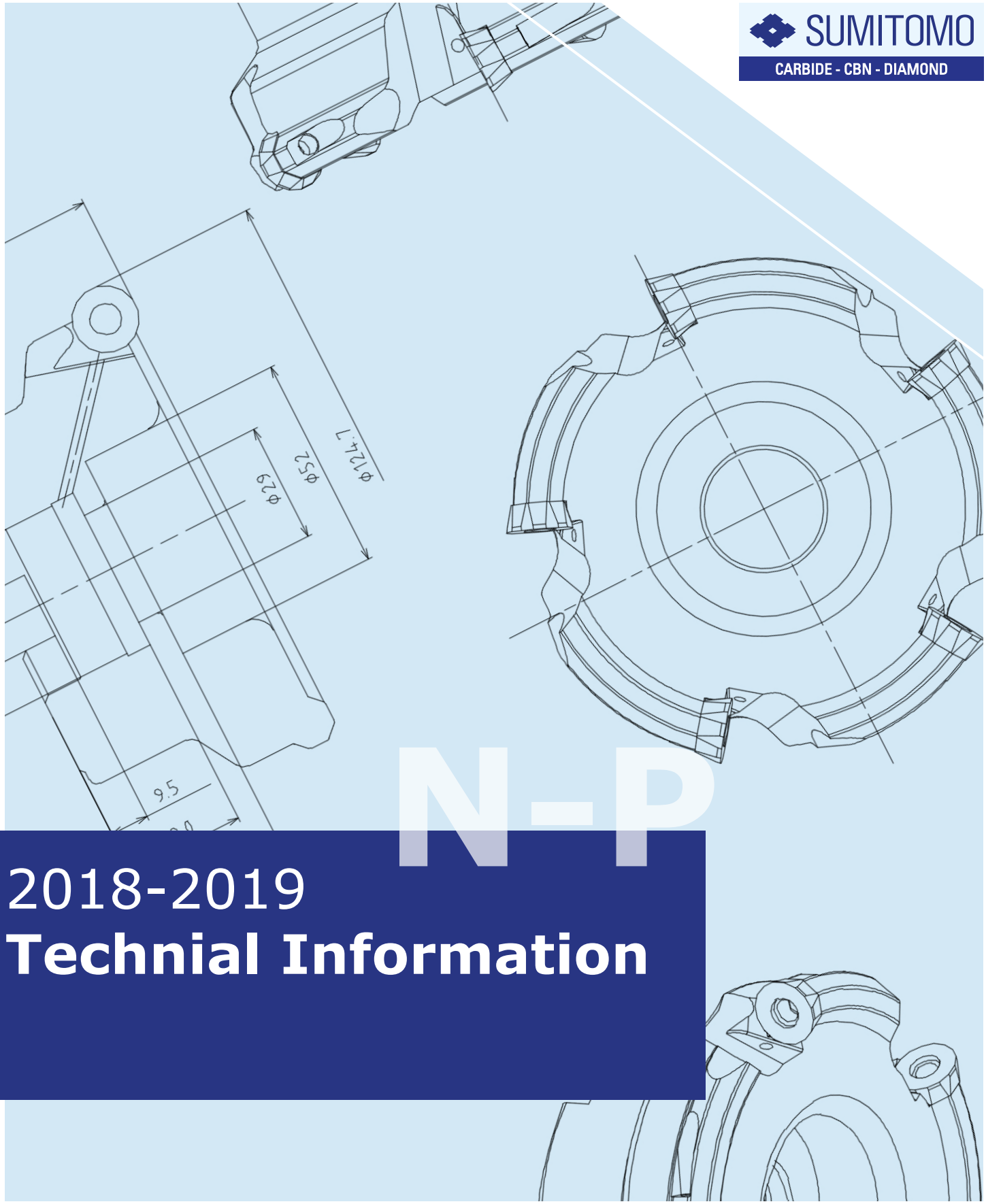
SUMITOMO
CARBIDE - CBN - DIAMOND



N-P

2018-2019
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SUMITOMO ELECTRIC GROUP

Technical Guidance References

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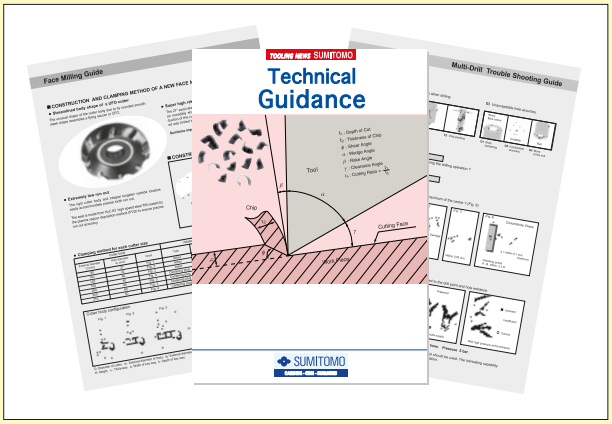

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Basics of Turning

■ Calculating Power Requirement

$$P_c = \frac{d_{oc} \cdot f \cdot v_c \cdot K_c}{60 \times 10^3 \times \eta}$$

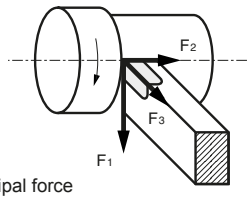
$$H = \frac{P_c}{0{,}75}$$

P_c : Net power requirement (KW)
v_c : Cutting speed (m/min)
f : Feed rate (mm/rev)
a_p : Depth of cut (mm)
η : Machine efficiency (0,70 ~ 0,85)
K_c : Specific cutting force (N/mm²)
H : Required horsepower (HP)

● Rough value of specific cutting force (K_c)

General steel :	2.500 ~ 3.000 N/mm²
Cast iron :	1.500 N/mm²
Aluminum :	800 N/mm²

■ Cutting Force



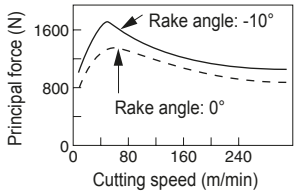
F_1 : Principal force
F_2 : Feed force
F_3 : Back force

● Calculating cutting force

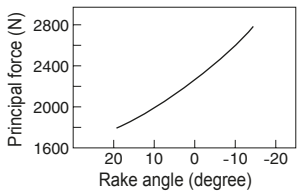
$$P = K_c \cdot q = \frac{k_c \times d_{oc} \times f}{1000}$$

P : Cutting force (N)
K_c : Specific cutting force (N/mm²)
q : Chip area (mm²)
d_{oc} : Depth of cut (mm)
f : Feed rate (mm/rev)

■ Cutting Speed and Cutting Force



■ Rake Angle and Cutting Force



■ Calculating Cutting Speed

① Calculating rotational speed from cutting speed

$$n = \frac{1000 \cdot v_c}{\pi \cdot D}$$

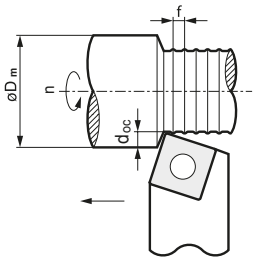
n : Spindle speed (min⁻¹)
v_c : Cutting speed (m/min)
D : Diameter of workpiece (mm)
$\pi \approx 3{,}14$

(Eg.) v_c =150m/min, D=100mm

$$n = \frac{1000 \times 150}{3{,}14 \times 100} = 478\ (\text{min}^{-1})$$

② Calculating cutting speed from rotational speed

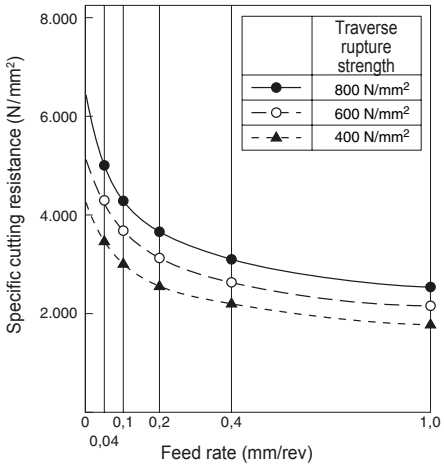
$v_c = \frac{\pi \cdot D \cdot n}{1.000}$	Refer to the above table



n : Spindle speed (min⁻¹)
v_c : Cutting speed (m/min)
f : Feed rate (mm/rev)
d_{oc} : Depth of cut (mm)
D_m : Diameter of workpiece (mm)

■ Feed Rate and Specific Cutting Force

(For carbon steel)



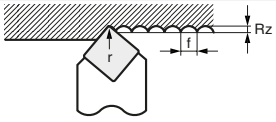
When feed rate decreases, specific cutting force increases.

■ Roughness

● Theoretical Surface Finish

$$Rz = \frac{f^2}{8 \times r}$$

Rz : Surface finish (mm)
f : Feed rate (mm/rev)
r : Nose radius (mm)



● Actual surface roughness

Steel :
Theoretical surface finish x 1,5 ~ 3
Cast iron :
Theoretical surface finish x 3 ~ 5

● Ways to Improve Surface Finish

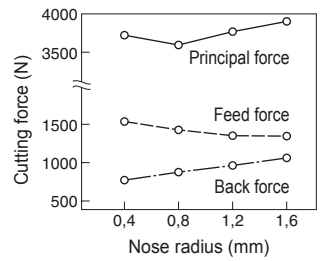
① Use an insert with a larger nose radius.

② Optimize the cutting speed and feed rate so that built-up edge does not occur.

③ Select an appropriate insert grade.

④ Use wiper insert.

■ Nose Radius and Cutting Force

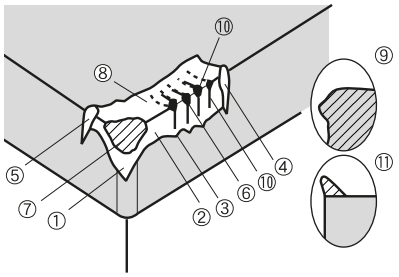


Large nose radius increases back force.

Work : 42CrMo4 (Hs38)
Inserts : TNGA2204○○
Holder : PTGNR2525-43
Condition : v_c =100m/min
d_{oc} =4mm
f =0,45mm/rev

Tool Failures and Tool Life

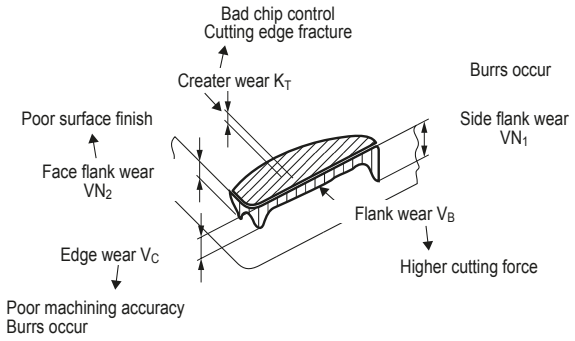
■ Forms of Tool Failures

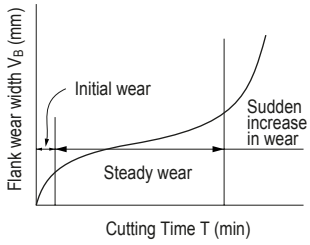
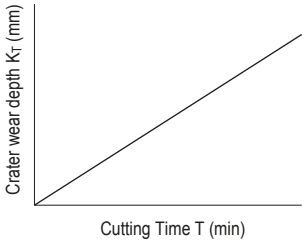


Cat.	No.	Name of Failure	Cause of Failure
Resulting from Mechanical causes	1~5	Flank Wear	Due to the scratching effect of hard grains contained in the work material.
	6	Chipping	Fine breakages caused by high cutting loads or chattering.
	7	Fracture	Due to the impact of an excessive mechanical force acting on the cutting edge.
Resulting from Chemical reactions	8	Crater Wear	Swaft chips removing tool material as it flow over the top face at high temperatures.
	9	Plastic Deformation	Cutting edge is depressed due to softening at high temperatures.
	10	Thermal Crack	Fatigue from rapid, repeated heating and cooling cycles during machining.
	11	Built-up Edge	Work material is pressure welded on the top face of the cutting edge.

■ Tool Wear

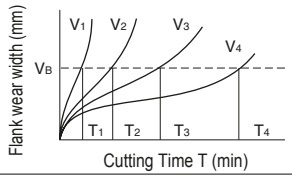
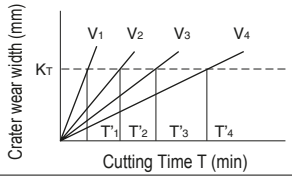
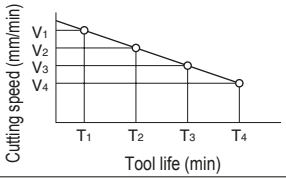
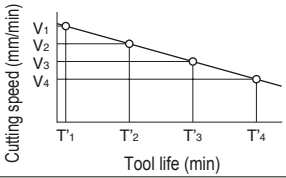
Forms of Tool Wear



Flank wear	Crater wear
	
Wear is rapid initially, then it proceeds more gradually in proportion with cutting time until a certain limit, beyond which it increases rapidly again.	Crater wear is more progressive with no sudden breakdown pattern.

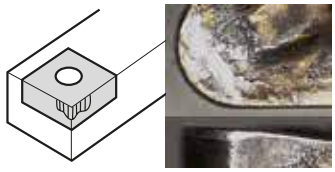
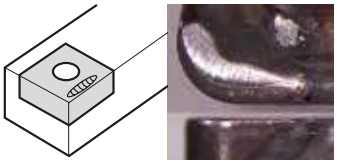
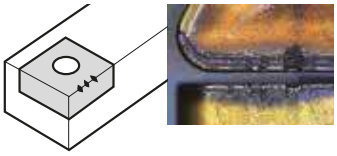
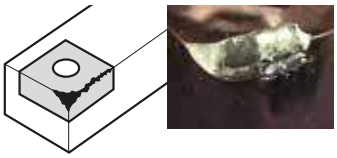
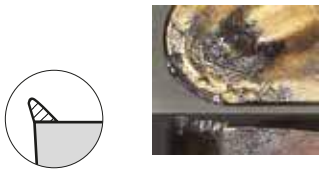
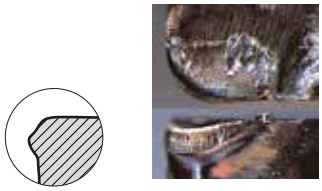
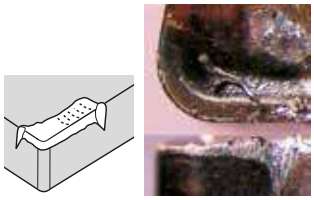
■ Tool Life (V-T)

Measure the relative tool lives of the specified wear, over a range of cutting speeds, then plot the tool life along the X-axis and the cutting speed along the Y-axis on a double logarithm graph.

	Flank wear	Crater wear
Tool wear		
Tool life		

Tool Failure and Remedies

■ Trouble Shooting Guide for Turning

	Damage	Cause	Countermeasures
Tool Edge Failure	Excessive flank wear 	- Grade lacks wear resistance. - Cutting speed ist too fast. - Feed rate ist far too slow.	- Select a wear resistant grade. P30 ⇨ P20 ⇨ P10 K20 ⇨ K10 ⇨ K01 - Use an insert with a larger rake angle. - Decrease the cutting speed. - Increase feed rates.
	Excessive crater wear 	- Grade lacks crater wear resistance. - Rake angle is too small. - Cutting speed is too fast. - Feed rate and depth of cut are too large.	- Select a more crater-resistant grade. - Use an insert with a larger rake angle. - Select an appropriate chipbreaker. - Decrease the cutting speed. - Decrease the D.O.C. and feed rate.
	Cutting edge chipping 	- Grade lacks toughness. - Insert falls off due to chip build-up. - Cutting edge lacks toughness. - Feed rate and depth of cut are too large.	- Change to tougher grades. P10 ⇨ P20 ⇨ P30 K01 ⇨ K10 ⇨ K20 - Increase amount of honing on cutting edge. - Reduce rake angle. - Reduce feed rates and depth of cut.
	Cutting edge fracture 	- Grades lacks toughness. - Cutting edge lacks toughness. - Holder lacks toughness. - Feed rarte is too fast. - Depth of cut is too large.	- Change to tougher grades. P10 ⇨ P20 ⇨ P30 K01 ⇨ K10 ⇨ K20 - Select a chipbreaker with a strong cutting edge. - Select a holder with a larger approach angle. - Select a holder with a larger shank size. - Decrease the D.O.C. and feed rate.
	Build-up edge 	- Inappropriate grade selection. - Dull cutting edge. - Cutting speed is too slow. - Feed rate ist too slow.	- Select a grade with less affinity to the work material. Coated carbide or cermet grades. - Select a grade with a smooth coating. - Use an insert with a larger rake angle. - Reduce amount of honing. - Increase cutting speeds. - Increase feed rates.
	Plastic deformation 	- Grade lacks thermal resistance. - Cutting speed is too fast. - Feed rate is too fast. - Depth of cut is too large. - Not enough cutting fluid.	- Select a more crater-wear-resistant grade. - Use an insert with a larger rake angle. - Decrease the cutting speed. - Reduce feed rates and depth of cut. - Supply a sufficient amount of coolant.
	Notch wear 	- Grade lacks wear resistance. - Rake angle is too small. - Cutting speed is too fast.	- Select a wear resistant grade. P30 ⇨ P20 ⇨ P10 K20 ⇨ K10 ⇨ K01 - Use an insert with a larger rake angle. - Alter depth of cutto shift the notch location.

