

FEED OF THE MAIN SPINDLE (vf)

$$vf = fr \cdot n \text{ (IPM)}$$

vf (IPM)	: Feed Speed of the Main Spindle (Z axis)
fr (IPR)	: Feed per Revolution
n (min^{-1})	: Rotational Speed of the Main Spindle



(Problem) What is the spindle feed (vf) when feed per revolution is .008 IPR and main axis spindle speed is 1350 min^{-1}?

(Answer) Substitute fr=.008, n=1350 into the formula

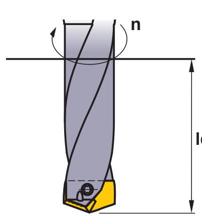
vf = fr×n = .008×1350 = 10.8 IPM

The answer is 10.8 IPM.

DRILLING TIME (Tc)

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

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



(Problem) What is the drilling time required for drilling a 1.2 inch length hole in alloy steel at a cutting speed of 165 SFM and feed .006 IPR ?

(Answer) Spindle Speed $n = \frac{165 \times 12}{.59 \times 3.14} = 1068.8 \text{ min}^{-1}$

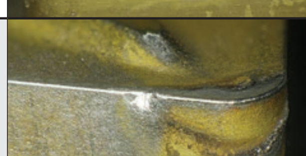
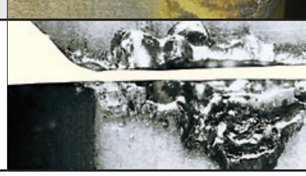
$$Tc = \frac{1.2 \times 1}{1068.8 \times .006} = .187$$

$$= .187 \times 60 \fallingdotseq 11.2 \text{ sec}$$

The answer is 11.2 sec.

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.
Welding		· Cutting speed is low. · Poor sharpness. · Unsuitable grade.	· Increase cutting speed. (For ANSI 1045, cutting speed 260 SFM.) · Increase rake angle. · Tool grade with low affinity. (Coated grade, cermet grade)
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 surface, chilled parts and machining hardened layer. · Friction caused by jagged shaped chips. (Caused by small vibration)	· Tool grade with high wear resistance. · Increase rake angle to improve sharpness.
Flaking		· Cutting edge welding and adhesion. · Poor chip disposal.	· Increase rake angle to improve sharpness. · Enlarge chip pocket.

MATERIAL CROSS REFERENCE LIST

CARBON STEEL

USA	Japan	Germany		U. K.		France	Italy	Spain	Sweden	China
AISI/SAE	JIS	W-nr.	DIN	BS	EN	AFNOR	UNI	UNE	SS	GB
A570.36	STKM 12A STKM 12C	1.0038	RSt.37-2	4360 40 C	–	E 24-2 Ne	–	–	1311	15
1015	–	1.0401	C15	080M15	–	CC12	C15, C16	F.111	1350	15
1020	–	1.0402	C22	050A20	2C	CC20	C20, C21	F.112	1450	20
1213	SUM22	1.0715	9SMn28	230M07	1A	S250	CF9SMn28	F.2111 11SMn28	1912	Y15
12L13	SUM22L	1.0718	9SMnPb28	–	–	S250Pb	CF9SMnPb28	11SMnPb28	1914	–
–	–	1.0722	10SPb20	–	–	10PbF2	CF10Pb20	10SPb20	–	–
1215	–	1.0736	9SMn36	240M07	1B	S300	CF9SMn36	12SMn35	–	Y13
12L14	–	1.0737	9SMnPb36	–	–	S300Pb	CF9SMnPb36	12SMnP35	1926	–
1015	S15C	1.1141	Ck15	080M15	32C	XC12	C16	C15K	1370	15
1025	S25C	1.1158	Ck25	–	–	–	–	–	–	25
A572-60	–	1.8900	StE380	4360 55 E	–	–	FeE390KG	–	2145	–
1035	–	1.0501	C35	060A35	–	CC35	C35	F.113	1550	35
1045	–	1.0503	C45	080M46	–	CC45	C45	F.114	1650	45
1140	–	1.0726	35S20	212M36	8M	35MF4	–	F210G	1957	–
1039	–	1.1157	40Mn4	150M36	15	35M5	–	–	–	40Mn
1335	SMn438(H)	1.1167	36Mn5	–	–	40M5	–	36Mn5	2120	35Mn2
1330	SCMn1	1.1170	28Mn6	150M28	14A	20M5	C28Mn	–	–	30Mn
1035	S35C	1.1183	Cf35	060A35	–	XC38TS	C36	–	1572	35Mn
1045	S45C	1.1191	Ck45	080M46	–	XC42	C45	C45K	1672	Ck45
1050	S50C	1.1213	Cf53	060A52	–	XC48TS	C53	–	1674	50
1055	–	1.0535	C55	070M55	9	–	C55	–	1655	55
1060	–	1.0601	C60	080A62	43D	CC55	C60	–	–	60
1055	S55C	1.1203	Ck55	070M55	–	XC55	C50	C55K	–	55
1060	S58C	1.1221	Ck60	080A62	43D	XC60	C60	–	1678	60Mn
1095	–	1.1274	Ck101	060A96	–	XC100	–	F.5117	1870	–
W1	SK3	1.1545	C105W1	BW1A	–	Y105	C36KU	F.5118	1880	–
W210	SUP4	1.1545	C105W1	BW2	–	Y120	C120KU	F.515	2900	–