Chip Control

Type of Chip Generation

	a	b	c	d
Shape				
Condition	Continuous chips with good surface finish.	Chip is sheared and separated by the shear angle.	Chips appear to be torn from the surface.	Chips crack before reaching the cutting point.
Application	Steel, Stainless steel	Steel, Stainless steel (Low speed)	Steel, Cast iron (Very low speed, very small feedrate)	Cast iron, Carbon
Influence factor	Easy ← Work deformation → Difficult Large ← Rake angle → Small Small ← D.O.C. → Large Fast ← Cutting speed → Slow			

Type of Chip Control

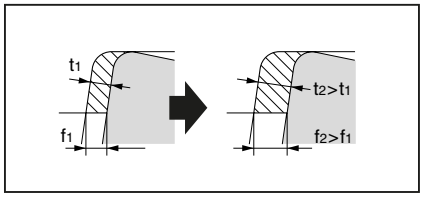
Feed rate	A	B	C	D	E
Large feed rate					
Small feed rate					
NC lathe (For automation)	×	×	○	○	△
General lathe (For safety)	×	○	○	○ ~ △	×

Good : C type, D type

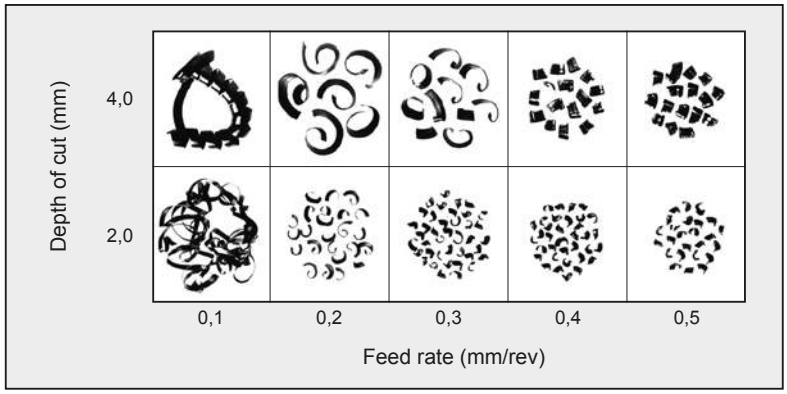
Poor
- A type : Twines around the tool or workpiece, damages the machined surface and affects safety.
- B type : Bulky, causes problems in the automatic chip conveyor and chipping occurs easily.
- E type : Causes spraying of chips, poor machined surface due to chattering, chipping, large cutting force and high temperatures.

Factor of Improvement Chip Control

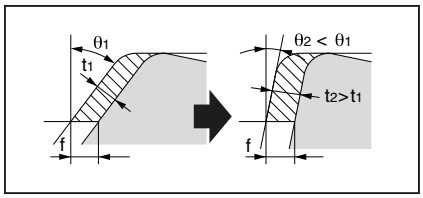
① Increase feed rate



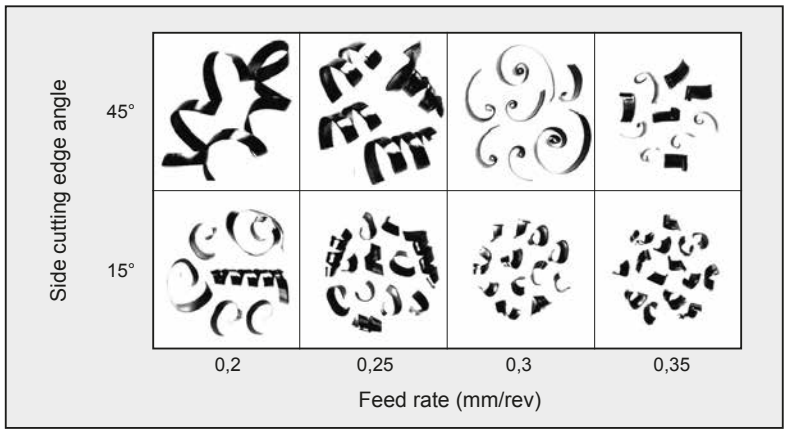
When feedrate increase, chips become thick and chip control improves.



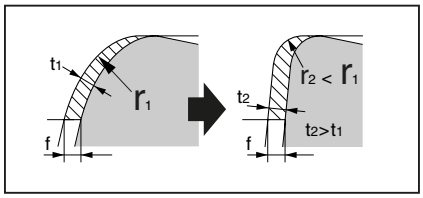
② Decrease side cutting edge



Even if feed rate is the same, smaller side cutting edge angle makes chips thick and chip control improves.

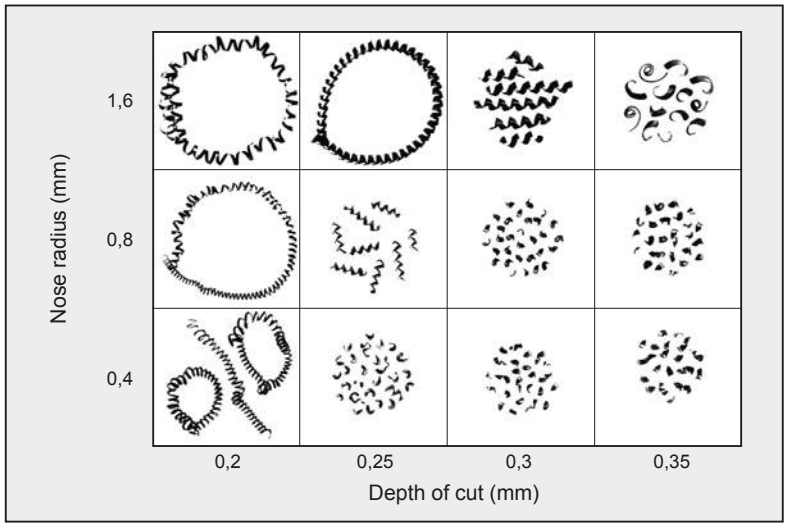


③ Decrease nose radius



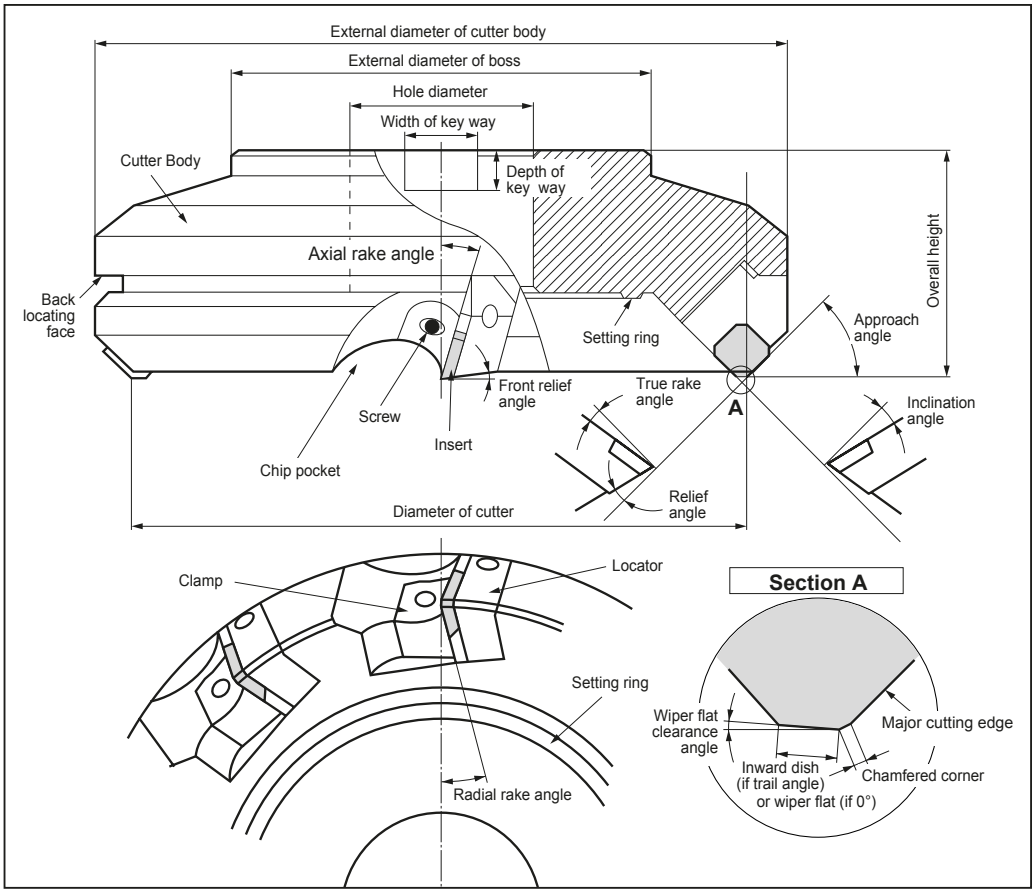
Even if depth of cut is the same, smaller nose radius makes chip thick and chip control improves.

* Cutting resistance increases in proportion with the width of the contact surface. Therefore, with a larger nose radius, cutting resistance and back force increases, chattering may also occur. However, with the same feedrate, a smaller nose radius would produce a poorer surface finish.



Basics of Milling

■ Parts of a Milling Cutter



■ Power Requirement

● Calculating cutting force

$$P_c = \frac{d_{oc} \cdot w_{oc} \cdot v_f \cdot K_c}{60 \times 10^6 \times \eta} \text{ (kW)}$$

● Horsepower

$$H = \frac{Pc}{0{,}75}$$

● Chip removal amount

$$Q = \frac{d_{oc} \times w_{oc} \times v_f}{1.000} \text{ (cm}^3\text{/min)}$$

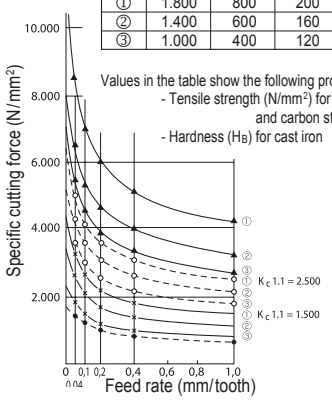
P_c : Net power requirement (kW)
H : Horsepower requirement (HP)
Q : Chip removal amount (cm³/min)
w_{oc} : Cutting width (mm)
v_f : Feed speed (mm/min)
d_{oc} : Depth of cut (mm)
η : Machine efficiency (0,70 ~ 0,85)
K_c : Specific cutting forrce (N/mm²)

Eg. rough value
(Steel : 2.500 ~ 3.000
Cast iron : 1.500)

● Relation between feed rate, work material, specific cutting force

Work-piece No.	Alloy steel	Carbon steel	Cast iron	Aluminum alloy
①	1.800	800	200	–
②	1.400	600	160	–
③	1.000	400	120	–

Values in the table show the following properties:
- Tensile strength (N/mm²) for alloy steel and carbon steel
- Hardness (H_B) for cast iron



● Calculating cutting speed

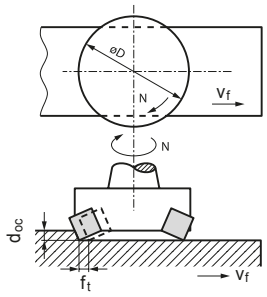
$$v_c = \frac{\pi \times D \times n}{1.000}$$

● Calculating feed rate

$$v_f = f_t \times z \times n$$

$$f_t = \frac{v_f}{z \times n}$$

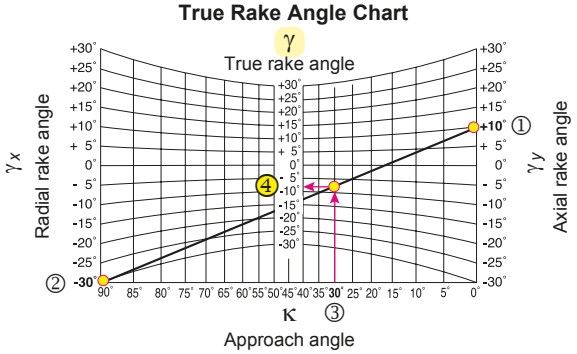
v_c : Cutting speed (m/min)
$\pi \approx 3{,}14$
D : Cutter diameter (mm)
n : Rotation speed (rpm)
v_f : Feed speed (mm/min)
f_t : Feed rate (mm/tooth)
z : Number of teeth



Functions of the Various Cutting Angles

	Description	Code	Functions	Influences
① ②	Axial rake angle Radial rake angle	γ_y γ_x	Controls chip removal direction, effects adhesion of the chips and thrust force etc.	Rake angles can vary from positive to negative (large to small) with typical combinations of positive and negative, positive and positive or negative and negative configurations.
③	Approach angle	κ	Controls chip thickness and chip removal direction	The effect of the small approach angle is to reduce the chip thickness and cutting force.
④	True rake angle (Effective rake angle)	γ	Controls cutting performance and ability to retain a cutting edge	- With a positive (large) angle, cutting ability and adhesion resistance are improved but the strength of the cutting edge is weakened. - With negative (small) angle, the strength of the cutting edge is improved but chips will tend to adhere more easily.
⑤	Inclination angle	λ	Controls chip removal direction	- With a positive (large) angle, the chip removal is satisfactory with less cutting resistance but the strengh of the corner is weaker.
⑥	Wiper flat clearance angle	α_f	Controls surface finish	A smaller clearance angle will produce a better surface finish.
⑦	Clearance angle	α	Controls edge strength, tool life and chattering, etc	

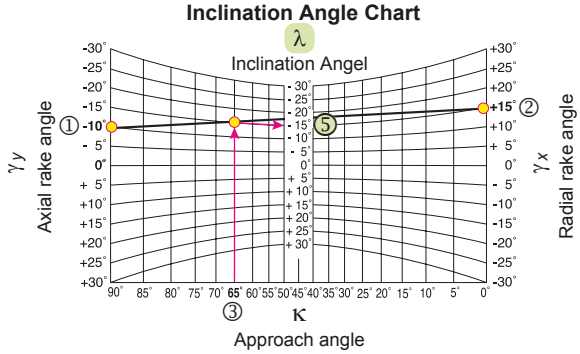
True Rake Angle Chart



Example in using the above chart:		Solution:
① γ_y :	Axial rake angle = +10°	True rake angle
② γ_x :	Radial rake angle = -30°	④ γ = - 8°
③ κ :	Approach angle = 30°	

Formula : $\tan\gamma = \tan\gamma_x \cdot \sin\kappa + \tan\gamma_y \cdot \cos\kappa$

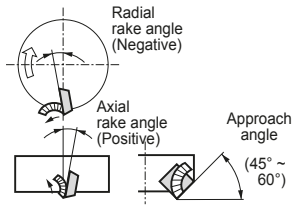
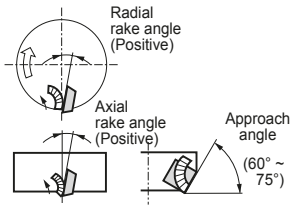
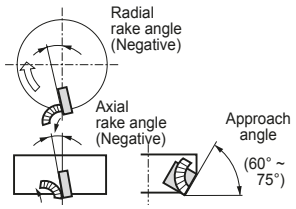
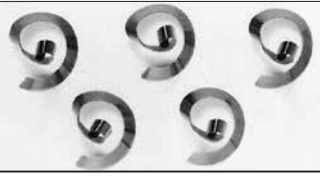
Inclination Angle Chart



Example in using the above chart :		Solution:
① γ_y :	Axial rake angle = -10°	Inclination angle
② γ_x :	Radial rake angle = +10°	⑤ λ = - 15°
③ κ :	Approach angle = 65°	

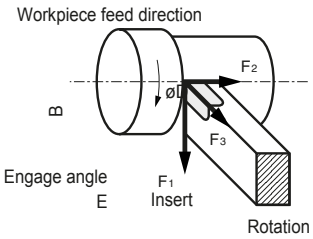
Formula : $\tan\lambda = \tan\gamma_y \cdot \sin\kappa - \tan\gamma_x \cdot \cos\kappa$

Rake Angle Combination

	Negative - Positive Type	Double Positive Type	Double Negative Type
The effects of the various angle configurations with relation to chip formation and chip removal. Chip removal direction Rotation			
Advantage	Excellent chip removal and good cutting action	Good cutting action	Double-sided inserts can be use and higher cutting edge strength
Disadvantage	Only single-sided inserts can be use	Lower cutting edge strength and only single-sided inserts can be use	Dull cutting action
Application	For Steel, Cast iron, Stainless steel, Alloy steel	For general milling of steel For low rigidly work piece	For light milling of cast iron and steel
Typical cutter	WGX, WGC, UFO	DPG	DNX, DGC, DNF
Chips (Eg.) Workpiece: 37Cr4 v_c = 130 m/min f_t = 0.23 mm/tooth d_{oc} = 3 mm			

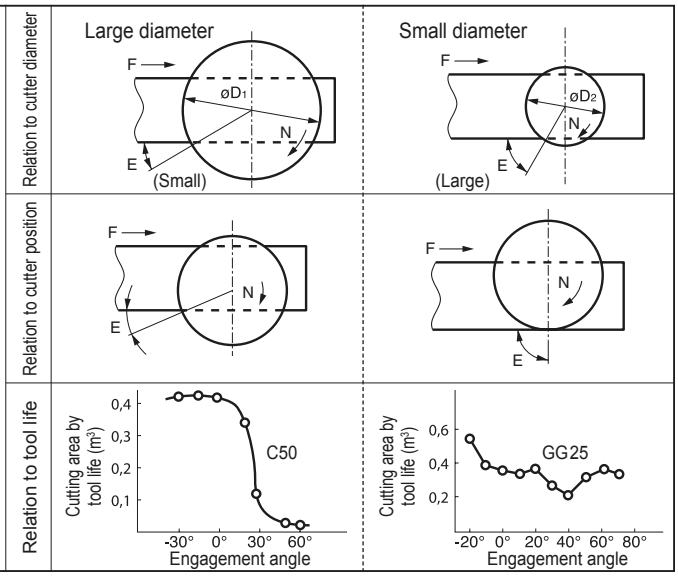
Basics of Milling

■ Relation Between Engage Angle and Tool Life

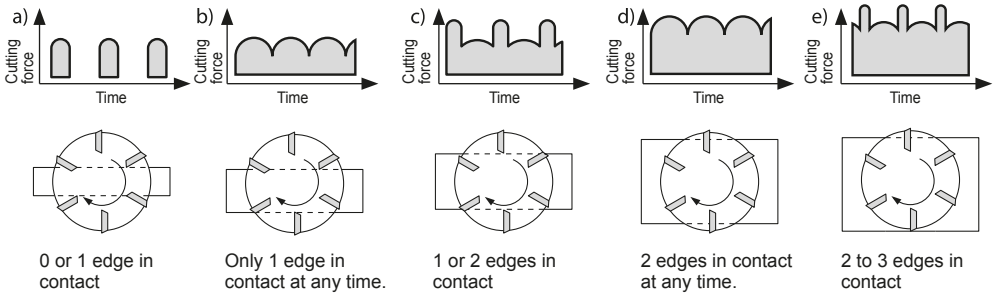


Engage angle denotes the angle by which the full length of the cutting edge comes in contact with the workpiece, with reference to the feed direction. The larger E is, the shorter the tool life.

To change the value of E:
1) Increase the cutter size
2) Shift the position of the cutter



● Relation between the number of simultaneously engaged cutting edges and cutting force:



■ To Improve Surface Roughness

① Milling inserts with wiper flat

When all the cutting edges have wiper flats, a few teeth are intentionally elevated to play the role of a wiper insert.

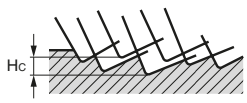
- Insert equipped with straight wiper flat (Face angle: Approx 15' - 1°)
- Insert equipped with curved wiper flat (Eg. curvature R500)

② Integral wiper insert system

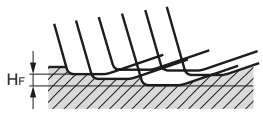
A system to protrude one or two inserts (wiper insert) with a smooth curved edge just a little beyond the other teeth to wipe the milled surface.

- (Applies to WGC, RF types etc.)

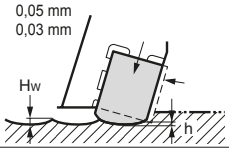
● Surface roughness without wiper flat



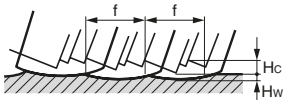
● Surface roughness with straight wiper flat



h : Projected value of wiper insert
Steels : 0,05 mm
Al : 0,03 mm

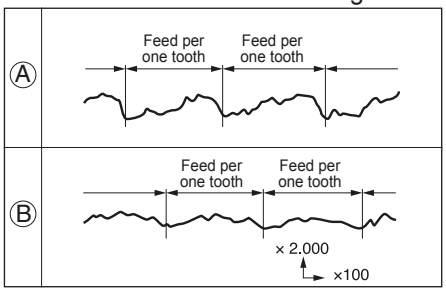


f : Feed rate per revolution



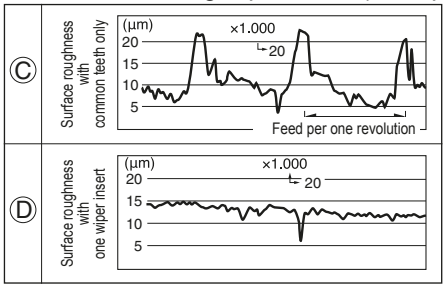
Hc : Surface roughness with only normal teeth
Hw : Surface roughness with wiper insert

● Influence of different face angles on surface finish



- Workpiece: 34CrMo4
- Cutter: DPG 5160 R (Single tooth)
- v_c = 154 m/min
  f_t = 0,234 mm/tooth
  d_{oc} = 2 mm
- Face angle
  Ⓐ : 28'
  Ⓑ : 6'

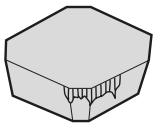
● Effects of having wiper insert (example)

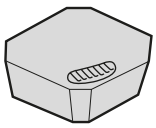


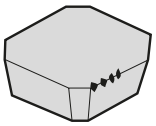
- Workpiece: GG25
- Cutter: DPG 4100 R
- Insert: SPKN 1203
- Axial run-out: 0,015 mm
- Radial run-out: 0,04 mm
- v_c = 105 m/min
- f_t = 0,29 mm/tooth (1,45 mm/rev)

Ⓒ : Only normal teeth
Ⓓ : with 1 wiper insert

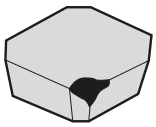
■ Trouble Shooting Guide for Milling

<table>
<tr><th colspan="2">Trouble</th><th colspan="2">Basic Remedies</th><th>Remedy Examples</th></tr>
<tr><td rowspan="5">Cutting Edge Failure</td><td>Excessive Flank Wear
  </td><td>Tool Material

Cutting Conditions</td><td>- Select a more wear resistant grade.
Carbide
P30 ⇨ P20 ⇨ K20 ⇨ K10 ⇨ { Coated / Cermet
- Reduce cutting speeds.
- Increase feedrate.</td><td>- Recommended insert grades
<table><tr><th></th><th>Steel</th><th>Cast Iron</th><th>Non-Ferrous Alloy</th></tr><tr><td>Finishing</td><td>T250A (Cermet)</td><td>ACK200 (Coated Carbide)
BN700 (SUMIBORON)</td><td>DA1000 (SUMIDIA)</td></tr><tr><td>Roughing</td><td>ACP100 (Coated Carbide)</td><td>ACK200 (Coated Carbide)</td><td>DL1000 (Coated Carbide)</td></tr></table></td></tr>
<tr><td>Excessive Crater Wear
  </td><td>Tool Material

Cutting Conditions</td><td>- Select a crater resistant grade.
- Reduce cutting speeds.
- Reduce depth-of-cut and feed rate.</td><td>- Recommended insert grades
<table><tr><th></th><th>Steel</th><th>Cast Iron</th><th>Non-Ferrous Alloy</th></tr><tr><td>Finishing</td><td>T250A (Cermet)</td><td>ACK200 (Coated Carbide)</td><td>DA1000 (SUMIDIA)</td></tr><tr><td>Roughing</td><td>ACP100 (Coated Carbide)</td><td>ACK200 (Coated Carbide)</td><td>DL1000 (Coated Carbide)</td></tr></table></td></tr>
<tr><td>Cutting Edge Chipping
  </td><td>Tool Material

Cutting Conditions

Tool Design</td><td>- Select tougher grade.
P10 ⇨ P20 ⇨ P30
K01 ⇨ K10 ⇨ K20
- Reduce feed rates.
- Select a negative-positive cutter configuration with a large approach angle.
- Reinforce the cutting edge (Honing).
- Select a strong edge insert (G → H).</td><td>- Recommended insert grades
<table><tr><th></th><th>Steel</th><th>Cast Iron</th></tr><tr><td>Finishing</td><td>ACP200 (Coated Carbide)</td><td>ACK200 (Coated Carbide)</td></tr><tr><td>Roughing</td><td>ACP300 (Coated Carbide)</td><td>ACK300 (Coated Carbide)</td></tr></table>
- Recommended cutter: WaveMill WGX type
- Cutting conditions:
Refer to recommended conditions listed in the general catalogue</td></tr>
<tr><td>Partial Fracture of Cutting Edges
  </td><td>Tool Material

Cutting Conditions

Tool Design</td><td>- If it is due to excessive low speeds or very low feed rates, select an adhesion resistant grade.
- If it is due to thermal cracking, select a thermal impact resistant grade.
- Select appropriate conditions with regards to the particular application.
- Select a negative-positive (or negative) cutter configuration with a large approach angle.
- Reinforce the cutting edge (Honing).
- Select a strong edge insert (G → H).
- Increase insert size -
(Thickness in particular).</td><td>- Recommended insert grades
<table><tr><th></th><th>Steel</th><th>Cast Iron</th></tr><tr><td>Roughing</td><td>ACP300
(Coated Carbide)</td><td>ACK300
(Coated Carbide)</td></tr></table>
- Recommended cutter: WaveMill WGX type
- Insert thickness: 3,18 → 4,76mm
- Insert type: Standard → Strong edge type
- Cutting conditions:
Refer to recommended conditions listed in the general catalogue</td></tr>
<tr><td rowspan="4">Others</td><td>Unsatisfactory Machined Surface Finish</td><td>Tool Material

Cutting Conditions

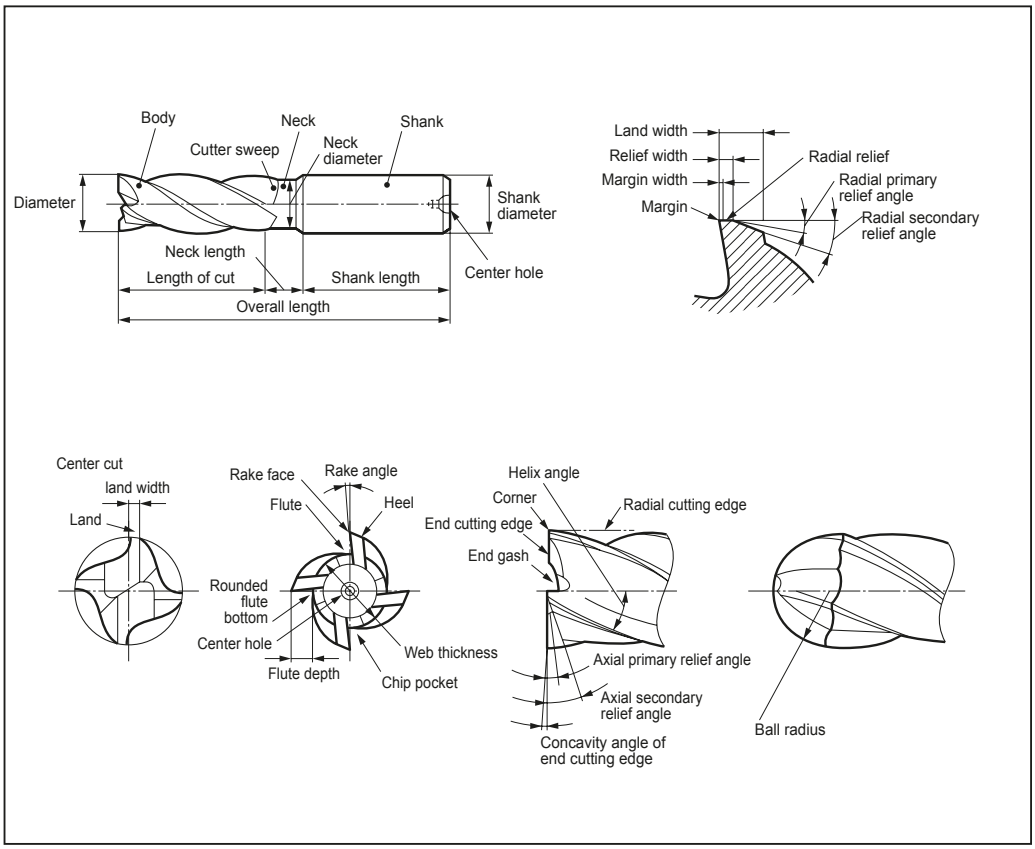
Tool Design</td><td>- Select an adhesion resistant grade.
Carbide → Cermet
- Increase cutting speeds.
- Improve axial run-out of cutting edges.
(Use a cutter with less run-out)
(Attach correct inserts)
- Use wiper inserts.
- Use special purpose cutters designed for finishing.</td><td>- Recommended insert grades
<table><tr><th colspan="2"></th><th>Steel</th><th>Cast Iron</th><th>Non-Ferrous Alloy</th></tr><tr><td>Roughing</td><td>Cutter Insert</td><td>WGX type*
ACP200
(Coated Carbide)</td><td>DGC type*
ACK200
(Coated Carbide)</td><td>FF type*
H1 (Carbide)
DL1000 (Coated Carbide)</td></tr><tr><td>Finishing</td><td>Cutter Insert</td><td>WGC type
T250A
(Cermet)</td><td>FMU type
BN700
(SUMIBORON)</td><td>RF type
DA1000
(SUMIDIA)</td></tr></table>
* marked cutters can be fitted with wiper inserts.</td></tr>
<tr><td>Chattering</td><td>Cutting Conditions
Tool Design

Others</td><td>- Reduce feed rates.
- Select a high rake cutter with sharp cutting edges
- Use an irregular pitched cutter.
- Improve workpiece and cutter clamp rigidity.</td><td>- Recommended cutters:
For steel: WaveMill WGX type
For cast iron: DNX type
For Non-ferrous alloy: High speed cutter for aluminium
RF type</td></tr>
<tr><td>Unsatisfactory Chip Control</td><td>Tool Design</td><td>- Select cutter with good chip removal features.
- Reduce number of teeth.
- Enlarge chip pocket.</td><td>- Recommended cutter: WaveMill WGX type</td></tr>
<tr><td>Edge Chipping on Workpiece</td><td>Tool Design

Cutting Conditions</td><td>- Select a large approach angle.
- Select a sharp cutting edge insert (G → L).
- Reduce feed rates.</td><td>- Recommended cutter: WaveMill WGX type</td></tr>
<tr><td>Burr on Workpiece</td><td>Tool Design
Cutting Conditions</td><td>- Select a cutter with sharp cutting edges.
- Increase feed rates.</td><td>- Recommended cutter: WaveMill WGX type + FG breaker
DGC type + FG breaker</td></tr>
</table>

Basics of Endmilling

Parts of an Endmill



Calculating Cutting Conditions

Cutting speed

$$v_c = \frac{\pi \cdot D \cdot n}{1.000} \qquad n = \frac{1.000 \cdot v_c}{\pi \cdot D}$$

Feed rate

$$v_f = f \times n$$

$$v_f = f_t \times z \times n \qquad f_t = \frac{v_f}{z \times n}$$

Depth of cut (D.O.C)

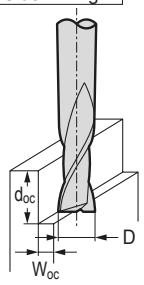
d_{oc} : Axial D.O.C. (depth)
w_{oc} : Radial D.O.C. (width)

Notch width (D_1)

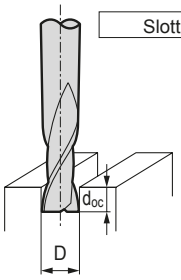
$$D1 = 2 \times \sqrt{2 \times R \times d_{oc} - d_{oc}^2}$$

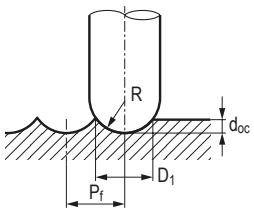
(Ball Endmill)

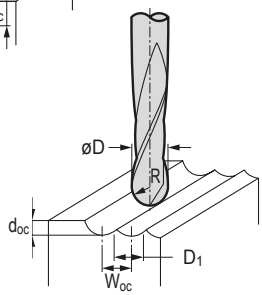
Side milling



Slotting



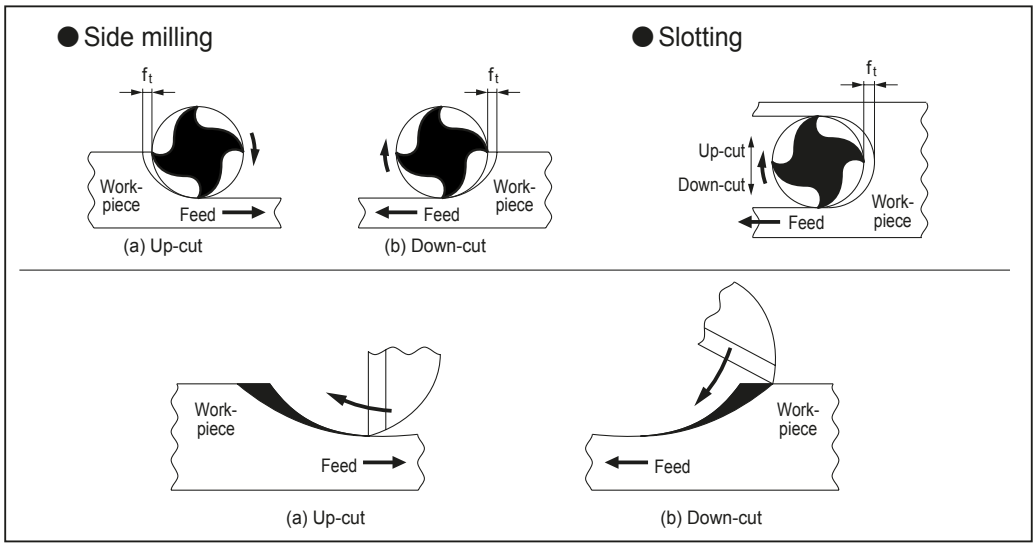


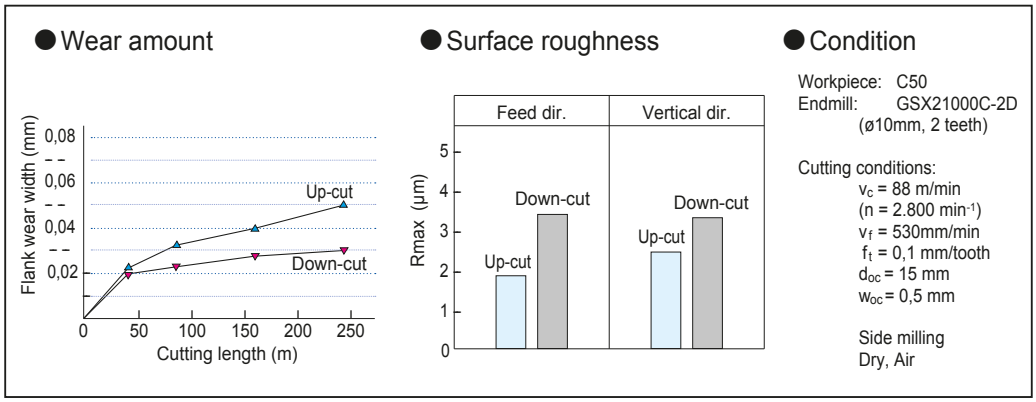


- v_c : Cutting speed (m/min)
- $\pi \approx 3{,}14$
- D : Endmill diameter (mm)
- n : Rotational speed (min^{-1})
- v_f : Feed speed (mm/min)
- f_r : Feed rate per revolution (mm/rev)
- f_t : Feed rate per tooth (mm/tooth)
- z : Number of teeth

● Cutting speed and feedrate are calculated using the same formula as square endmill.