ALLOY STEEL

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

USA	Japan	Germany		U. K.		France	Italy	Spain	Sweden	China
AISI/SAE	JIS	W-nr.	DIN	BS	EN	AFNOR	UNI	UNE	SS	GB
5140	SCr440	1.7045	42Cr4	–	–	–	–	42Cr4	2245	40Cr
5155	SUP9(A)	1.7176	55Cr3	527A60	48	55C3	–	–	–	20CrMn
–	SCM415(H)	1.7262	15CrMo5	–	–	12CD4	–	12CrMo4	2216	–
ASTM A182 F11, F12	–	1.7335	13CrMo4 4	1501-620Gr27	–	15CD3.5 15CD4.5	14CrMo45	14CrMo45	–	–
ASTM A182 F.22	–	1.7380	10CrMo910	1501-622 Gr31, 45	–	12CD9 12CD10	12CrMo9 12CrMo10	TU.H	2218	–
–	–	1.7715	14MoV63	1503-660-440	–	–	–	13MoCrV6	–	–
–	–	1.8523	39CrMoV13 9	897M39	40C	–	36CrMoV12	–	–	–
9840	–	1.6511	36CrNiMo4	816M40	110	40NCD3	38NiCrMo4(KB)	35NiCrMo4	–	–
4340	–	1.6582	34CrNiMo6	817M40	24	35NCD6	35NiCrMo6(KB)	–	2541	40CrNiMoA
5132	SCr430(H)	1.7033	34Cr4	530A32	18B	32C4	34Cr4(KB)	35Cr4	–	35Cr
5140	SCr440(H)	1.7035	41Cr4	530M40	18	42C4	41Cr4	42Cr4	–	40Cr
5115	–	1.7131	16MnCr5	(527M20)	–	16MC5	16MnCr5	16MnCr5	2511	18CrMn
4130	SCM420 SCM430	1.7218	25CrMo4	1717CDS110 708M20	–	25CD4	25CrMo4(KB)	55Cr3	2225	30CrMn
4137 4135	SCM432 SCCRM3	1.7220	34CrMo4	708A37	19B	35CD4	35CrMo4	34CrMo4	2234	35CrMo
4140 4142	SCM 440	1.7223	41CrMo4	708M40	19A	42CD4TS	41CrMo4	42CrMo4	2244	40CrMoA
4140	SCM440(H)	1.7225	42CrMo4	708M40	19A	42CD4	42CrMo4	42CrMo4	2244	42CrMo 42CrMnMo
–	–	1.7361	32CrMo12	722M24	40B	30CD12	32CrMo12	F.124.A	2240	–
6150	SUP10	1.8159	50CrV4	735A50	47	50CV4	50CrV4	51CrV4	2230	50CrVA
–	–	1.8509	41CrAlMo7	905M39	41B	40CAD6 40CAD2	41CrAlMo7	41CrAlMo7	2940	–
L3	–	1.2067	100Cr6	BL3	–	Y100C6	–	100Cr6	–	CrV, 9SiCr
–	SKS31 SKS2, SKS3	1.2419	105WCr6	–	–	105WC13	100WCr6 107WCr5KU	105WCr5	2140	CrWMo
L6	SKT4	1.2713	55NiCrMoV6	BH224/5	–	55NCDV7	–	F.520.S	–	5CrNiMo
ASTM A353	–	1.5662	X8Ni9	1501-509	–	–	X10Ni9	XBNi09	–	–
2515	–	1.5680	12Ni19	–	–	Z18N5	–	–	–	–
–	–	1.6657	14NiCrMo134	832M13	36C	–	15NiCrMo13	14NiCrMo131	–	–
D3 ASTM D3	SKD1	1.2080	X210Cr12	BD3	–	Z200C12	X210Cr13KU X250Cr12KU	X210Cr12	–	Cr12
D2	SKD11	1.2601	X153CrMoV12	BD2	–	–	X160CrMoV12	–	–	Cr12MoV
A2	SKD12	1.2363	X100CrMoV5	BA2	–	Z100CDV5	X100CrMoV5	F.5227	2260	Cr5Mo1V
H13 ASTM H13	SKD61	1.2344	X40CrMoV51 X40CrMoV51	BH13	–	Z40CDV5	X35CrMoV05KU X40CrMoV51KU	X40CrMoV5	2242	40CrMoV5
–	SKD2	1.2436	X210CrW12	–	–	–	X215CrW121KU	X210CrW12	2312	–
S1	–	1.2542	45WCrV7	BS1	–	–	45WCrV8KU	45WCrSi8	2710	–
H21	SKD5	1.2581	X30WCrV93	BH21	–	Z30WCV9	X28W09KU	X30WCrV9	–	30WCrV9
–	–	1.2601	X165CrMoV12	–	–	–	X165CrMoW12KU	X160CrMoV12	2310	–
W210	SKS43	1.2833	100V1	BW2	–	Y1105V	–	–	–	V
T4	SKH3	1.3255	S 18-1-2-5	BT4	–	Z80WKCV	X78WCo1805KU	HS18-1-1-5	–	W18Cr4VCo5
T1	SKH2	1.3355	S 18-0-1	BT1	–	Z80WCV	X75W18KU	HS18-0-1	–	–
–	SCMnH/1	1.3401	G-X120Mn12	Z120M12	–	Z120M12	XG120Mn12	X120MN12	–	–
HW3	SUH1	1.4718	X45CrSi93	401S45	52	Z45CS9	X45CrSi8	F.322	–	X45CrSi93
D3	SUH3	1.3343	S6-5-2	4959BA2	–	Z40CSD10	15NiCrMo13	–	2715	–
M2	SKH9, SKH51	1.3343	S6/5/2	BM2	–	Z85WDCV	HS6-5-2-2	F.5603	2722	–
M7	–	1.3348	S 2-9-2	–	–	–	HS2-9-2	HS2-9-2	2782	–
M35	SKH55	1.3243	S6/5/2/5	BM35	–	6-5-2-5	HS6-5-2-5	F.5613	2723	–

MATERIAL CROSS REFERENCE LIST

STAINLESS STEEL (FERRITIC, MARTENSITIC)

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

STAINLESS STEEL (AUSTENITIC)

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

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

HEAT RESISTANT STEEL

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

GRAY CAST IRON

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

DUCTILE CAST IRON

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

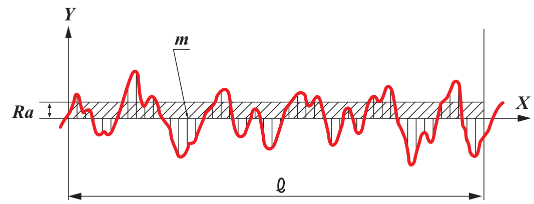
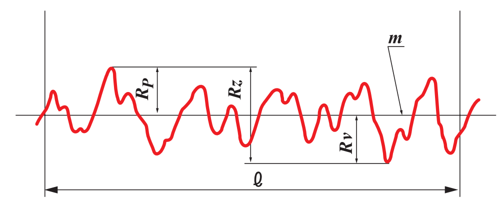
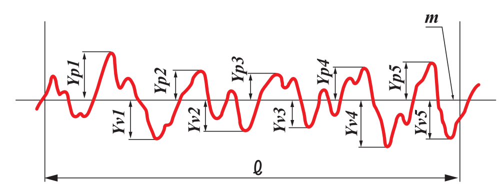
MALLEABLE CAST IRON

USA	Japan	Germany		U. K.		France	Italy	Spain	Sweden	China
AISI/SAE	JIS	W-nr.	DIN	BS	EN	AFNOR	UNI	UNE	SS	GB
–	FCMB310	–	–	8 290/6	–	MN 32-8	–	–	08 14	–
32510	FCMW330	–	GTS-35	B 340/12	–	MN 35-10	–	–	08 15	–
40010	FCMW370	0.8145	GTS-45	P 440/7	–	Mn 450	GMN45	–	08 52	–
50005	FCMP490	0.8155	GTS-55	P 510/4	–	MP 50-5	GMN55	–	08 54	–
70003	FCMP540	–	GTS-65	P 570/3	–	MP 60-3	–	–	08 58	–
A220-70003	FCMP590	0.8165	GTS-65-02	P 570/3	–	Mn 650-3	GMN 65	–	08 56	–
A 220-80002	FCMP690	–	GTS-70-02	P 690/2	–	Mn 700-2	GMN 70	–	08 62	–

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):** $Ra=\frac{1}{\ell}\int_0^{\ell} \lvert f(x) \rvert dx$ (µm)	
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.** $Rz=Rp+Rv$ (µm)	
Ten-Point Mean Roughness	Rz_{JIS}	**Rz_{JIS} 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).** $Rz_{JIS}=\frac{(Yp1+Yp2+Yp3+Yp4+Yp5)+(Yv1+Yv2+Yv3+Yv4+Yv5)}{5}$ (µm)	 *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 **Rz_{JIS}**	Sampling Length for **Rz • Rz_{JIS}** 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 Rz_{JIS} is the cutoff value and sampling length multiplied by 5, respectively.

TECHNICAL DATA

N

HARDNESS COMPARISON TABLE

HARDNESS CONVERSION NUMBERS OF STEEL

Brinell Hardness (HB), 10 mm Ball, Load: 3,000 kgf		Vickers Hardness (HV)	Rockwell Hardness (3)				Shore Hardness (HS)	Tensile Strength (Approx.) MPa (2)
Standard Ball	Tungsten Carbide Ball		A Scale, Load: 60 kgf, Diamond Point (HRA)	B Scale, Load: 100 kgf, 1/16" Ball (HRB)	C Scale, Load: 150 kgf, Diamond Point (HRC)	D Scale, Load: 100 kgf, Diamond Point (HRD)		
—	—	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), 10 mm Ball, Load: 3,000 kgf		Vickers Hardness (HV)	Rockwell Hardness (3)				Shore Hardness (HS)	Tensile Strength (Approx.) MPa (2)
Standard Ball	Tungsten Carbide Ball		A Scale, Load: 60 kgf, Diamond Point (HRA)	B Scale, Load: 100 kgf, 1/16" Ball (HRB)	C Scale, Load: 150 kgf, Diamond Point (HRC)	D Scale, Load: 100 kgf, Diamond Point (HRD)		
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

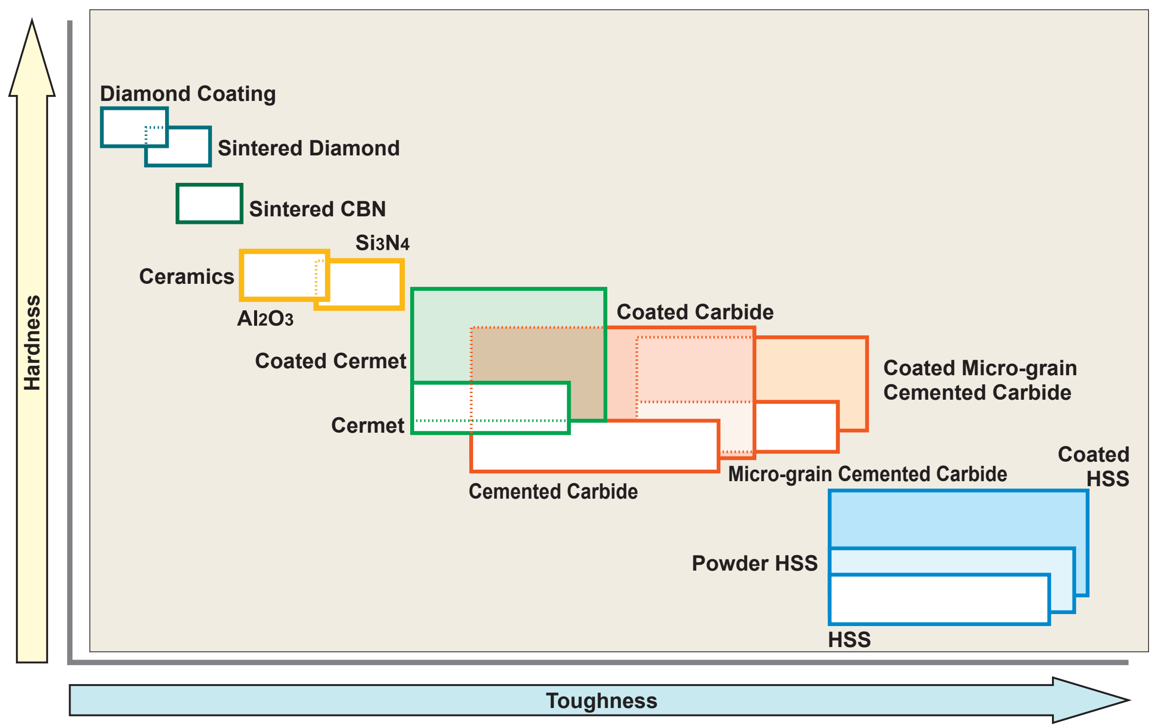
Note 1) The above list is the same as that of AMS Metals Hand book with tensile strength in approximate metric value and Brinell hardness over a recommended range.

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.