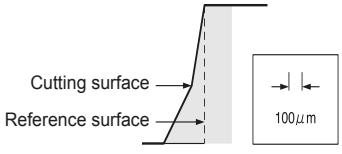
■ Up-cut and Dowm-cut





■ Relation Between Cutting Condition and Deflection

Endmill			Side milling: Work material: Pre-hardened steel (40HRC); Cutting data: v_c = 25m/min, d_{oc} = 12 mm, W_{oc} = 0,8 mm		Slotting: Work material: Pre-hardened steel (40HRC); Cutting data: v_c = 25m/min, d_{oc} = 8 mm, W_{oc} = 8 mm (Up-cut side / Down-cut side)	
Cat. No.	Number of teeth	Helix angle	Feed rate 0,16 mm/rev	Feed rate 0,11 mm/rev	Feed rate 0,05 mm/rev	Feed rate 0,03 mm/rev
			Style	Style	Style	Style
			Up-cut / Down-cut	Up-cut / Down-cut	Up-cut / Down-cut	Up-cut / Down-cut
SSM 2080	2	30°				
SSM 4080	4	30°				



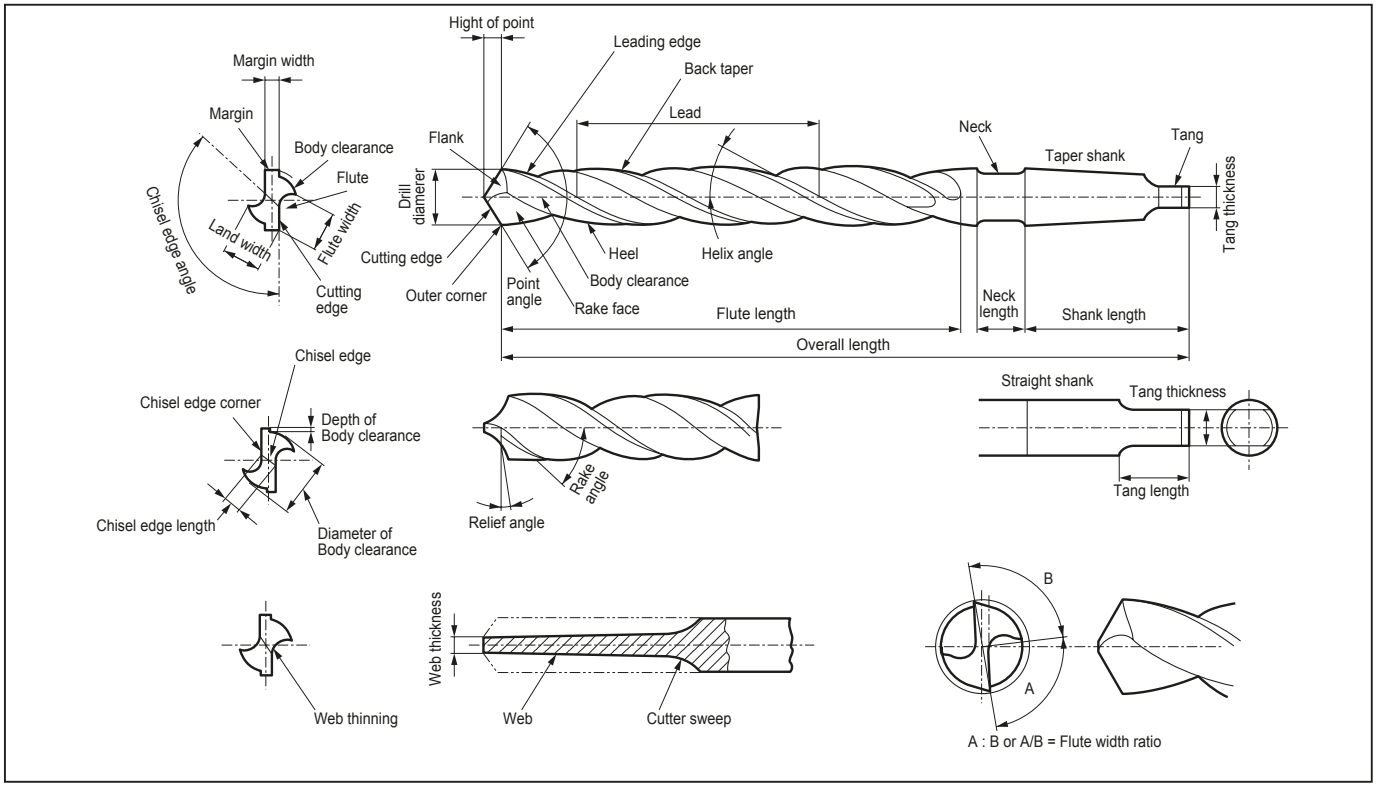
Tool Failure and Remedies

■ Trouble Shooting Guide for Endmilling

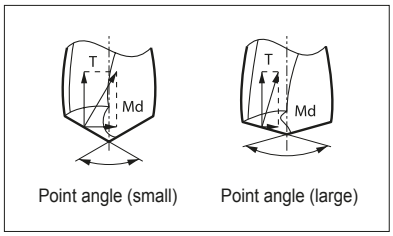
	Failure	Cause		Remedies
Cutting Edge Failure	Excessive Wear	Cutting Conditions	- Cutting speed is too fast - Feed rate is too fast	- Decrease cutting speed and feed rate.
		Tool Shape	- The flank relief angle ist too small	- Change to an appropriate flank relief angle.
		Tool Material	- Insufficient wear resistance	- Select a substrate with more wear resistance - Use a coated tool
	Chipping	Cutting Conditions	- Feed rate ist too fast - Cutting depth is too deep - Tool overhang ist too long	- Decrease cutting speed. - Reduce depth of cut - Adjust tool overhang for correct length
		Machine Area	- Work clamps are weak - Tool is not firmly attached	- Clamp the work piece firmly - Make sure the tool is seated in the chuck properly
	Tool Fracture	Cutting Conditions	- Feed rate ist too fast - Cutting depth is too deep - Tool overhang ist too long - Cutting edge is too long	- Decrease cutting speed. - Reduce depth of cut - Reduce tool overhang as much as possible - Select a tool with a shorter cutting edge
Others	Shoulder Deflection	Cutting Conditions	- Feed rate is too fast - Cutting depth is too deep - Tool overhang is too long - Cutting on the down-cut	- Decrease cutting speed. - Reduce depth of cut - Adjust tool overhang for correct length - Change directions to up-cut
		Tool Shape	- Helix angle is large	- Use a tool with a smaller helix angle
	Unsatisfactory Machined Surface Finish	Cutting Conditions	- Feed rate is too fast	- Decrease cutting speed.
			- Packing of chips	- Use air blow - Use an insert with a larger relief pocket.
	Chattering	Cutting Conditions	- Cutting speed is too fast - Cutting on the up-cut - Tool overhang is too long	- Decrease cutting speed. - Change directions to down-cut - Adjust tool overhang for correct length
		Tool Shape	- Rake angle is large	- Use a tool with an appropriate rake angle
		Machine Area	- Work clamps are weak - Tool is not firmly attached	- Clamp the work piece firmly - Make sure the tool is seated in the chuck properly
	Packing of Chip	Cutting Conditions	- Feed rate is too fast - Cutting depth is too deep	- Decrease cutting speed. - Reduce depth of cut
		Tool Shape	- Too many teeth	- Reduce number of teeth
			- Packing of chips	- Use air blow

Basics of Drilling

■ Parts of a Drill

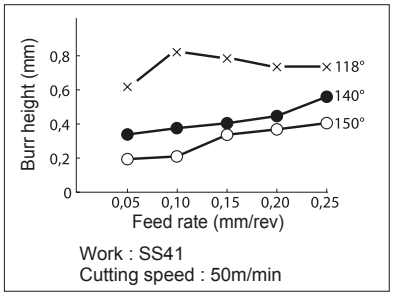


● Point Angle and Force



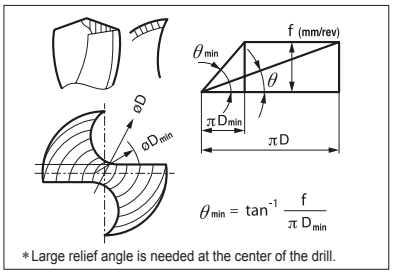
When point angle is large, thrust becomes large but torque becomes small.

● Point Angle and Burr



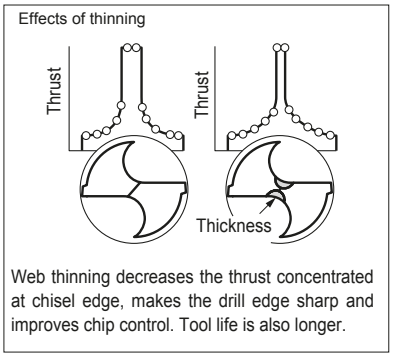
When point angle is large, burr height becomes low.

● Min. Requirement Relief Angle



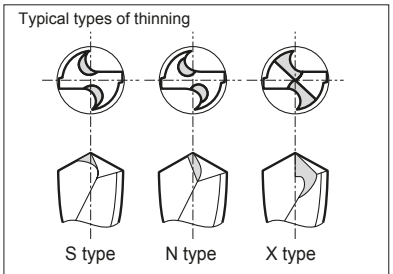
＊Large relief angle is needed at the center of the drill.

● Web Thickness and Thrust



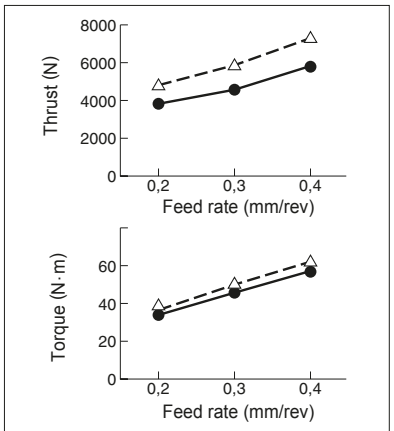
Web thinning decreases the thrust concentrated at chisel edge, makes the drill edge sharp and improves chip control. Tool life is also longer.

● Decrease Chisel Width by Thinning



S type : Standard type used generaly.
N type : Suitable for thin web drills.
X type : For hard-to-cut material or deep hole drilling.

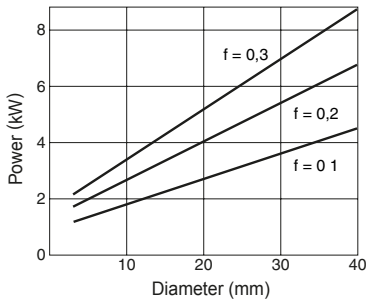
● Width of Edge Threatment and Cutting Force

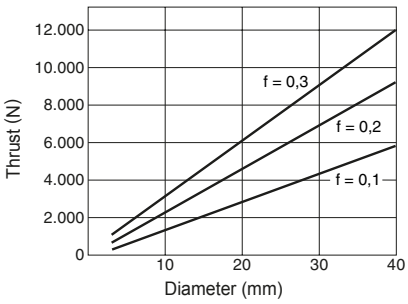


Drill: KDS 215 MAK
Work material: C50 (230HB)
Cutting conditions:
v_c = 50 m/min, Water soluble

Basics of Drilling

■ Reference of Power Requirement and Thrust





Work material:
C48 (220HB)

■ Cutting Condition Selection

● Control cutting force for low rigid machine

The following table shows the relation between edge treatment width and cutting force. If a problem caused by cutting force occurs, reduce either the feedrate or the edge treatment width.

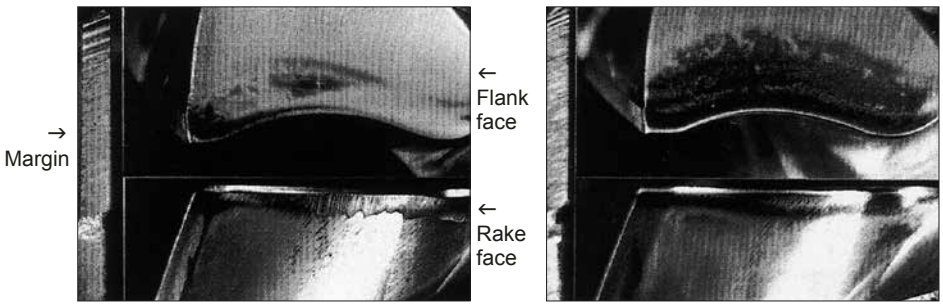
Condition		Edge treatment width			
		0,15mm		0,05mm	
v_c (m/min)	f (mm/rev)	Torque (N• m)	Thrust (N)	Torque (N• m)	Thrust (N)
40	0,38	12,8	2.820	12,0	2.520
50	0,30	10,8	2.520	9,4	1.920
60	0,25	9,2	2.320	7,6	1.640
60	0,15	6,4	1.640	5,2	1.100

Drill : ø10
Work material:
C50 (230HB)

● High speed machining recommendation

When there is surplus capacity with enough machine power and rigidity drilling at normal recommended cutting conditions, we recommend higher drilling speeds.

Wear example

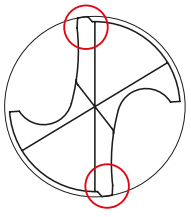


Vc=60m/min　　Vc=120m/min

Work material: C50 (230HB)
Cutting data: f = 0,3 mm/rev
d_{oc} = 50mm
Tool life: 600 holes (Cutting length : 30m)

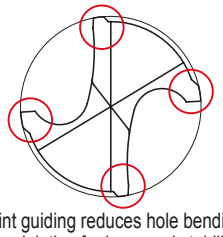
■ Explanation of Margins (Difference between single and double margins)

● Single Margin (2 guides: circled parts)



● Shape used on most drills

● D Double Margin (4 guides: circled parts)

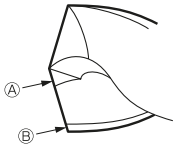


● 4-point guiding reduces hole bending and undulation for improved stability and accuracy during deep hole drilling.

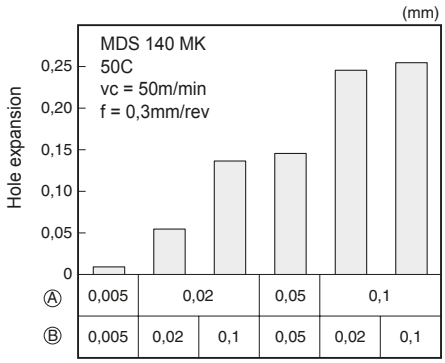
Basics of Drilling

■ Run-out Accuracy

Run-out of the lip height B and thinning point A are important.

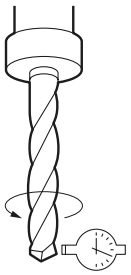


Ⓐ : The run-out accuracy of thinning point
Ⓑ : The difference of lip height

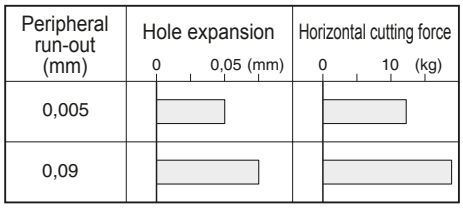


■ Peripheral Run-out Accuracy when Tool Rotates

Drill run-out when mounted on the machine spindle must be within 0,03mm. If the run-out is large, the drilled hole will also be large causing an increase in the horizontal cutting force, which may result in drill breakage if the machine or work clamping is not rigid.



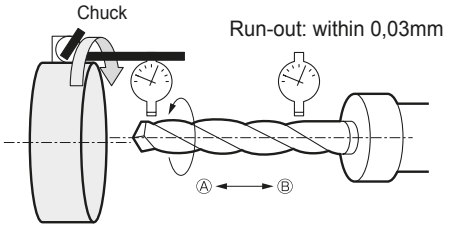
Run-out: within 0,03mm



Drill: MDS120MK
Work material: C50 (230HB)
Cutting data: v_c=50 m/min, f=0,3 mm/rev, d_{oc} =38mm
Water soluble

■ Peripheral Run-out Accuracy when Workpiece Rotates

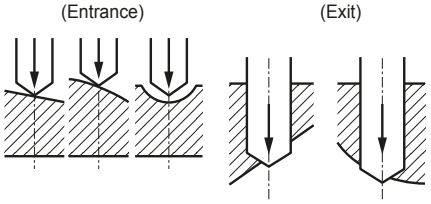
When use on a lathe, run-out at point A must be within 0,03mm, this value must be similar when taken at position B.



■ Influence of Workpiece Surface

● Workpiece with slanted or uneven surface

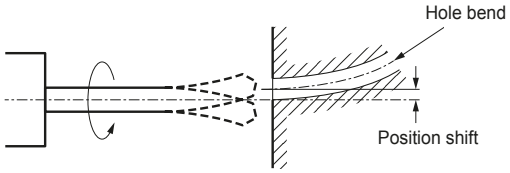
If the surface of the hole entrance or exit is slanted or uneven, decrease the feedrate to 0,1~0,15mm/rev at these points.



■ How to Use Long Drill

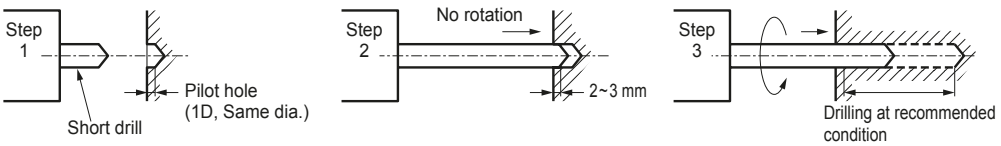
● Problem

When using a long drill (e.g. XHGS type and XHT type), DAK type or SMDH-D type drills at high rotational speeds, the run-out of the drill tip may cause a position shift at the entry point making the drill hole bent and resulting in drill breakage.

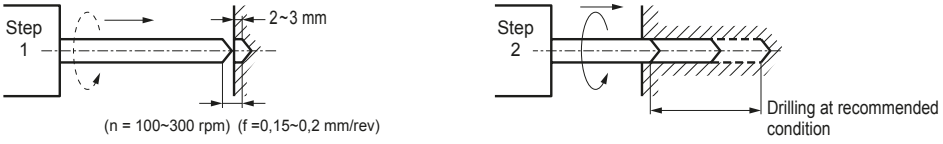


● Remedies

Method 1.



Method 2. Low rotational speed minimizes centrifugal forces and prevents drill bending.