CUTTING TOOL MATERIALS

The chart 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, as they offer a good 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 • ℃

TECHNICAL DATA

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GRADE CHAIN

For Cutting Tools

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

Coated Carbide
- **P** Steel: MC6115 (CVD) NEW – MS6015 (PVD) – MP6120 (PVD) – MC6125 (CVD) NEW – MC6135 (CVD) NEW
  - UH6400 (CVD) – FH7020 (CVD) – VP15TF (PVD) – MP6130 (PVD) – VP10RT (PVD) – VP20RT (PVD) – VP30RT (PVD) – VP20MF (PVD) – UP20M (PVD)
- **M** Stainless Steel: MC7015 (CVD) – MC7020 (CVD) – MC7025 (CVD) – MS7025 (PVD) NEW – 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: MC5105 (CVD) NEW – MH515 (CVD) – MC5115 (CVD) NEW – MY5015 (CVD) – MC5125 (CVD) NEW – MC520 (CVD) NEW – MC5020 (CVD) – VP15TF (PVD)
  - VP10RT (PVD) – VP20RT (PVD)
- **N** Non-Ferrou: 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 Material: 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 (CBN&PCD)
- **N** Non-Ferrou Non-Metal: MD205 – MD220 – MD230 – MD2030
- Sintered Alloy: MB4120
- **K** Cast Iron: BC5110 (PVD) NEW – MBS140 – BC5030 (PVD) – MB4120
- **H** Hardened Material: BC8105 (PVD) – MB8110 – BC8110 (PVD) – BC8210 (PVD) NEW – MB8120 – BC8120 (PVD) – BC8220 (PVD) NEW – MB8130 – BC8130 (PVD)

Micro-grain Cemented Carbide
- Steel Cast Iron: SF10 – MF07 – MF10 – TF15 – MF20 – MF30

GRADE COMPARISON TABLE

CEMENTED CARBIDE

	ISO Classification	ISO Symbol	Mitsubishi Materials	Kennametal	Sandvik	Seco Tools	Iscar	Sumitomo Electric	Tungaloy	Kyocera	Walter	Ingersoll
Turning	P	P01										
		P10					IC70	ST10P	TH10			
		P20	UTi20T				IC70 IC50M	ST20E	KS20			P20
		P30	UTi20T				IC50M IC54	A30 A30N	UX30 KS15F			
		P40					IC54	ST40E	TX40			
	M	M10		KU10 K313 K68		890	IC07	EH510	TH10			
		M20	UTi20T	KU10 K313 K68		HX 883	IC07 IC08 IC20	EH520	KS20			
		M30	UTi20T				IC08 IC20 IC28	A30 A30N	UX30			
		M40					IC28		TU40			
	K	K01	HTi05T	KU10 K313 K68				H1 H2	KS05F			
		K10	HTi10	KU10 K313 K68		890	IC20	EH510	TH10	KW10 GW15		K10
		K20	UTi20T	KU10 K313 K68	H13A	HX	IC20	G10E H10E EH520	KS15F KS20	GW25		
		K30	UTi20T			883		G10E H10E				
	N	N01			H10			H1 H2	KS05F	GW05 KW10		
		N10	HTi10	KU10 K313 K68	H10 HBA	890	IC08 IC20	EH510	TH10	KW10 GW15	WK1	K10
		N20		KU10 K313 K68	H10 HBA	HX KX	IC08 IC20	G10E EH520	KS15F			K10
		N30				883						
	S	S01	MT9005							SW05		
		S10	MT9005 RT9010 MT9015	KU10 K313 K68	H10A H10F H13A	HX 883	IC07 IC08	EH510	KS05F TH10	SW10	WS10 WK1	K10
		S20	RT9010 TF15	KU10 K313 K68		883	IC07 IC08	EH520	KS15F KS20	SW25		
		S30	TF15									
Milling	P	P10										
		P20	UTi20T	K125M			IC50M IC28	A30N				
		P30	UTi20T	GX	SM30		IC50M IC28	A30N	UX30			
		P40					IC28					
	M	M10										
		M20	UTi20T				IC08 IC20	A30N				
		M30	UTi20T		SM30		IC08 IC28	A30N				
		M40					IC28					
	K	K01	HTi05T	K115M,K313								
		K10	HTi10	K115M K313			IC20	G10E	TH10	KW10 GW25	WK10	IN05S
		K20	UTi20T		H13A	HX	IC20	G10E		GW25		IN05S IN10K IN15K
		K30	UTi20T									IN10K IN15K

Note 1) The above table is selected from a publication. We have not obtained approval from each company.

MICRO GRAIN

	ISO Classification	ISO Symbol	Mitsubishi Materials	Kennametal	Sandvik	Seco Tools	Sumitomo Electric	Tungaloy	Kyocera	Walter	Ingersoll
Cutting Tools	Z	Z01	**SF10 MF07 MF10**		PN90 6UF,H3F 8UF,H6F		F0	F MD05F MD1508			IN05S
		Z10	**HTi10 MF20**		H10F	890	XF1 F1 AFU	MD10 MD0508 MD07F	FW30		IN05S
		Z20	**TF15 MF30**		H15F	890 883	AF0 SF2 AF1	EM10 MD20 G1F			IN05S
		Z30				883	A1 CC				

CERMET

	ISO Classification	ISO Symbol	Mitsubishi Materials	Kennametal	Sandvik	Seco Tools	Iscar	Sumitomo Electric	Tungaloy	Kyocera	Walter	Ingersoll
Turning	P	P01	**AP25N* VP25N***				IC20N IC520N*	T1000A	NS520 GT720*	CCX* TN610 PV710* PV30*		CT3000 PV3010* PV3030*
		P10	**NX2525 AP25N* VP25N***	KT315 KT125	CT5015 GC1525*	TP1020 TP1030* CM CMP*	IC20N IC520N* IC530N*	T1500A T1500Z*	NS520 NS9530 GT9530* AT9530*	CCX* TN60 TN610 PV710* TN620 PV720*	WEP10C*	CT3000 PV3010* PV3030*
		P20	**NX2525 AP25N* VP25N* NX3035 MP3025***	KT325 KT1120 KT5020*	GC1525*	TP1020 TP1030*	IC20N IC520N* IC30N IC530N* IC75T	T1500A T1500Z* T2500A T2500Z* T3000Z*	NS9530 GT9530* AT9530*	TN60 TN620 PV720* TN6020	WEP10C*	
		P30	**MP3025* VP45N***				IC75T	T3000Z*		PV730* PV90*		
	M	M10	**NX2525 AP25N* VP25N***	KT125	GC1525*	TP1020 TP1030* CM CMP*		T1000A T1500Z*		TN60 TN620 PV720* TN6020		CT3000 PV3010* PV3030*
		M20	**NX2525 AP25N* VP25N***					T1500A T1500Z*		TN90 TN6020 TN620 PV720* PV90*		CT3000 PV3010* PV3030*
		M30								PV730*		
	K	K01	**NX2525 AP25N***					T1000A	NS520 GT720*	CCX* PV7005*		PV3030*
		K10	**NX2525 AP25N***	KT325 KT125	CT5015				NS520 NS9530 GT9530*	CCX* PV7005* TN60		CT3000 PV3010* PV3030*
		K20	**NX2525 AP25N***									CT3000 PV3010*
Milling	P	P10	**NX2525**			C15M	IC30N			TN620M TN60		
		P20	**MX3020 NX2525**	KT530M HT7 KT605M	CT530	C15M MP1020	IC30N	T250A T2500A		TN100M TN620M TN60		IN60C
		P30	**MX3030 NX4545**				IC30N	T4500A	NS740			
	M	M10	**NX2525**				IC30N			TN60		
		M20	**MX3020 NX2525**	KT530M HT7 KT605M	CT530	C15M	IC30N	T250A T2500A		TN100M		
		M30	**MX3030 NX4545**					T4500A				
	K	K01										
		K10	**NX2525**							TN60		
		K20	**NX2525**	KT530M HT7								