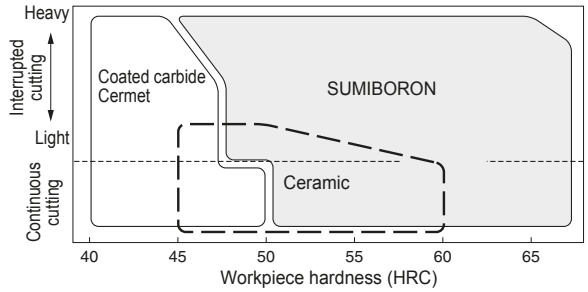


Tool Failure and Remedies

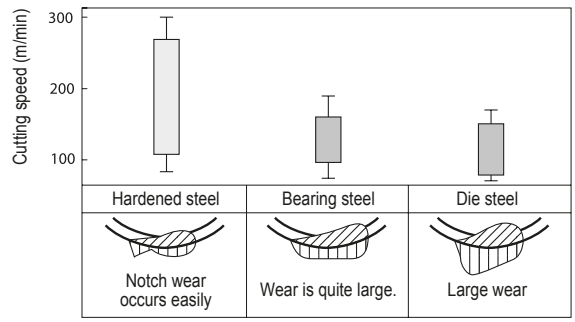
■ Trouble Shooting Guide for Drilling

Failure		Basic Remedies		Remedies Examples
Drill Failure	Excessive Wear on Cutting Edge	Cutting Conditions	- Use higher cutting speeds. - Increase feed rates.	- Vc=80~100m/min - Refer to recommended cutting conditions listed in the general catalogue.
		Cutting Fluid	- Reduce pressure if useing internal coolant. - Use cutting fluid with more lubricity.	- Below 1,5MPa.
	Chisel Point Chipping	Tool Design	- Increase size of chisel width. - Increase amount of honing on cutting edge.	
		Cutting Conditions	- Reduce depth-of cut. - Reduce feed rate at entry point.	- f = 0,05~0,1 mm/rev .
		Others	- Improve workpiece clamping rigidity.	
	Chipping on Peripheral Cutting Edge	Tool Design	- Increase amount of honing on cutting edge. - Reduce the amount of front flank angle.	
		Cutting Conditions	- Reduce cutting speeds. - Increase feed rates.	- Refer to recommended cutting conditions listed in the general catalogue.
		Cutting Fluid Others	- Use cutting fluid with more lubricity. - Improve workpiece clamp rigidity.	
	Margin Wear	Tool Design	- Increase amount of back taper. - Reduce margin width.	
		Cutting Conditions	- Reduce cutting speeds. - Increase feed rates.	- Refer to recommended cutting conditions listed in the general catalogue.
		Cutting Fluid Others	- Use cutting fluid with more lubricity. - Schedule for earlier regrind.	
	Drill Breakage	Tool Design	- Increase amount of back taper. - Reduce margin width.	
		Cutting Conditions	- Reduce cutting speeds.	- Refer to recommended cutting conditions listed in the general catalogue.
		Cutting Fluid Others	- Use cutting fluid with more lubricity. - Improve workpiece clamp rigidity.	
Unsatisfactory Hole Accuracy	Oversized Holes	Tool Design	- Improve overall dril rigidity. (large web, small flute). - Reduce drill point angle.	- 130°~120°
		Cutting Conditions	- Reduce feed rate at entry phase. - Reduce cutting speeds.	- f = 0,05~0,1 mm/rev - Refer to recommended cutting conditions listed in the general catalogue.
		Cutting Fluid Others	- Improve workpiece clamp rigidity. - Improve drill clamp precision. - Improve drill clamp rigidity.	- Drill run-out below 0,02mm
	Poor Surface Finish	Tool Design	- Increase amount of back taper.	
		Cutting Conditions	- Increase cutting speeds.	- Refer to recommended cutting conditions listed in the general catalogue.
		Cutting Fluid	- Use cutting fluid with more lubricity.	
	Holes are Not Straight	Tool Design	- Reduce amount of edge honing.	
		Cutting Conditions	- Reduce feedrates.	- Refer to recommended cutting conditions listed in the general catalogue.
		Others	- Improve workpiece clamp rigidity. - Improve drill clamp precision. - Improve drill clamp ridigity.	- Drill run-out below 0,02mm
Unsatisfactory Chip Control	Packing of Chips	Cutting Conditions	- Increase cutting speeds. - Increase feed rates.	- Refer to recommended cutting conditions listed in the general catalogue.
		Cutting Fluid	- Reduce pressure if using internal coolant.	- Below 1,5MPa.
	Long Stringy Chips	Tool Design	- Reduce amount of edge honing.	
		Cutting Conditions	- Increase feed rates.	- Refer to recommended cutting conditions listed in the general catalogue.
		Cutting Fluid	- Reduce pressure if using internal coolant.	- Below 1,5MPa.

Application Map of the Various Tool Materials

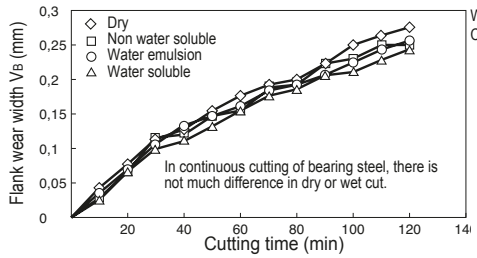


Work Materials and Cutting Speed Recommendations



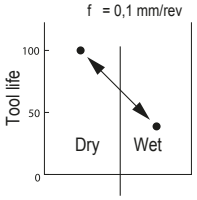
Influence of Coolant on Tool Life

● Continuous cutting



● Interrupted cutting

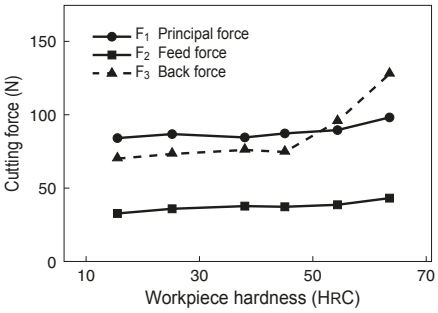
Work material: X155CrVMo12-1
Cutting data: v_c = 100 m/min
d_{oc} = 0,2 mm
f = 0,1 mm/rev

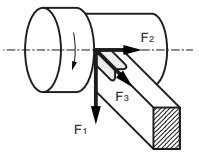


Work material: 100Cr6 (HRC58~62)
Insert: TPGN160304
Cutting data: v_c = 100 m/min
d_{oc} = 0,15 mm
f = 0,1 mm/rev

For continuous cutting, the influence of coolant on tool life is minimal. However for interrupted cutting, coolant will shorten the tool life because of thermal cracking.

Relation Workpiece Hardness and Cutting Forces

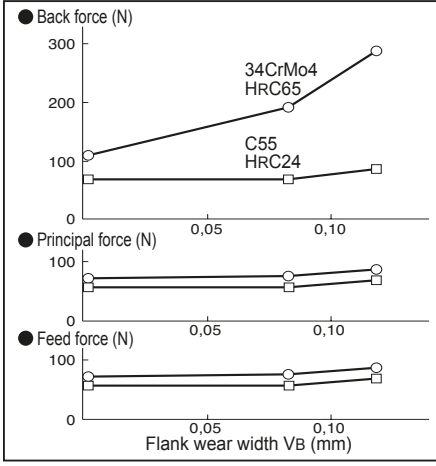




Work material: C105W1
Cutting data: v_c = 120 m/min
d_{oc} = 0,2 mm
f = 0,1 mm/rev

Back force increases substantially for harder work materials.

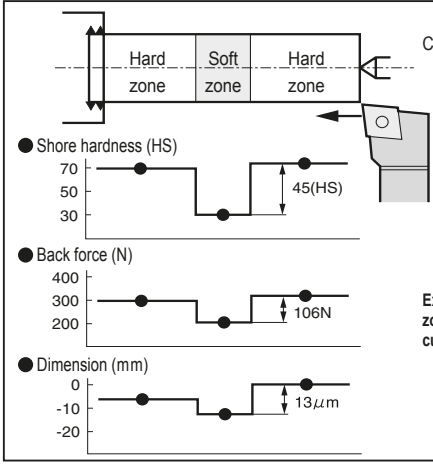
Relation between Flank Wear and Cutting Force



Cutting data: v_c = 80 m/min
d_{oc} = 0,15 mm
f = 0,1 mm/rev

For hardened steel machining, back force increases substantially due to the expansion of flank wear.

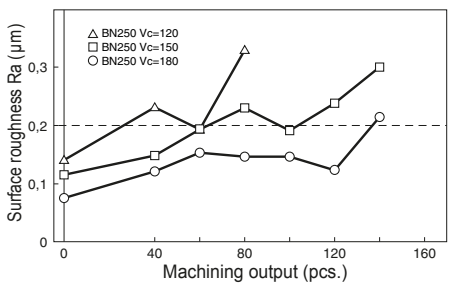
Workpiece Hardness on Cutting Force and Accuracy



Cutting data: v_c = 120 m/min
d_{oc} = 0,5 mm
f = 0,3 mm/rev
dry

External dimension at the soft zone is smaller due to lower cutting forces.

Relation Cutting Speed and Surface Roughness



Work material: 25CrMo4 (HRC58~62)
Holder: MTXNR2525
Insert: TNMA160408NU

Cutting data:
v_c= 120, 150, 180 m/min
d_{oc} = 0,15 mm
f = 0,045 mm/rev
Wet

At high cutting speeds, surface roughness is more stable.

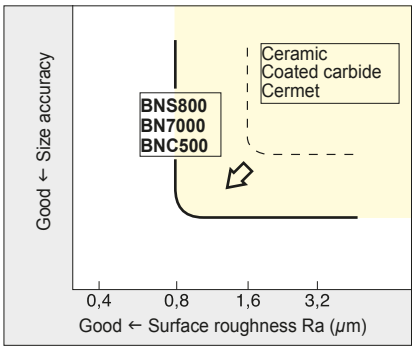
Improvement of Surface Roughness by Altering the Feedrate

Constant Feedrate	Variable Feedrate
Previous edge position f Stationary notch location	f Shifting notch location
	

Varying the feedrate spreads the notch location over a larger area, surface finish improves and notch wear decreases.

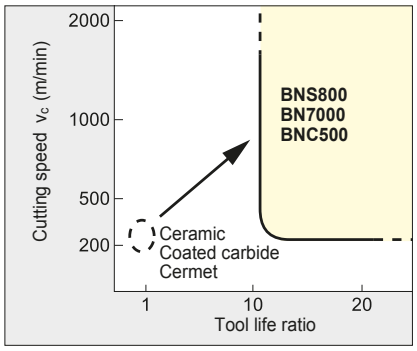
■ Advantages of Using SUMIBORON for Cast Iron Machining

● Higher accuracy

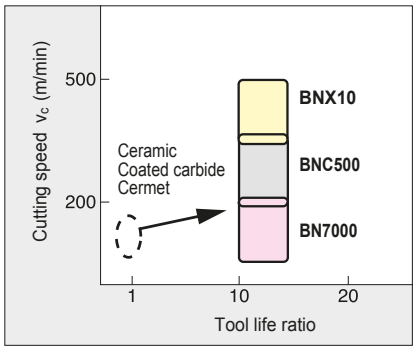


● Longer tool life at higher cutting speeds

GG: Grey cast iron

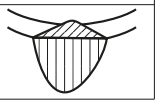


GGG: Ductile cast iron

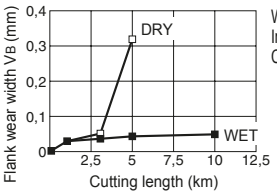


■ Turning

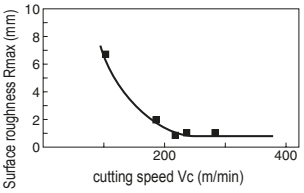
● Cast iron structure and wear shape examples

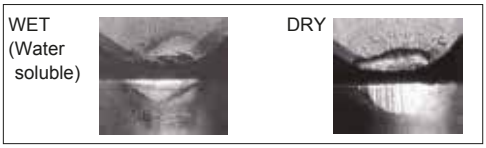
		GG	GGG
Structure			
	Matrix	Pearlite	Pearlite + Ferrite
Tool wear shape	Wet		
	Dry	 Crater wear	

($v_c \geq 200$ m/min)



Work material: GG25
Insert: SNGN120408(BN500)
Cutting data: v_c = 450 m/min
d_{oc} = 0,25 mm
f = 0,15 mm/rev
Continuous cutting





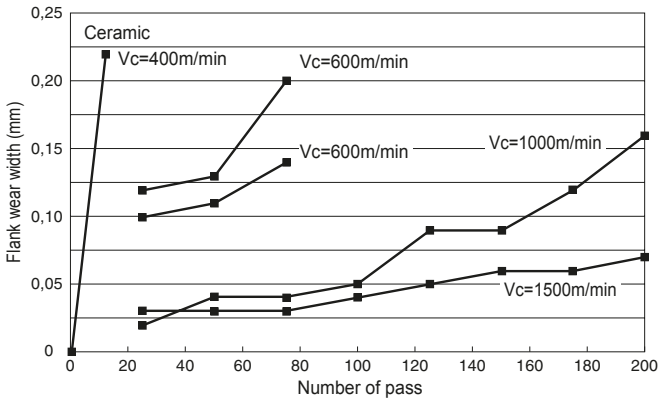
For machining cast iron with SUMIBORON, cutting speeds (Vc) should be 200m/min and above. WET cutting is recommended.

Machine: N/C lathe
Work material: GG25 (HB200)
Holder: MTJNP2525
Insert: TNMA160408(BN500)
Cutting data: v_c = 110~280 m/min
d_{oc} = 0,1 mm
f = 0,1 mm/rev
WET

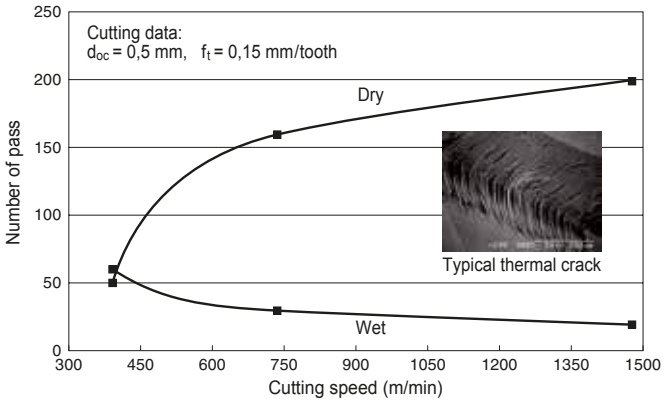
■ Milling

SUMIBORON BN Finish Mill EASY

- High speed machining Vc = 2000m/min
- Surface Roughness Rz=3,2 (Ra=1,0)
- Running cost is reduced because of economical insert
- Easy insert setting with the aid of a setting gauge
- Safe, anti-centrifugal force construction for high speed conditions

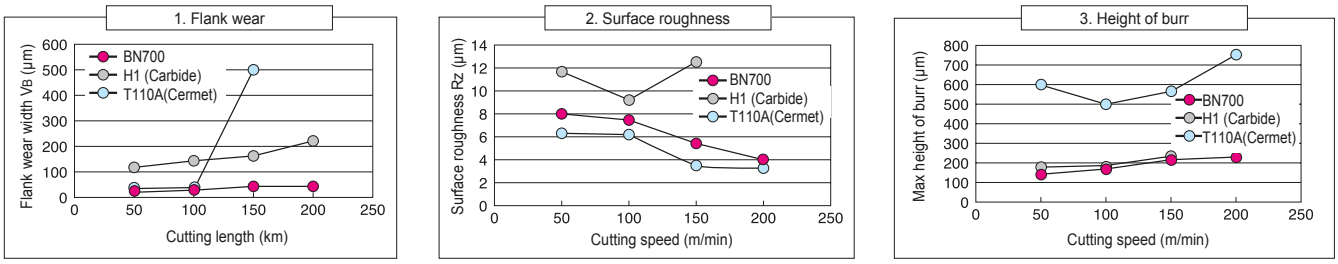


Work material: GG25
Tool material: BN700
Cutting data: d_{oc} = 0,5 mm, f_t = 0,1 mm/tooth, DRY



Dry cutting is recommended for high speed milling of cast iron with SUMIBORON.

■ Powder Metal



Work material: SMF4040 equivalent
Process details: ø100~300mm heavy interrupted facing with grooves and drilled holes. (after 40 passes)
Insert: TNGA160404 Cutting data: f=0.1mm/rev, d=0.1mm, Wet

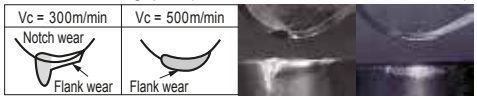
For general power metal components, carbide and cermet grades can perform up to Vc=100m/min. However, around Vc=120m/min, wear becomes rapid and surface roughness deteriorates with increased burrs.
SUMIBORON on the other hand, exhibits stability and superior wear resistance, burr prevention and surface roughness especially at high speeds.

■ Heat Resistive Alloy

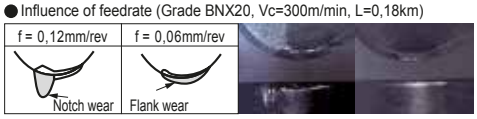
● Ni based alloy

Typical tool damage of CBN tool when cutting Inconel 718

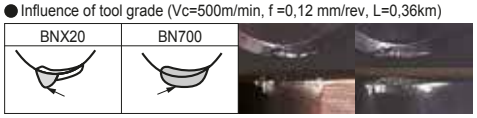
● Influence of cutting speed (Grade BNX20, f =0,06 mm/rev., L=0,72km)



● Influence of feedrate (Grade BNX20, Vc=300m/min, L=0,18km)



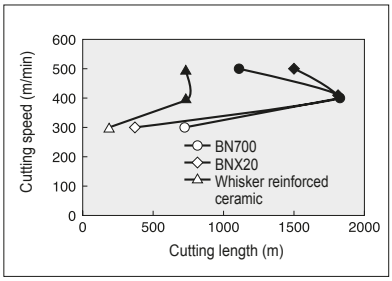
● Influence of tool grade (Vc=500m/min, f =0,12 mm/rev, L=0,36km)



Cutting data: d_{oc} = 0,3mm, WET

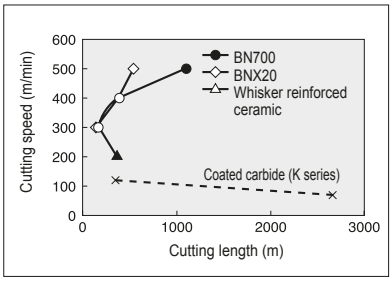
0,5mm

Cutting data: f = 0,06mm/rev, d_{oc} = 0,3mm, WET



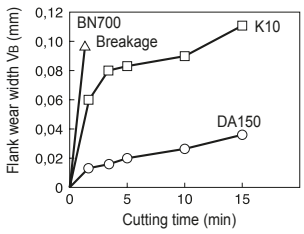
Tool life criteria
Notch wear = 0,25mm
Or flank wear = 0,25mm
BNX20 is recommended for high speed and low feedrate condition.
BN700 is recommended for cutting speeds below 240m/min

Cutting data: f = 0,12mm/rev, d_{oc} = 0,3mm, WET

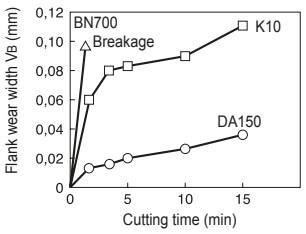


Tool life criteria
Notch wear = 0,25mm
Or flank wear = 0,25mm
BN700 is recommended for cutting at high feedrates.
(Over f=0,1mm/rev)

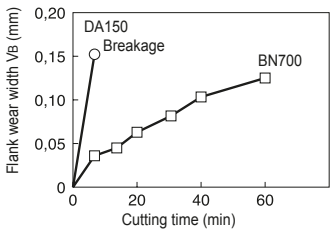
● Ti based alloy



Work Material: Ti-6Al-4V
Insert: DNM120404NF
Cutting data: v_c = 100m/min, d_{oc} = 0,1mm, f = 0,05mm/rev, WET
SUMIDIA positive type inserts are extremely good for Ti alloy, due to high cutting edge strength and high wear resistance.