*Coated Cermet
Note 1) The above table is selected from a publication. We have not obtained approval from each company.

GRADES COMPARISON TABLE

CVD COATED GRADE

	ISO Classification	ISO Symbol	Mitsubishi Materials	Kennametal	Sandvik	Seco Tools	Iscar	Sumitomo Electric	Tungaloy	Kyocera	Walter	Ingersoll
Turning	P	P01	MC6115	KCP05B KCP05	GC4305 GC4415	TP0501 TP1501	IC9150 IC8150 IC428	AC810P AC8015P	T9105 T9205	CA510 CA5505	WPP01	TT8105B
		P10	MC6115 MY5015 MC6125	KCP10B KCP10 KCP25	GC4315 GC4325 GC4415	TP1501 TP2501	IC9150 IC8150 IC8250	AC810P AC8020P	T9205 T9105 T9115 T9215	CA510 CA5505 CA515 CA5515	WPP01 WPP05 WPP10G	TT8115B TT8125B
		P20	MC6115 MC6125 MC6135 MY5015	KCP25B KCP30B KCP25 KCP25C	GC4315 GC4325 GC4425	TP2501	IC8250 IC9250 IC8350	AC8020P AC820P AC2000 AC8025P	T9115 T9125 T9215 T9225	CA025P CA515 CA5515 CA525 CA5525 CR9025	WPP10S WPP20S WPP20G	TT8125B TT5100
		P30	MC6125 MC6135 UH6400	KCP30B KCP30	GC4325 GC4335 GC4425	TP3501	IC8350 IC9250 IC9350	AC6030M AC8035P AC830P AC630M	T9125 T9135 T9225 T9235	CA025P CA525 CA5525 CA530 CA5535 CR9025	WPP30S WPP30G	TT5100 TT8135B
		P40	MC6035 UH6400	KCP40 KCP40B	GC4335	TP3501 TP40	IC9350	AC6030M AC8035P AC630M AC830P	T9135 T9235	CA530 CA5535		TT7100
	M	M10	MC7015 US7020	KCM15B KCM15	GC2015 GC2220	TM1501 TM2000	IC6015 IC8250	AC610M AC6020M	T6120 T6215	CA6515	WAM20	TT9215
		M20	MC7015 US7020 MC7025	KCM15 KCM25B KCP40B	GC2015 GC2220	TM2000 TM2501	IC8150 IC6015	AC6020M AC610M AC6030M AC630M	T6120 T6215	CA6515 CA6525		TT5100 TT9215
		M30	MC7025 US735	KCM35B KCP40	GC2025	TM4000 TM3501	IC8250 IC6025	AC6030M AC630M	T6130	CA6525		TT9225 TT9235
		M40	US735	KCM35B	GC2025	TM4000 TM3501	IC6025	AC6030M AC630M				TT9235
	K	K01	MC5105	KCK05B KCK05	GC3205 GC3210	TK0501 TH1500	IC5005	AC405K AC4010K	T505 T5105	CA4505 CA310	WKK10S	TT7005
		K10	MC5115 MH515 MY5015	KCK15B KCK15 KCK20 KCK20B	GC3205 GC3210	TK0501 TK1501	IC5005 IC5010 IC428	AC405K AC4010K AC4015K AC415K	T515 T5115	CA315 CA4515	WKK20S	TT7015
		K20	MC5125 MH515 MY5015	KCK20B KCK20	GC3225	TK1501	IC5010 IC8150	AC4015K AC415K AC420K	T5115 T5125	CA320 CA4515	WKP30S	
		K30	MC6115		GC3225			AC8025P	T5125			
	S	S01	US905		S05F S205					CA6515 CA6525		TT3005 TT9215
Milling	P	P10				MP1501	IC5400 IC5600	ACP2000 XCU2500 ACP100			WKP25S	IN6515
		P20	MC7020 F7030	KCPM20	GC4220	MP1501 MP2501 T25M	IC5400 IC5500	ACP2000 XCU2500 ACP100	T3130 T3225		WKP35S WKP35 WKP35G	IN6537
		P30	MC7020 F7030	KCPK30	GC4330 GC4230	MP1501 MP2501 TM25 T350M	IC5500	XCU2500 ACP100	T3130 T3225			IN6537
		P40			GC4340 GC4240	MM4500 T350M						
	M	M10						XCU2500 XCS2000				
		M20	MC7020 F7030	KC925M		MP2501 MS2500 T25M T350M		ACP100 ACM200 XCU2500 XCS2000	T3130 T3225	CA6535		IN6530
		M30	MC7020 F7030	KC930M	GC2040	MP2501 T25M T350M	IC5820	ACP100 XCU2500 ACM200 XCS2000	T3130 T3225	CA6535		IN7035
		M40		KC930M KC935M		MM4500 T350M						
	K	K01										
		K10	MC520 MC5020					XCK2000 ACK200	T1215 T1115	CA420M	WAK15	
		K20	MC520 MC5020	KC915M	GC3220 GC3330 K20W	MP1501	IC5100	ACK200 XCK2500 XCK2000 ACK200	T1115		WKP25	IN6515
		K30		KC920M KC925M KCPK30 KC930M KC935M	GC3330 GC3040	MP1501	IC5100 DT7150				WKP35G	IN6530
	S	S01										
		S10				MP2501	IC5820	ACM200 XCS2000		CA6535	WSM45X	
		S20			GC2040	MP2501 MS2500 T350M T25M	IC5820	ACM200 XCS2000		CA6535		
		S30			S40T	MS2500 T350M T25M				CA6535		IN6535 IN7035

Note 1) The above table is selected from a publication. We have not obtained approval from each company.

PVD COATED GRADE

	ISO Classification	ISO Symbol	Mitsubishi Materials	Kennametal	Sandvik	Seco Tools	Iscar	Sumitomo Electric	Tungaloy	Kyocera	Walter	Ingersoll
Turning	P	P01										
Turning	P	P10	VP10MF MS6015	KCU10 KC5010 KC5510	GC1125	CP200 TS2000	IC250 IC807 IC907 IC908		AH710	PR1705 PR930 PR1025 PR1115 PR1225 PR1725		TT4410
Turning	P	P20	VP10RT VP20RT VP15TF VP20MF MS6015	KCS10 KCU10 KC5025 KC5525	GC1525 GC1125	TS2500	IC1007 IC250 IC308 IC807 IC808 IC907 IC908 IC1008 IC1028 IC3028		AH725 AH120 J740 SH730 SH725	PR930 PR1025 PR1725 PR1115 PR1225 PR1425 PR1535		TT9080 TT4430
Turning	P	P30	VP10RT VP20RT VP15TF VP20MF MS7025	KCU25 KC5525	GC1125	CP500	IC228 IC250 IC328 IC330 IC354 IC528 IC1008 IC1028	AC1030U AC530U	AH725 AH120 SH730 GH730 GH130 AH740 J740 SH725 AH7025	PR1025 PR1725 PR1225 PR1425 PR1535 PR1625		TT7220
Turning	P	P40				CP500 CP600	IC228 IC328 IC528 IC928 IC1008 IC1028		AH740	PR1535		TT8020
Turning	M	M01				CP200 TS2000				PR1725		
Turning	M	M10	VP10MF	KCS10 KCU10 KC5010	GC1525 GC1115 GC1125 GC1105	CP200 TS2000 TS2500	IC354 IC807 IC907 IC1007		AH8005 AH630 AH6225	PR1025 PR1225 PR930 PR1725	WSM20 WSM20S	TT4410 TT5080
Turning	M	M20	VP10RT VP20RT VP15TF VP20MF MS7025 MS9025	KCU25 KC5025 KCU10 KC5010 KCS10	GC1525 GC1115 GC1125	TS2500 CP500 CP600	IC354 IC808 IC908 IC1008 IC1028	AC1030U AC530U AC6040M	AH725 AH120 SH730 AH630 SH725 AH8015 AH7025 AH6225	PR1025 PR1225 PR930 PR1535 PR1725	WSM30 WSM30S	TT4430 TT9080
Turning	M	M30	VP10RT VP20RT VP15TF VP20M VP20MF MS7025 MP7035	KC5025 KCU25	GC1125 GC2035	CP500 CP600	IC228 IC250 IC328 IC1008 IC1028	AC530U AC1030U AC6040M	AH725 AH120 SH730 J740 AH645 SH725 AH6235	PR1025 PR1725 PR1535 PR1225		TT8020 TT8080
Turning	M	M40	MP7035		GC2035	CP600	IC328 IC928 IC1008 IC1028	AC530U AC6040M AC1030U	AH645 AH6235	PR1535 PR1225		
Turning	K	K01										
Turning	K	K10		KCU10 KCS10 KC5010 KC5510		CP200 TS2000	IC350 IC1008		GH110 AH110			TT6080
Turning	K	K20	VP10RT VP20RT VP15TF	KCU15 KCU25		CP200 TS2000 TS2500	IC228 IC808 IC830 IC908 IC1007 IC1008	AC1030U AC530U	AH7025 AH120			
Turning	K	K30	VP10RT VP20RT VP15TF	KCU25 KC5525		CP500	IC228 IC350 IC808 IC830 IC908 IC928 IC1007 IC1008		AH120 GH130			
Turning	S	S01	MP9005 VP05RT			TH1000	IC804 IC807 IC907	AC510U AC5005S AC5015S	AH8005	PR005S PR015S	WSM10 WSM10S	
Turning	S	S10	MP9005 MP9015 VP10RT	KCU10 KC5010 KCS10 KCS10B	GC1105	CP200 TS2000 TS2050 TS2500 TH1000	IC806 IC807	AC5005S AC510U AC520U AC5015S AC5025S	AH8005 AH8015	PR005S PR015S	WSM20 WSM20S	TT5080 TT3010
Turning	S	S20	MP9015 MT9015	KCU10 KCU25 KC5025 KCS10 KC5010 KCS10B	GC1105 GC1115 GC1125	TS2000 TS2500 CP200	IC228 IC328 IC808 IC908 IC928 IC806	AC520U AC5015S AC5025S	AH7025 AH8015	PR015S PR1535	WSM30 WSM30S	TT4430 TT3020 TT9080
Turning	S	S30	MS9025 MP9025 VP15TF VP20RT	KCU25 KC5025	GC1125	CP600	IC928 IC830	AC1030U	AH630 AH7025	PR015S PR1535		TT8020
Milling	P	P01							AH710 AH110			
Milling	P	P10		KC505M KC715M KC510M KC515M	GC1010 GC1130		IC250 IC350 IC808 IC810 IC910 IC950	ACU2500 ACP200	AH120 AH725	PR830 PR1225		IN4015 IN2004
Milling	P	P20	MP6120 VP15TF	KC522M KC525M KC527M KC610M KC620M KC635M KC715M KC730M KTPK20	GC1010 GC1030 GC1130 GC2030	F25M MP3000	IC250 IC328 IC330 IC350 IC808 IC810 IC830 IC910 IC928 IC950	ACU2500 ACP200	AH3135 AH3225 AH725 AH120 AH9130 AH6030 AH9030	PR830 PR1225 PR1230 PR1525		IN2004 IN2205

Note 1) The above table is selected from a publication. We have not obtained approval from each company.