Work Material: Ti-6Al-4V
Insert: DNM120404NF
Cutting data: v_c = 100m/min, d_{oc} = 0,1mm, f = 0,05mm/rev, WET
SUMIDIA positive type inserts are extremely good for Ti alloy, due to high cutting edge strength and high wear resistance.

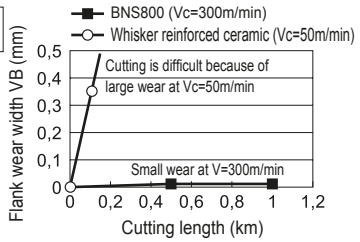


Work Material: Ti-6Al-4V
Insert: DNMA150412
Cutting data: Vc = 120m/min, d_{oc} = 0,3mm, f =0,25mm/rev, WET
Negative type insert BN700 is excellent for high efficiency cutting. (For large depth of cut and high feedrates)

● Hard facing alloys

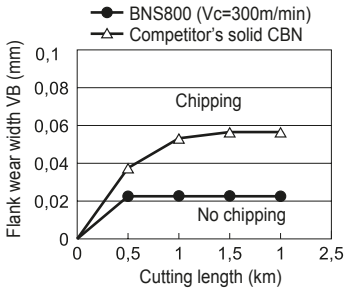
Work material: Colmonoy No.6 (Ni-based self fluxing alloy)

Insert: SNGN090308
Cutting data:
v_c = 50, 300 m/min
f = 0,1 mm/rev
d_{oc} = 0,2 mm
Wet



Work material: Stellite SF-20 (Co-based Self-fluxing alloy)

Insert: SNGN090308
Cutting data:
v_c = 50 m/min
f = 0,1 mm/rev
d_{oc} = 0,2 mm
Dry

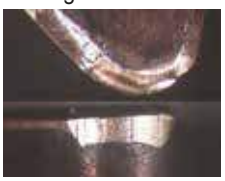


BNS800
(Vc=300m/min, After 2km Cutting)

Whisker reinforced ceramic
(Vc=50m/min, After 10m Cutting)

BNS800
(After 2km of cutting)

Competitor's solid CBN
(After 2km of cutting)

	Damage		Remedies
Cutting Edge Failure	Large flank wear 	Tool material Tool design Cutting condition	☞ Select a more wear resistant grade. ☞ Reduce the cutting force. ☞ Reduce the NL width and angle. ☞ Positive inserts preferred ☞ Check the cutting speed. ☞ Reduce the cutting speed to less than 200m/min. ☞ Higher feed rate reduces the overall tool-to-work contact time.
	Large crater wear 	Tool material Tool design Cutting condition	☞ Crater wear resistant grades are recommended. Continuous ~ Light interrupted cutting = BNC2010 Light ~ Medium interrupted cutting = BNX20 Medium ~ Heavy interrupted cutting = BNX25 ☞ Determine the cutting edge geometry after inspecting the used inserts closely. ☞ Sharpen the cutting edge to prevent crater wear. ☞ Strengthen the cutting edge to prevent crater breakage. ☞ Check the cutting speed. ☞ Reduce the cutting speed to less than 200m/min. ☞ Higher feed rates are recommended.
	Breakage at bottom of crater 		
	Flaking 	Tool material Tool design Cutting condition	☞ Flaking is caused by high back forces and back force is related to flank wear. ☞ Select a more wear resistant grade. ☞ A sharper cutting edge helps prevent flaking. ☞ Reduce the NL angle and width ☞ Positive inserts preferred ☞ Reduce flank wear with lower speed and higher feed rates. ☞ Reducing tool-to-work contact time effectively reduces flank wear.
	Chipping at notch position 	Cutting condition	☞ If surface finish is affected, consider using the “Variable Feed rate” method to improve finishing. ☞ For other cases, use remedies similar to that for normal wear.
	Chipping at notch position 	Tool material Tool design Cutting condition	☞ Caused by impact shocks to the cutting edge. Chattering may also be a contributing factor. ☞ Select a tougher grade. ☞ Strengthen the cutting edge. ☞ Large NL angle, Honing. ☞ Higher feed rates are recommended to lessen the number of impacts.
	Chipping at nose position 	Tool material Tool design Cutting condition	☞ Caused by impact shocks to the cutting edge. Chattering may also be a contributing factor. ☞ Select a tougher grade. ☞ Strengthen the cutting edge. ☞ Large NL angle, Honing. ☞ Higher feedrates are recommended to lessen the number of impacts.
	Thermal crack 	Cutting condition Tool design Tool material	☞ Thermal shocks generate vertical crack lines across the cutting edge. Completely dry condition is recommended. ☞ If dry condition machining is already observed, then reduction of cutting temperatures and cutting force is necessary. ☞ Decrease cutting speed, feedrate, depth of cut. ☞ Sharpen cutting edge. ☞ Select more thermal conductivity grade.

■ Steel and Non-Ferrous Metal Symbols Chart

● Carbon Steels

JIS	AISI	DIN
S10C	1010	C10
S15C	1015	C15
S20C	1020	C22
S25C	1025	C25
S30C	1030	C30
S35C	1035	C35
S40C	1040	C40
S45C	1045	C45
S50C	1049	C50
S55C	1055	C55

● Ni-Cr-Mo Steels

SNCM220	8620	21NiCrMo2
SNCM240	8640	—
SNCM415	—	—
SNCM420	4320	—
SNCM439	4340	40NiCrMo6
SNCM447	—	34NiCrMo6

● Cr Steels

SCr415	—	15CrMo5
SCr420	5120	20Cr4
SCr430	5130	34Cr4
SCr435	5132	37Cr4
SCr440	5140	41Cr4
SCr445	5147	—

● Cr-Mo Steels

SCM415	—	15CrMo5
SCM420	—	20CrMo5
SCM430	4131	25CrMo4
SCM435	4137	34CrMo4
SCM440	4140	42CrMo4
SCM445	4145	—

● Mn Steels and Mn-Cr Steels for Structural Use

SMn420	1522	—
SMn433	1534	—
SMn438	1541	—
SMn443	1541	—
SMnC420	—	—
SMnC443	—	—

● Cr-Mo Steels

SK1	—	—
SK2	W1-11 1/2	—
SK3	W1-10	C105W1
SK4	W1-9	—
SK5	W1-8	C80W1
SK6	—	C80W1
SK7	—	C70W2

● High Speed Steels

JIS	AISI	DIN
SKH2	T1	—
SKH3	T4	S18-1-2-5
SKH10	T15	S12-1-4-5
SKH51	M2	S6-5-2
SKH52	M3–1	—
SKH53	M3–2	S6-5-3
SKH54	M4	—
SKH56	M36	—

● Alloy Tool Steels

SKS11	F2	—
SKS51	L6	—
SKS43	W2-9 1/2	—
SKD1	D3	X210Cr12
SKD11	D2	X155CrVMo12-1
SKD61	—	X40CrVMo5-1

● Grey Cast Iron

FC100	No 20B	GG-10
FC150	No 25B	GG-15
FC200	No 30B	GG-20
FC250	No 35B	GG-25
FC300	No 45B	GG-30
FC350	No 50B	GG-35

● Nodular Cast Iron

FCD400	60-40-18	GGG-40
FCD450	—	GGG-40.3
FCD500	80-55-06	GGG-50
FCD600	—	GGG-60
FCD700	100-70-03	GGG-70

● Ferritic Stainless Steels

SUS405	405	X10CrAl13
SUS429	429	—
SUS430	430	X6Cr17
SUS430F	430F	X7CrMo18
SUS434	434	X6CrMo17 1

● Martensitic Stainless Steels

SUS403	403	—
SUS410	410	X10Cr13
SUS416	416	—
SUS420JI	420	X20Cr13
SUS420F	420F	—
SUS431	431	X20CrNi17 2
SUS440A	440A	—
SUS440B	440B	—
SUS440C	440C	—

● Austenitic Stainless Steels

JIS	AISI	DIN
SUS201	201	—
SUS202	202	—
SUS301	301	X12CrNi17 7
SUS302	302	—
SUS302B	302B	—
SUS303	303	X10CrNiS18 9
SUS303Se	303Se	—
SUS304	304	X5CrNiS18 10
SUS304L	304L	X2CrNi19 11
SUS304NI	304N	—
SUS305	305	X5CrNi18 12
SUS308	308	—
SUS309S	309S	—
SUS310S	310S	—
SUS316	316	X5CrMo17 12 2
SUS316L	316L	X2CrNiMo17 13 2
SUS316N	316N	—
SUS317	317	—
SUS317L	317L	X2CrNiMo18 16 4
SUS321	321	X6CrNiTi18 10
SUS347	347	X6CrNiNb18 10
SUS384	384	—

● Heat Resisting Steels

SUH31	—	—
SUH35	—	—
SUH36	—	X53CrMnNi21 9
SUH37	—	—
SUH38	—	—
SUH309	309	—
SUH310	310	CrNi2520
SUH330	N08330	—

● Ferritic Heat Resisting Steels

SUH21	—	CrAl1205
SUH409	409	X6CrTi12
SUH446	446	—

● Martensitic Heat Resisting Steels

SUH1	—	X45CrSi9 3
SUH3	—	—
SUH4	—	—
SUH11	—	—
SUH600	—	—

References

■ Hardness Scale Comparision Chart

● Approx. metric value and Brinell hardness of steel

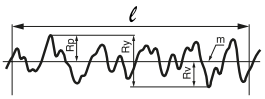
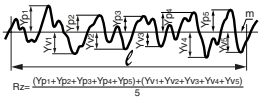
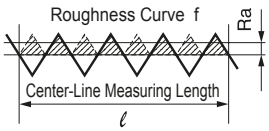
Brinell Hardness 10mm Ball 3.000kgf (HB)	Rockwell Hardness				Vickers Hardness 50kgf	Shore Hardness	Traverse Rupture Strength (N/mm^2)
	„A“ Scale Diamond, brale 60kgf (HRA)	„B“ Scale 100kgf 1/10“ Ball (HRB)	„C“ Scale Diamond, brale 150kgf (HRC)	„D“ Scale Diamond, brale 100kgf (HRD)	(HV)	(HS)	
—	85,6	—	68,0	76,9	940	97	—
—	85,3	—	67,5	76,5	920	96	—
—	85,0	—	67,0	76,1	900	95	—
767	84,7	—	66,4	75,7	880	93	—
757	84,4	—	65,9	75,3	860	92	—
745	84,1	—	65,3	74,8	840	91	—
733	83,8	—	64,7	74,3	820	90	—
722	83,4	—	64,0	73,8	800	88	—
712	—	—	—	—	—	—	—
710	83,0	—	63,3	73,3	780	87	—
698	82,6	—	62,5	72,6	760	86	—
684	82,2	—	61,8	72,1	740	—	—
682	82,2	—	61,7	72,0	737	84	—
670	81,8	—	61,0	71,5	720	83	—
656	81,3	—	60,1	70,8	700	—	—
653	81,2	—	60,0	70,7	697	81	—
647	81,1	—	59,7	70,5	690	—	—
638	80,8	—	59,2	70,1	680	80	—
630	80,6	—	58,8	69,8	670	—	—
627	80,5	—	58,7	69,8	667	79	—
601	79,8	—	57,3	68,7	640	77	—
578	79,1	—	56,0	67,7	615	75	—
555	78,4	—	54,7	66,7	591	73	2055
534	77,8	—	53,5	65,8	569	71	1985
514	76,9	—	52,1	64,7	547	70	1890
495	76,3	—	51,0	63,8	528	68	1820
477	75,6	—	49,6	62,7	508	66	1730
461	74,9	—	48,5	61,7	491	65	1670
444	74,2	—	47,1	60,8	472	63	1585
429	73,4	—	45,7	59,7	455	61	1510
415	72,8	—	44,5	58,8	440	59	1460
401	72,0	—	43,1	57,8	425	58	1390
388	71,4	—	41,8	56,8	410	56	1330
375	70,6	—	40,4	55,7	396	54	1270
363	70,0	—	39,1	54,6	383	52	1220
352	69,3	(110,0)	37,9	53,8	372	51	1180
341	68,7	(109,0)	36,6	52,8	360	50	1130
331	68,1	(108,5)	35,5	51,9	350	48	1095

Brinell Hardness 10mm Ball 3.000kgf (HB)	Rockwell Hardness				Vickers Hardness 50kgf	Shore Hardness	Traverse Rupture Strength (N/mm^2)
	„A“ Scale Diamond, brale 60kgf (HRA)	„B“ Scale 100kgf 1/10“ Ball (HRB)	„C“ Scale Diamond, brale 150kgf (HRC)	„D“ Scale Diamond, brale 100kgf (HRD)	(HV)	(HS)	
321	67,5	(108,0)	34,3	50,1	339	47	1060
311	66,9	(107,5)	33,1	50,0	328	46	1025
302	66,3	(107,0)	32,1	49,3	319	45	1005
293	65,7	(106,0)	30,9	48,3	309	43	970
285	65,3	(105,5)	29,9	47,6	301	—	950
277	64,6	(104,5)	28,8	46,7	292	41	925
269	64,1	(104,0)	27,6	45,9	284	40	895
262	63,6	(103,0)	26,6	45,0	276	39	875
255	63,0	(102,0)	25,4	44,2	269	38	850
248	62,6	(101,0)	24,2	43,2	261	37	825
241	61,8	100,0	22,8	42,0	253	36	800
235	61,4	99,0	21,7	41,4	247	35	785
229	60,8	98,2	20,5	40,5	241	34	765
223	—	97,3	(18,8)	—	234	—	—
217	—	96,4	(17,5)	—	228	33	725
212	—	95,5	(16,0)	—	222	—	705
207	—	94,6	(15,2)	—	218	32	690
201	—	93,8	(13,8)	—	212	31	675
197	—	92,8	(12,7)	—	207	30	655
192	—	91,9	(11,5)	—	202	29	640
187	—	90,7	(10,0)	—	196	—	620
183	—	90,0	(9,0)	—	192	28	615
179	—	89,0	(8,0)	—	188	27	600
174	—	87,8	(6,4)	—	182	—	585
170	—	86,8	(5,4)	—	178	26	570
167	—	86,0	(4,4)	—	175	—	560
163	—	85,0	(3,3)	—	171	25	545
156	—	82,9	(0,9)	—	163	—	525
149	—	80,8	—	—	156	23	505
143	—	78,7	—	—	150	22	490
137	—	76,4	—	—	143	21	460
131	—	74,0	—	—	137	—	450
126	—	72,0	—	—	132	20	435
121	—	69,8	—	—	127	19	415
116	—	67,6	—	—	122	18	400
111	—	65,7	—	—	117	15	385

1) Figures within the ( ) are not commonly used
2) Rockwell A, C and D scales utilises a diamond brale
3) 1 N/mm^2 = 1 MPa

■ Finished Surface Roughness

● Types of Surface Roughness Measurements

Types	Symbol	Method of Determination	Descriptive Figure
Maximum Height	※1) Ry	This is the value (expressed in µm) measured from the deepest valley to the highest peak of the reference line, ℓ, extracted from the profile. (Disregard unusually high peaks and deep valleys as they are considered as flaws.)	
Ten-point Mean Roughness	※2) Rz	From the profile, extract a portion to be the reference line, ℓ. Select the 5 highest peak and 5 deepest valleys. Measure the distance between the two lines and express it in µm. (1 µm = 0,001mm)	
Calculated Roughness	Ra	This method is to obtain a center line between the peaks and valleys within the reference line, ℓ. Fold along the center line to superimpose the valleys against the peaks. (Shaded portions with dashed outline on the right figure). Take the total shaded area and divided it by ℓ in µm.	

Designated values of the above types of surface roughness, standard reference length values and the triangular symbol classifications are shown on the table on the right.

※1) Ry : According to new **JIS B 0601**:2001 (Old symbol: Rz)
※2) Rz : According to new **JIS B 0601**:2001 (Old symbol: Rz_{JIS})

Designated values for ※1) Ry	Designated values for ※2) Rz	Designated values for Ra	Standard reference length values, ℓ (mm)	Triangular Symbols
(0,05S) 0,1S 0,2S 0,4S	(0,05Z) 0,1Z 0,2Z 0,4Z	(0,013a) 0,025a 0,05a 0,10a	—	▽▽▽▽
0,8S	0,8Z	0,20a	0,25	
1,6S 3,2S 6,3S	1,6Z 3,2Z 6,3Z	0,4a 0,8a 1,6a	0,8	▽▽▽
12,5S (18S) 25S	12,5Z (18Z) 25Z	3,2a 6,3a	2,5	▽▽
(35S) 50S (70S) 100S	(35Z) 50Z (70Z) 100Z	12,5a 25a	—	▽
(140S) 200S (280S) 400S (560S)	(140Z) 200Z (280Z) 400Z (560Z)	(50a) (100a)	—	—

Remarks: The designated values in the brackets do not apply unless otherwise stated.