GRADES COMPARISON TABLE

PVD COATED GRADE

	ISO		Mitsubishi Materials	Kennametal	Sandvik	Seco Tools	Iscar	Sumitomo Electric	Tungaloy	Kyocera	Walter	Ingersoll
	Classification	Symbol										
Milling	P	P30	**MP6120** **VP15TF** **MP6130** **VP30RT**	KC735M KC725M KC530M KCPM40	GC1010 GC1030 GC2030 GC1130	F25M MP3000 F30M MP2050	IC250 IC328 IC330 IC350 IC830 IC845 IC928 IC950	ACU2500 ACP200 ACP300	AH725 AH130 AH140 AH3035 AH6030 AH3225 AH9130	PR1230 PR1525	WSP45S WSP45G	IN1040 IN1540 IN2040 IN2205
		P40	**VP30RT**	KC735M KCPM40	GC2030 GC1030 GC1130	F40M T60M	IC328 IC330 IC830 IC928	ACP300	AH140 AH3035	PR1525		
	M	M01					IC907					
		M10		KC715M KC515M	GC1025 GC1030 GC1010 GC1130			ACM100 ACU2500	AH725	PR1225		
		M20	**VP15TF** **MP7130** **MP7030** **VP20RT**	KC610M KC635M KC730M KC522M KC525M KCPM40 KTPK20	GC1025 GC1030 GC1040 GC2030 S30T	F25M MP3000	IC250 IC808 IC830 IC928	ACU2500 ACP200	AH725 AH6030 AH130 AH330 AH9130	PR1025 PR1225	WSM35S WSM35G	IN2205
		M30	**VP15TF** **MP7130** **MP7030** **VP20RT** **MP7140** **VP30RT**	KC725M KC735M KCPM40 KC530M	S30T GC1040 GC2030	F30M F40M MP3000 MP2050	IC250 IC328 IC330 IC380 IC830 IC882 IC928	ACP200 ACP300 ACM300	AH130 AH140 AH730 AH3135 AH4035 AH9130	PR830 PR1225 PR1525 PR1535	WSP45S WSP45G	IN1515 IN1530 IN2005 IN2505 IN2205
		M40	**MP7140** **VP30RT**			F40M MP2050	IC250 IC328 IC330 IC882	ACP300 ACM300	AH140 AH3135 AH4035	PR1525 PR1535		
	K	K01	**MP8010**						AH110 AH330			
		K10	**MP8010**	KCKP10 KC514M KC515M KC527M KC635M KCK20B	GC1010	MK2050	IC350 IC810 IC830 IC900 IC910 IC928 IC950 IC380	ACU2500 ACK3000	AH110 AH725 AH120 AH330	PR1210 PR1510	WKK25S WKK25G	IN2510 IN2004
		K20	**VP15TF** **VP20RT**	KTPK20 KC514M KC610M KC520M KC620M KC524M KCK20B	GC1010 GC1020	MK2000 MK2050	IC350 IC808 IC810 IC830 IC910 IC928 IC950	ACU2500 ACK3000 ACK300	AH120 AH9130 AH9030	PR1210 PR1510		IN1030 IN2010 IN2015 IN2205
		K30	**VP15TF** **VP20RT**	KC522M KC725M KC524M KC735M	GC1020	MK2050	IC350 IC808 IC830 IC928 IC950	ACK300 ACK3000	AH120			IN1510 IN2030 IN2205
	S	S01					IC907 IC808		AH110 AH710	PR1210		
		S10	**MP9120** **VP15TF**	KC510M	GC1130 GC1010 GC1030 GC2030	MS2050	IC907 IC840 IC910 IC808	EH520Z EH20Z ACM100	AH120 AH725	PR1210		
		S20	**MP9120** **VP15TF** **MP9130** **MP9030**	KC522M KC525M KCSM30 KCPM40	S30T GC2030 GC1030 GC1130	MS2050 MP2050	IC808 IC830 IC928 IC328 IC330 IC840 IC882 IC380	EH520Z EH20Z ACK300 ACP300	AH725 AH6030 AH130	PR1535	WSM35S WSM35G	IN2205
		S30	**MP9140**	KC725M KCPM40	GC2030 GC1040	MS2050 F40M KCSM40	IC830 IC882 IC928	ACP300 ACM300	AH130 AH3135	PR1535	WSP45G	IN2205
	H	H01	**MP8010** **VP05HT**						AH110 AH710		WHH15 WHH15X	
		H10	**VP15TF** **VP10H**	KC505M KC510M	GC1130 GC1010 GC1030	MH1000 F15M	IC808 IC907		AH110 AH120 AH710			
		H20	**VP15TF**		GC1030 GC1130	F15M	IC808 IC380		AH120 AH3135 AH725 AH9030			
		H30				MP3000 F30M	IC380		AH3135			

Note 1) The above table is selected from a publication. We have not obtained approval from each company.

CBN

	ISO Classification	ISO Symbol	Mitsubishi Materials	Sandvik	Sumitomo Electric	Tungaloy	Kyocera
Turning	H	H01	**BC8105** **BC8210** **BC8110** **MB8110**	CB7105 CB7015	BNC2010 BN1000	BXA10 BXM10 BX310	KBN05M KBN510
		H10	**BC8210** **BC8110** **BC8220** **BC8120** **MB8110** **MB8120**	CB7115 CB7125 CB7025	BNC2010 BNC2115 BN2000	BXA10 BXA20 BXM20 BX330	KBN020 KBN05M KBN25M KBN525
		H20	**BC8220** **BC8120** **MB8120**	CB7125 CB7025	BNC2020 BNC2125 BN2000	BXA20 BXM20 BX360	KBN020 KBN25M
		H30	**BC8130** **MB8130**	CB7525 CB7135	BNC300 BN350	BXC50 BX380	KBN35M
	S	S01	**MB730**		BN700 BN7000	BX950	
	K	K01	**BC5110** **MB5015**		BNC8115 BNS8125	BX910	
		K10	**MB4120**	CB7525	BNC8115 BNS8125	BX480	KBN475 KBN60M
		K20	**MB4120**		BNC8115 BNS8125	BX480	KBN475 KBN60M
		K30	**BC5030** **MBS140**	CB7925	BNC8115 BNS8125	BX480	
	Sintered Alloy		**MB4120**		BN7115 BN7000	BX480 BX470	KBN70M KBN570

PCD

	ISO Classification	ISO Symbol	Mitsubishi Materials	Sandvik	Sumitomo Electric	Tungaloy	Kyocera
Turning	N	N01	**MD205**	CD05	DA90	DX180 DX160	KPD230
		N10	**MD220**	CD10	DA150	DX140	KPD010
		N20	**MD220**		DA2200	DX120	
		N30	**MD230** **MD2030**		DA1000	DX110	KPD001

Note 1) The above table is selected from a publication. We have not obtained approval from each company.