Spare Parts

P

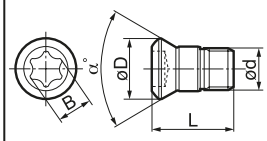
P1 ~ P8

Screw P2-P4
Lever Pin, Shim, Nut P4-P6
Shim Pin, Eccentric Pin P7
Wrench P8

Screw

■ Screw

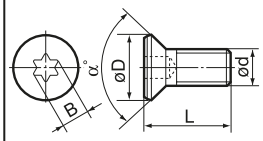
High Precision Screw



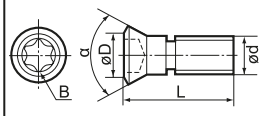
Cat. No.	Stock	Dimensions (mm) d	Pitch	L	D	B	α°	(N·m)
BFTG0408F	●	M4	0,5	7,5	5,7	T15	61	3,4
BTTG0409F	●	M4	0,5	8,4	6,15	T15	61	3,4
BFTG0513F	●	M5	0,5	13	6,8	T20	61	5,0
BFTG0617F	●	M6	0,75	16,5	8	T25	61	7,5
BFTG0621F	●	M6	0,75	21	9,5	T25	61	7,5
BFTG0825F	●	M8	0,75	24,5	12	T25	61	7,5

Torx Flat Head Screw

Cat. No.	Stock	Dimensions (mm) d	Pitch	L	D	B	α°	(N·m)
BFTX02506		M						
BFTX02508	●	M2,5	0,45	7,5	3,45	T8	60	-
BFTX0309		M3	0,5	8,8	4,2	T10	60	-
BFTX03508	●	M3,5	0,6	8	5,1	T10	52	2,0
BFTX03584	●	M3,5	0,6	7,4	5,2	T15	60	3,0
BFTX03588	●	M3,5	0,6	8,8	5,2	T15	60	3,4
BFTX0408	●	M4	0,7	8	5,5	T15	60	-
BFTX0414	●	M4	0,7	14,5	5,5	T15	60	3,0
BFTX0515		M5	0,8	15	7	T20	60	-
BFTX0613		M6	1,0	13	9	T25	60	-
BFTX0615		M6	1,0	15	9	T25	60	-
BFTX0617		M6	1,0	17	9	T25	60	-

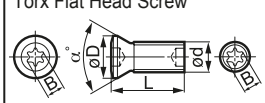


Cat. No.	Stock	Dimensions (mm) d	Pitch	L	D	B	α°	(N·m)
BFTX0203A	●	M2	0,4	3	2,7	T6	90	0,5
BFTX0204A	●	M2	0,4	4,3	2,7	T6	90	0,5
BFTX0305A	●	M3	0,5	5,3	4,3	T10	90	-
BFTX0306A	●	M3	0,5	5,8	4,3	T10	90	2,0
BFTX0307A	●	M3	0,5	6,8	4,3	T10	90	2,0
BFTX0407A	●	M4	0,7	7,3	5,6	T15	90	3,4
BFTX0410A	●	M4	0,7	10,3	5,6	T15	90	3,4
BFTX0509A	●	M5	0,8	9,3	6,9	T20	90	5,0



Cat. No.	Stock	Dimensions (mm) d	Pitch	L	D	B	α°	(N·m)
BFTX01604N	●	M1,6	0,35	4,2	2,4	T6	60	0,2
BFTX0203N	●	M2	0,4	3	2,7	T6	60	0,5
BFTX0204N	●	M2	0,4	4,3	2,7	T6	60	0,5
BFTX02205N	●	M2,5	0,45	4,5	3	T6	60	0,5
BFTX02505N	●	M2,5	0,45	4,5	3,45	T8	60	1,1
BFTX02506N	●	M2,5	0,45	5,5	3,45	T8	60	1,5
BFTX02508NV	●	M2,5	0,45	7,5	3,5	T8	60	1,5
BFTX0306N	●	M3	0,5	5,8	4,2	T10	60	2,0
BFTX0307N	●	M3	0,5	6,5	4,2	T10	60	2,0
BFTX0309N	●	M3	0,5	9	4,2	T10	60	3,0
BFTX0312N		M3	0,5	12	5,4	T10	60	-
BFTX03509N	●	M3,5	0,6	8,5	4,9	T10	60	-
BFTX0406N	●	M4	0,7	6	5,6	T15	60	-
BFTX0407N	●	M4	0,7	7	5,6	T15	60	3,0
BFTX0409N	●	M4	0,7	9	5,6	T15	60	3,4
BFTX0412N	●	M4	0,7	12	5,5	T15	60	3,0
BFTX0509N	●	M5	0,8	9	7	T20	60	5,0
BFTX0511N	●	M5	0,8	11,5	7	T20	60	5,0
BFTX0513N	●	M5	0,8	13	7	T20	60	5,0
BFTX0515N	●	M5	0,8	15	7	T20	60	-
BFTX0615N	●	M6	1,0	15	9	T25	60	5,0
BFTX0619N	❍	M6	1,0	19	9	T25	60	5,0

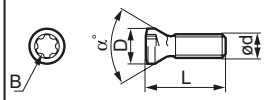
Torx Flat Head Screw



Cat. No.	Stock	Dimensions (mm) d	Pitch	L	D	B	α°	(N·m)
BFTX0410T8L	●	M4	0,7	9,6	5,6	T8	60	1,1
BFTX0410T8R	●							

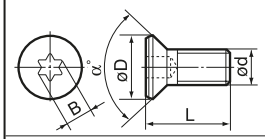
■ Screw

Torx Plus Flat Head Screw



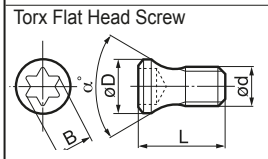
Cat. No.	Stock	Dimensions (mm) d	Pitch	L	D	B	α°	(N·m)
BFTX01804IP	●	M1,8	0,35	3,7	2,45	6IP	60	0,5
BFTX02505IP	●	M2,5	0,45	4,5	3,45	8IP	60	-
BFTX02506IP	●	M2,5	0,45	5,5	3,45	8IP	60	-
BFTX0305IP	●	M3	0,5	5,3	3,8	8IP	60	2,0
BFTX0306IP	●	M3	0,5	6	3,8	8IP	60	2,0
BFTX0307IP		M3	0,5	7	4,3	10IP	55	2,0
BFTX03512IP	●	M3,5	0,6	11,5	5,3	15IP	60	3,0
BFTX03584IP	●	M3,5	0,6	7,4	5,1	15IP	60	-
BFTX03510IP08	●	M3,5	0,6	10	5,3	8IP	60	-
BFTX03510IP15	●	M3,5	0,6	10	5,3	15IP	60	-
BFTX0407IP	●	M4	0,7	8,0	5,6	15IP	60	3,0
BFTX0409IP	●	M4	0,7	9,0	5,6	15IP	60	3,0
BFTX0412IP	●	M4	0,7	12	5,5	15IP	56	3,0
BFTX0418IP	●	M4	0,7	18	5,5	15IP	60	-
BFTX04513IP20	●	M4,5	0,75	13,1	6,8	20IP	60	-
BFTX0511IP	●	M5	0,8	11,5	7	20IP	60	-
BFTX0513IP	●	M5	0,8	13	7	20IP	60	-
BFTX0615IP	●	M6	1,0	15	9	25IP	60	-

Torx Flat Head Screw



Cat. No.	Stock	Dimensions (mm) d	Pitch	L	D	B	α°	(N·m)
BFTX03510SD	❑	M3,5	0,6	10	5,3	T10	60	2,0
BFTX03517SD		M3,5	0,6	17	5,3	T10	60	2,0
BFTX0517SD	❑	M5	0,8	17	7,2	T20	60	5,0
BFTX0618SD		M6	1,0	18		T25	60	7,5

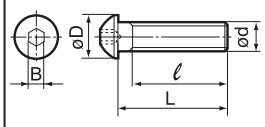
Torx Flat Head Screw



Cat. No.	Stock	Dimensions (mm) d	Pitch	L	D	B	α°	(N·m)
BFTY02205	●	M2,2	0,45	5,0	3,05	T7	60	-
BFTY02206	●	M2,2	0,45	5,6	3,05	T7	60	1,0

Button Head Cap Screw

Hexagonal Hole Type



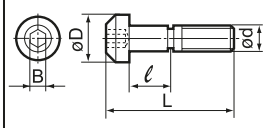
T Type with Torx Hole

(BH410T)

Cat. No.	Stock	Dimensions (mm) d	Pitch	L	ℓ	D	B	(N·m)
BH0304		M3	0,5	4	Full	5,5	2	-
BH0306	●	M3	0,5	6	Full	5,5	2	-
BH0308 (FBUP3-A0-9)	●	M3	0,5	8	Full	5,5	2	1,0
BH0310	●	M3	0,5	10	Full	5,5	2	-
BH03504		M3,5	0,6	4	Full	7	2	-
BH0408		M4	0,7	8	Full	6	2,5	-
BH0410T	❑	M4	0,7	10	Full	7,5	T15	-
BH0415	❑	M4	0,7	15	Full	7,5	2,5	-
BH0510		M5	0,8	10	Full	9,5	3	-
BH0516	●	M5	0,8	16	14,4	9,5	3	-
BH0616	●	M6	1,0	16	14	10,5	4	-
BH0620	●	M6	1,0	20	Full	10,5	4	-
BH0824R		M8	1,25	24	20	12	4	-
BH0824L		M8	1,25	24	20	12	4	-
BH0825	❑	M8	1,25	25	22,5	14	5	-
BH0830R		M8	1,25	30	26	12	4	-
BH0830L		M8	1,25	30	26	12	4	-
BH0832		M8	1,25	32	29,5	14	5	-
BH1030R		M10	1,5	30	26	14	5	-
BH1030L		M10	1,5	30	26	14	5	-
BH1036R		M10	1,5	36	32	14	5	-
BH1036L		M10	1,5	36	32	14	5	-

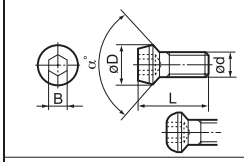
■ Screw

Phillip Head Cap Screw



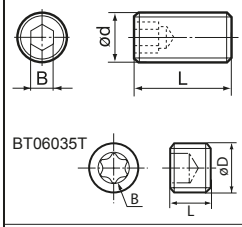
Cat. No.	Stock	Dimensions (mm) d	Pitch	L	ℓ	D	B	N·m
BHA0525	●	M5	0,8	25,5	9,5	8,5	3	4,0
BHA0625	●	M6	1,0	30	11,3	10,5	4	4,5
BHA0834	❑	M8	1,25	34,2	12,7	12,0	5	-
BHE0407	❑	M4	0,7	9,5	2	5,7	2,5	1,8
BHE0510	❑	M5	0,8	13	3	7,7	3	2,7

Button Head Screw



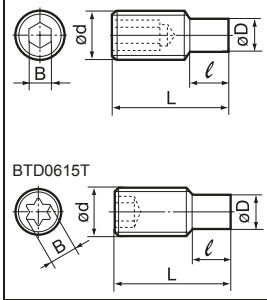
Cat. No.	Stock	Dimensions (mm) d	Pitch	L	D	B	α°	N·m
BHF0203L		M2	0,4	4	3	1,5	90	
BHF0203B		M2	0,4	5,5	3,5	1,5	90	
BHF0306R		M3	0,5	6,3	4,2	2	90	1,0
BHF0308R		M3	0,5	8	4,2	2	90	1,0
BHF0623	❑	M6	1,0	23	12	4	90	7,0

Set Screw



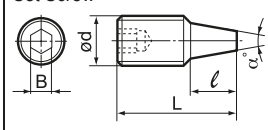
Cat. No.	Stock	Dimensions (mm) d	Pitch	L	D	B	α°	N·m
BT0306		M3	0,5	6	-	1,5	-	-
BT0310	❑	M3	0,5	10	-	1,5	-	-
BT0404	●	M4	0,7	4	-	2	-	-
BT0506	●	M5	0,8	6	-	2,5	-	-
BT0510	❑	M5	0,8	10	-	2,5	-	-
BT0610		M6	1,0	10	-	3	-	-
BT0612		M6	1,0	12	-	3	-	-
BT0620		M6	1,0	20	-	3	-	-
BT06035T		M6	1,0	3,5	-	T15	-	-

Set Screw



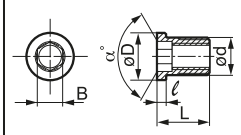
Cat. No.	Stock	Dimensions (mm) d	Pitch	L	ℓ	D	B	N·m
BTD0408		M4	0,7	8	2	2,8	2	-
BTD0410		M4	0,7	10	2	2,8	2	-
BTD0412		M4	0,7	12	2	2,8	2	-
BTD0508		M5	0,8	8	3	3,5	2,5	-
BTD05F09		M5	0,5	9	2	4	T15	-
BTD0510	❑	M5	0,8	10	3	3,5	2,5	3,0
BTD0518		M5	0,8	18	4	3,5	2,5	-
BTD0609	●	M6	1,0	9	2	4	3	-
BTD0615		M6	1,0	15	5	4	3	-
BTD0618		M6	1,0	18	5	4	3	-
BTD0620		M6	1,0	20	5	4	3	-
BTD0812		M8	1,25	12	2	5	4	-
BTD0818		M8	1,25	18	6	5	4	-
BTD0820		M8	1,25	20	6	5	4	-
BTD0825		M8	1,25	25	8,5	5	4	-
BTD0615T		M6	1,0	15	5	4,3	T20	-

Set Screw



Cat. No.	Stock	Dimensions (mm) d	Pitch	L	ℓ	D	B	α°	N·m
BTT0407	●	M4	0,5	7	2,6	2	60	-
BTT0411	●	M4	0,5	11	2,6	2	60	-
BTT0511		M5	0,8	11	5	2	20	-
BTT0615		M6	1,0	15	6	2,5	20	

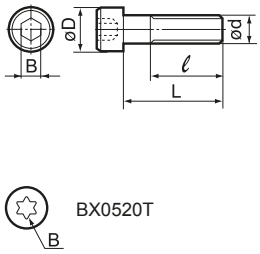
Special Hollow Screw



Cat. No.	Stock	Dimensions (mm) d	Pitch	L	ℓ	D	B	N·m
BW0507F	●	M5	0,5	7	1,2	6,3	3,5	-
BW0609F		M6	0,75	9	1,5	7,7	4	-
BW0508F-SD		M5	0,5	8	1,2	6,3	3,5	
BW0810F-SD	❑	M8	0,75	10	1,8	10	5	
BW0912F-SD		M9	0,75	12				

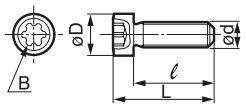
■ Screw

Cap Screw



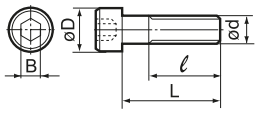
Cat. No.	Stock	Dimensions (mm) d	Pitch	L	ℓ	D	B	N·m
BX0304		M3	0,5	4	Full	5,5	2,5	-
BX0308		M3	0,5	8	Full	5,5	2,5	-
BX0315		M3	0,5	15	Full	5,5	2,5	-
BX0320		M3	0,5	20	Full	5,5	2,5	-
BX0408		M4	0,7	8	Full	7	3	-
BX0410		M4	0,7	10	Full	7	3	-
BX0414	●	M4	0,7	14	Full	7	3	-
BX0425		M4	0,7	25	20	7	3	-
BX0508	●	M5	0,8	8	Full	8,5	4	-
BX0510	●	M5	0,8	10	Full	8,5	4	-
BX0512	●	M5	0,8	12	Full	8,5	4	-
BX0515	❍	M5	0,8	15	Full	8,5	4	-
BX0520	●	M5	0,8	20	Full	8,5	4	5,0
BX0520T	●	M5	0,8	20	16	8,5	T20	-
BX0615	❑	M6	1,0	15	Full	10	5	-
BX0620	❍	M6	1,0	20	Full	10	5	-
BX0622	●	M6	1,0	22	18	10	5	-
BX0625		M6	1,0	25	18	10	5	-
BX0820		M8	1,25	20	Full	13	6	-

Cap Screw (Torx Plus)



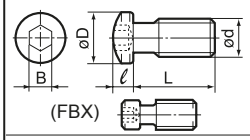
Cat. No.	Stock	Dimensions (mm) d	Pitch	L	ℓ	D	B	N·m
BXD02208IP	●	M2,2	0,45	7,5	5,7	3,5	8IP	-
BXD02509IP	●	M2,5	0,45	9	7	4,1	10IP	-
BXD03011IP	●	M3	0,5	10,5	8	4,9	15IP	-
BXD03512IP	●	M3,5	0,6	11,5	8,8	5,5	15IP	-
BXD04014IP	●	M4	0,7	12,5	9,5	6	20IP	-
BXD04515IP	●	M4,5	0,75	14,3	10,8	6,8	25IP	-

Cap Screw



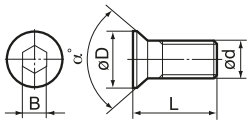
Cat. No.	Stock	Dimensions (mm) d	Pitch	L	ℓ	D	B	N·m
EHBX0512	●	M5	0,8	12	10,5	8	4	-

Fastener Bolt



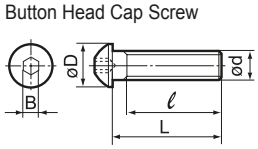
Cat. No.	Stock	Dimensions (mm) d	Pitch	L	ℓ	D	B	N·m
FBH0512	●	M5	0,8	12	2	7,3	3	-
FBX0811	●	M8	1,25	11,1	4,9	8,5	4	-
FBX0817	●	M8	1,25	17,1	4,9	8,5	4	-

Flat Head Screw



Cat. No.	Stock	Dimensions (mm) d	Pitch	L	ℓ	B	α°	N·m
FBUP2-A0-8	❑	M3	0,5	10	5,5	2	82	1,0
FBUP3-A0-8		M3,5	0,6	12	7	2	82	1,0
FBUP4-A0-8		M5	0,8	15	9,3	3	82	2,7
BFX0307R		M3	0,5	7	4	2	60	1,0
BFX0407R		M4	0,7	6,5	5,8	2,5	90	1,8
BFX0410R		M4	0,7	9,5	5,8	2,5	90	1,8
BFX0508		M5	0,8	8	7,5	3	90	2,7
BFX0511R		M5	0,8	10,5	7,5	3	90	2,7
BFX0611R		M6	1,0	11	9,5	3	90	2,7