INSERT CHIP BREAKER COMPARISON TABLE

NEGATIVE INSERT TYPE

ISO Classifi-cation	Cutting Mode	Mitsubishi Materials	Kennametal	Sandvik	Seco Tools	Walter	TaeguTec	Sumitomo Electric	Tungaloy	Kyocera
P	Finish	FH, FP FY, FS	FF	LC	FF1, FF2	FP5	FLP FA FX	FA, FB FL	01* TF, 11 ZF	GP, PP, VF XP, XP-T, XF
	Light	LP SA, SH	K LF, FN	XF PF MF	MF2	MP3, FV5	FM MLP FG	SU LU, FE SX, SE	PS NS, 27 TSF, AS, TQ	PQ HQ, CQ
	Light (Mild Steel)	SY					FC		17	XQ, XS
	Light (With Wiper)	SW	FW	WL, WF	W-FF2 W-MF2	FW5, NF	WS	LUW, SEW	FW, SW AFW, ASW	WF WP, WQ
	Medium	MP MA MH	MP, P MN	PM QM, XM XMR	MF3 MF5, M3 M5	MP5, MV5 MU5	PC, MP, FT MT MGP	GU UG GE, UX	PM, NM, ZM TA, TM, AM, 28 DM, 33, 37, 38	PG, CJ, GS PS, HS PT
	Medium (With Wiper)	MW	MW, RW	WMX, WM WR	W-M6, W-M3 W-MF5	MW5, NM	WT	GUW		WE
	Rough	RP GH Std.	RN, RP	PR, HM Std.	M6, MR6, MR7	RP5, RP7 RV5	RGP RT Std.	MU, MX, ME UZ	TH, THS Std.	PH GT Std.
	Heavy	HZ HL, HM, HX HV	MR, RP RM RH	QR, PR HR, MR	R4, R5 R57, RR6, R7 R68, RR9	HU3, NRF HU5 HU7, NRR	RX, RH HD, HY, HT HZ, EH	MP HG, HP HU, HW, HF	TRS, 57 TU TUS, 65	PX
M	Finish Light	SH, LM	FF, FP LF*	XF, MF	FF1, FF2 MF1	FM5	SF	SU, EF	SS	MQ, SK*
	Medium	MS, GM MM, MA ES	MS, MP UP	MM QM, XM K	MF3 MF4 MF5, M3	MM5, RM5 MU5	ML EM, MM VF	EX, EG, UP GU HM	SA, SF SM S	MS, MU TK ST
	Heavy	GH, RM HL, HZ	MR, RP	MR MR	M5, M6, R6 R56, RR6, R7 R8,PR9	HU5		EM, MU MP	TH, SH	
K	Finish Light	LK, MA	FN	KF	MF2 M3, M4	MK5	FG		CF	KQ
	Medium	MK, GK Std.	RP,UN	KM	M5	RK5, MV7	MC	UZ, GZ, UX	CM Std.	KG, Std., C
	Rough	RK		KR, KRR	MR7	RK7 RV7	KT			KH. GC, PH
	Heavy	Flat Top	Flat Top		MR9 Flat Top	Flat Top		Flat Top	CH, Flat Top	ZS, Flat Top
S	Finish	FS*, FJ*	FS*, FF	SF	MF1	FM5	FA	EF		MQ, SK*
	Light	LS,MJ,MJ*	LF *, MS, FN	SGF*	MF3	NFT MS3	EA, SF	SU*	HRF	
	Medium	MS MA	UP, P, NGP*	NGP*, SM QM	M1 M3	NMS, NMT MU5		EG, EX, UP	SDM, HRM, 28 SA, HMM	SQ MS, MU, TK
	Heavy	RS, GJ	RP	SR, SMR	MR3 MR4	NRS, NRT HU5	ET	MU		SG, SX

*Peripheral ground type insert.

Note 1) Above charts are based on published data and not authorized by each manufacturer.

7°POSITIVE INSERT TYPE

ISO Classifi-cation	Cutting Mode	Mitsubishi Materials	Kennametal	Sandvik	Seco Tools	Walter	TaeguTec	Sumitomo Electric	Tungaloy	Kyocera
P	Finish	SMG*	LF*	UM*		FP2*	SL* SA*	FF* FC*, SC*	JP* JS*, 01*	CF*,CK* GQ*,GF* SKS*, SK*
	Finish Light	FP, FV LS-P* LP, SV	UF, 11 LF, FP	PF, UF	FF1 F1, MF2	PF4, FP4	FA, FX SM*, FG	FB, FP, LU LB, SU	PF, PSF PS, PSS, TSF	GP, PP, VF XP
	Light (With Wiper)	SW	FW	WF	W-F1	FW4, PF		LUW, SDW		WP
	Medium	MV MP, Std.	MF, MP	PM, UM PR, UR	M3 F2, M5	FP6, MP4 MP6, RP4	PC SH*, MT	GU MU	TM, 23 PM, 24	HQ, MF* XQ, GK
	Medium (With Wiper)	MW	MW	WM	W-MF2 W-M3	MW4, PM	WT		SW	
M	Finish | Light	FS-P* FM LS-P* LM	LF, UF FP	MF, UF	F1, F2 MF2	FM2* FM4	FA FG	FF* FC*, SI* LU LB, SU	JP* PF, PSF PS, PSS	CF*,CK* GQ*,GF* MQ*,SK*
	Medium	MM Std.	MP	MM, UM MR, UR	M3 M5	FM6 MM4, RM4	PC MT	GU, MU	PM	HQ, GK
K	Medium	MK, Std. Flat Top	Flat Top	KF, KM, UM, KR	F1, M3, M5	FK6, MK4 RK4, RK6	MT	MU, Flat Top*	Flat Top, CM	Flat Top*
N	Medium	AZ*	HP*	AL*	AL*	FN2*, PM2* MN2*	FL*	AG* AW*	AL*	AP* AH*
S	Finish Light	FS*, LS* FS-P*, LS-P* FJ* LS, MS	LF* HP*	UM* UF, MF UM, MM		FM2* FM4, FM6 MM4, RM4	SA*, FA, FG SL*, SM* SH*, PC, MT	FF* SI* GU	Std.	CF*, CK* GQ*, GF* SK*, MQ

*Peripheral ground type insert.

Note 1) Above charts are based on published data and not authorized by each manufacturer.

11°POSITIVE INSERT TYPE

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

*Peripheral ground type insert.

Note 1) Above charts are based on published data and not authorized by each manufacturer.

Memo

Memo

Memo

Memo