Button Head Cap Screw

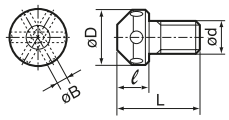


Cat. No.	Stock	Dimensions (mm) d	Pitch	L	ℓ	D	B	N·m
FBUP3-A0-9	●	M3	0,5	8	Full	5,5	2	1,0

Screw, Lever Pin

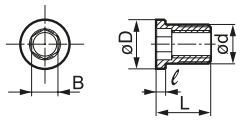
■ Screw

Axial adjustment Screw



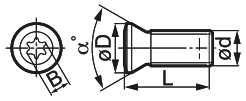
Cat. No.	Stock	Dimensions (mm) d	Pitch	L	ℓ	D	B	N·m
FMJ	●	M4	0,5	15	5	6	3	-
FMUJ	●	M4	0,7	17	6,5	6	1	-
RFJ	❑	M4	0,7	12	6	6	2	-
SRFJ	❑	M4	0,7	17	6,5	6	2	-

Special Hollow Screw



Cat. No.	Stock	Dimensions (mm) d	Pitch	L	ℓ	D	B	N·m
KGBS1111	●	M5	0,5	8	1,2	6	3,5	
KGBS1221	●	M6	0,75	9	1,5	7,5	4,5	

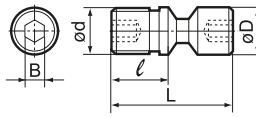
Torx Flat Head Screw



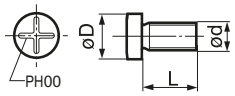
Cat. No.	Stock	Dimensions (mm) d	Pitch	L	D	B	α°	N·m
KSS1111	●	3,5	0,6	11	5,2	T15	55	3,5
KSS1221	●	4,5	0,75	12	6,6	T15,3	55	4,5

Screw for Lever Lock

(LCS2B)



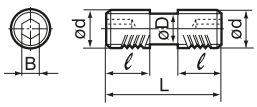
Cat. No.	Stock	Dimensions (mm) d	Pitch	L	ℓ	D	B	N·m
LCS2B		M3	0,5	10	3,05	3,6	2	-
LCS3	●	M6	1,0	17	10	6	2,5	-
LCS3B-SD	●	M5	0,8	9,5	4,2	5	2	-
LCS3DB-SD	●	M5	0,8	12	6	5	2	-
LCS3S		M6	1,0	15	10	6	2,5	-
LCS3TB-SD	●	M6	1,0	16,7	9,6	6	2,5	-
LCS3TE	●	M6	1,0	15,5	8,5	6	2,5	-
LCS4	●	M8	1,0	21	10	8	3	-
LCS4B-SD	●	M6	1,0	13,4	9	6	2,5	-
LCS41BS-SD	●	M8	1,0	17	9,3	8	3	-
LCS42BS-SD	●	M8	1,0	20,7	9,8	8	3	-
LCS4CA	●	M8	1,0	17,5	10	8	3	-
LCS5	●	M8	1,0	25	12	8	3	-
LCS5B-SD	❑	M8	1,0	20,5	12,3	8	3	-
LCS5DB-SD	❑	M8	1,0	21,1	11,4	8	3	-
LCS6	❑	M10	1,0	27,2	14,4	9,8	4	-
LCS6B-SD	●	M10	1,0	27,2	14,4	10	4	-
LCS10	●	M5	0,8	14,5	8,5	5	2	-
LCS12	●	M6	1,0	17	9,6	6	2,5	-
LCS16	●	M6	1,0	21	13,6	6	2,5	-
LCS20	●	M8	1,0	23,5	13,2	8	3	-
LCS25		M10	1,0	30	17,4	10	4	-
LCS32		M12	1,0	36	19,3	12	5	-



Cat. No.	Stock	Dimensions (mm) d	Pitch	L	-	D	-	N·m
MIB1.6-2	●	M1,6	0,35	2,0	-	2,4	-	0,2
MIB1.6-2.5	●	M1,6	0,35	2,5	-	2,4	-	0,2
MIB1.6-3	●	M1,6	0,35	3,0	-	2,4	-	0,2

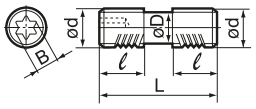
■ Double Screw

Double Screw



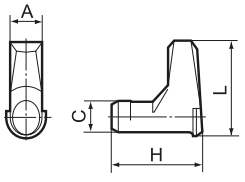
Cat. No.	Stock	Dimensions (mm) d	Pitch	L	ℓ	D	B	N·m
WB4-8		M4	0,7	7,5	3	3,0	2	-
WB5-10	●	M5	0,8	10	4	3,8	2,5	-
WB5-12	●	M5	0,8	12	5	3,8	2,5	-
WB6-13	❑	M6	1,0	13	5	4,5	3	-
WB6-16	●	M6	1,0	16	6	4,5	3	-
WB6-20	❑	M6	1,0	20	8,5	4,5	3	-
WB6-30		M6	1,0	30	12	4,5	3	-
WB8-20		M8	1,25	20	8,5	6,2	4	-
WB8-24		M8	1,25	24	8,5	6,2	4	-
WB8-30	●	M8	1,25	30	11,5	6,2	4	-
WB8F-30	❑	M8	1,0	30	11,5	6,2	4	-

Torx Double Screw

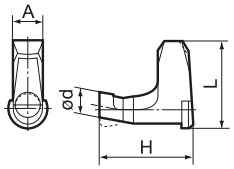


Cat. No.	Stock	Dimensions (mm) d	Pitch	L	ℓ	D	B	N·m
WB6-16T	❑	M6	1,0	16	6	4,5	T20	-
WB7-15T	●	M7	1,0	15	5,5	5	T25	-
WB7F-15T	●	M7	0,75	15	8,5	5,5	T25	-
WB7F-20TL	●	M7	0,75	20	8,5	5,5	T25	-
WB8-22T	●	M8	1,25	22	8,5	6,2	T27	-
WB8-22TL		M8	1,25	22	8,5	6,2	T27	-
WB8-30T	●	M8	1,25	30	11,5	6,2	T27	-
WB8-30TL		M8	1,25	30	11,5	6,2	T27	-
WB8R-16T	❑	M8	1,25	14	5,5	6,2	T27	-

■ Lever Pin



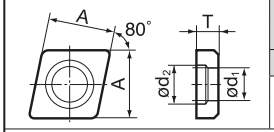
Cat. No.	Stock	Dimensions (mm) A	H	L	C			
LCL3		3,7	12	10	3,6			
LCL3-SD	●	3,7	12	10	3,55			
LCL3C-SD	❑	3,1	7,8	9,9	3,1			
LCL3D-SD	●	3,7	11,5	12	3,55			
LCL3DB-SD	●	3,1	9,4	11,5	3,1			
LCL3S		3,7	10,6	10	3,6			
LCL3T-SD	●	2,6	6,3	7,2	2,15			
LCL4		4,7	14	14,55	4,7			
LCL4-SD	●	4,65	13,2	13,35	4,7			
LCL4C-SD	●	4,65	10	13,35	4,7			
LCL4D-SD	●	4,65	14,8	16	4,7			
LCL4T-SD	●	4,65	13,2	13,35	4,7			
LCL5		6	17	17,1	6			
LCL5-SD	●	6	17,3	16,65	6			
LCL5C-SD	❑	7,5	18,1	20,5	7,5			
LCL6-SD	●	7,5	21	20,5	7,5			
LCL8		8,6	25,4	25,4	8,6			



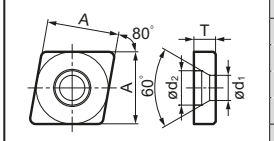
LCL06	●	2,5	6,28	7,0	2			
LCL09	●	3,5	9,3	10,75	3			
LCL10	●	3,4	11,8	10,8	3			
LCL12	●	3,7	13,4	12,9	3,5			
LCL16	●	4,6	17,6	18,4	4,4			
LCL20	❑	6	18,9	20,4	5,6			
LCL32		8,5	26,8	29,8	8			

Shim

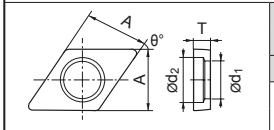
Shim



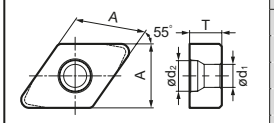
Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		
CCS09T3	●	8,525	2,38	5,4	6,4		



Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		
CNS1204	●	12,57	4,76	4,4	6,0		
CNS1606	●	15,75	4,76	5,5	7,5		
CNS1906	●	18,70	6,35	5,5	7,5		
CNS2509	●	25,27	6,35	6,6	9,5		
CNS1203B	●	12,57	3,18	3,4	4,5		
CNS1204B	●	12,57	4,76	4,4	6,0		

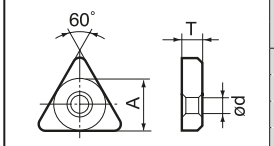


Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		
DCS11T3	●	8,5	2,38	5,3	6,4		

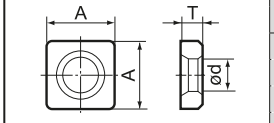


Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		
DNS1504	●	12,57	6,35	4,4	6,0		
DNS1506	●	12,57	4,76	4,4	6,0		
DNS1104B	●	9,45	4,73	3,4	4,5		
DNS1504B	●	12,57	6,35	4,4	6,0		
DNS1506B	●	12,57	4,76	4,4	6,0		

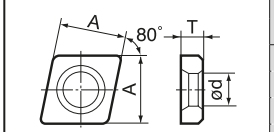
Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		
HE060011E	●						



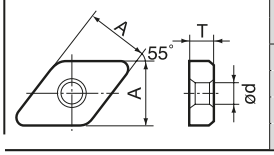
Cat. No.	Stock	Dimensions (mm)					
		A	T	d			
LST317SD	●	9,5	2,7	5,2			
LST42SD	●	12,65	3,18	6,9			



Cat. No.	Stock	Dimensions (mm)					
		A	T	d			
LSS32SD	●	9,48	3,18	5			
LSS42SD	●	12,65	3,18	6,9			
LSS53SD	❑	15,85	4,76	7,9			
LSS63SD	●	19	4,76	10			

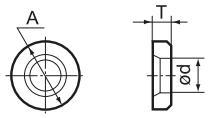


Cat. No.	Stock	Dimensions (mm)					
		A	T	d			
LSC32SD	●	9,48	3,18	5			
LSC42SD	●	12,65	3,18	6,9			
LSC53SD	●	15,85	4,76	7,9			
LSC63SD	❑	19	4,76	10			

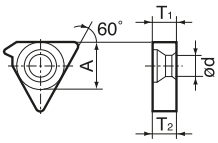


Cat. No.	Stock	Dimensions (mm)					
		A	T	d			
LSD32SD	●	8,5	3,18	5			
LSD42SD	●	12,65	3,18	6,9			

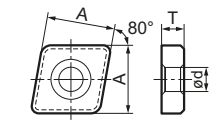
Shim



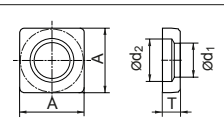
Cat. No.	Stock	Dimensions (mm)					
		A	T	d			
LSR817	❑	8,4	2,7	5,2			
LSR10	●	8,4	3,18	4,7			
LSR12	●	10	3,18	4,7			
LSR16	●	13,5	4,76	6,3			
LSR20	●	17,2	4,76	7,9			
LSR25		22	6,35	9,5			



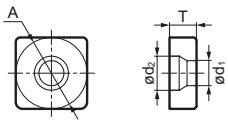
Cat. No.	Stock	Dimensions (mm)					
		A	T_1	T_2	d_2		
LSTE31-0	●	9,5	2,7	2,7	5,2		
LSTE31-1	●	9,5	2,67	2,91	5,2		
LSTE31-2	●	9,5	2,64	3,11	5,2		



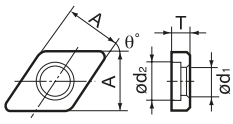
Cat. No.	Stock	Dimensions (mm)					
		A	T	d			θ°
SCND433	❑	12,65	4,76	3,4			80
SCN0903	❑	9,5	3,18	3,4			



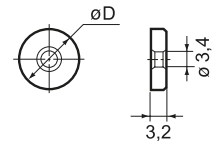
Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		
SCS1204	●	11,5	3,18	6,4	7,9		



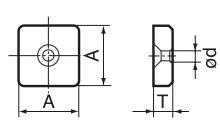
Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		
SNS1204	●	12,57	4,76	4,4	6,0		
SNS1506	●	15,75	4,76	5,5	7,5		
SNS1906	●	18,92	6,35	5,5	7,5		
SNS2507	●	25,27	7,93	6,6	9,5		
SNS2509	●	25,27	6,35	6,6	9,5		



Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		θ°
SVW322		9,5	3,18	4,7	6,5		35
SFW433		12,65	4,76	6,2	8,0		50
SDW323	●	9,5	3,18	4,7	6,5		55
SDW423	●	12,65	3,18	6,2	8,0		55
SDW433	●						
SCW423	●	12,65	3,18	6,2	8,0		80
SCW433	●						
SCW635	●	19	4,76	9	11,5		80



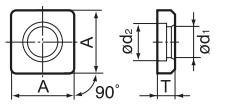
Cat. No.	Stock	Dimensions (mm)					
		D					
SRND32	●	9,5					
SRND42	●	12,7					



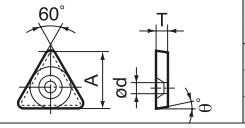
Cat. No.	Stock	Dimensions (mm)					
		A	T	d			
SSND423	●	12,5	3,18	3,4			
SSN0903	❑						

Shim, Nut

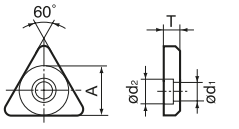
■ Shim



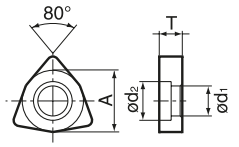
Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		
SSW423	●	12,65	3,18	6,2	8		
SSW433	●	12,65	4,76	6,2	8		
SSW635	●	19	4,76	9	11,5		



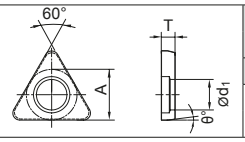
Cat. No.	Stock	Dimensions (mm)					
		A	T	d			θ°
STPD322	●	8,4	3,18	3,4			6
STPD422	●	11,0	3,18	3,4			6



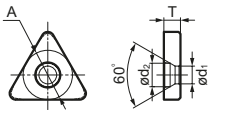
Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		
STW323	●	9,5	3,18	4,7	6,5		
STW434	●	12,65	4,76	6,2	8		



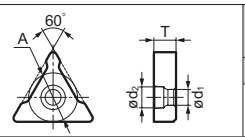
Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		
SWW433	●	12,65	5,15	6,2	8		
SWW544	●						
LSW317	●						



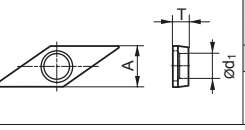
Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		θ°
TCS16T3	●	8,8	2,38	5,3	6,3		7



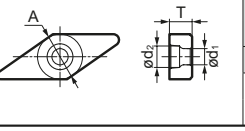
Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		
TNS1604	●	9,45	4,76	3,4	4,5		
TNS1603B	●	9,45	3,18	3,4	4,5		
TNS1604B	●	9,45	4,76	3,4	4,5		



Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		
TRW5505	●	10,5	4,76	3,4	4,5		



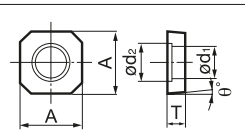
Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		
VCS1604	●	8,25	3,18	5,3	6,4		



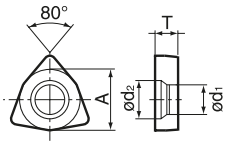
Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		
VNS1604	●	9,45	4,76	3,4	4,5		

■ Shim

Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		
WFXS4R	●	10,17	3,0	5,5	7,5		

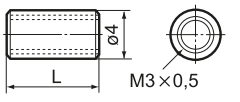


Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		θ°
WGCS13R	●	10,7	3,0	5,5	7,5		5

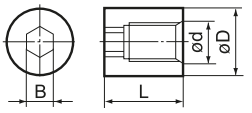


Cat. No.	Stock	Dimensions (mm)					
		A	T	d_1	d_2		
WNS0604	●	9,52	3,18	3,5	4,5		
WNS0804	●	12,57	4,76	4,4	6,3		
WNS0603B	●	9,27	3,18	3,4	4,5		
WNS0803B	●	12,57	3,18	3,4	4,5		
WNS0804B	●	12,57	4,76	4,4	6,0		

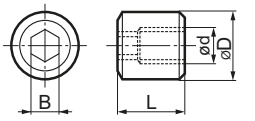
■ Nut



Cat. No.	Stock	Dimensions (mm)					
		L					
BNBW-2	●	3					
BNBW-4	❑	4					
BNBW-7	❑	7					



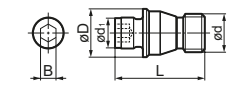
Cat. No.	Stock	Dimensions (mm)					
		d	L	D	B		
CPM32N	●	M4	7,5	7	3		
CPM43N	●	M5	8,5	7	3		
CPM43S	●	M5	6	7	3		
CPM54N	❑						



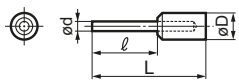
Cat. No.	Stock	Dimensions (mm)					
		d	Pitch	L	D	B	
CPV33N	●	M4	0,5	6,0	6,0	2,5	

Shim Pin, Eccentric Pin

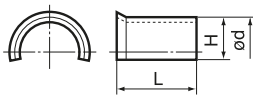
■ Shim Pin



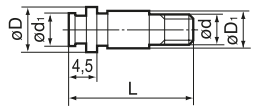
Cat. No.	Stock	Dimensions (mm)					
		d	Pitch	L	D	d_1	B
HE060011P	●	M6	0,75	14,5	7,8	5,0	2,5



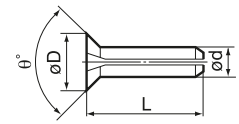
Cat. No.	Stock	Dimensions (mm)					
		d	D	L			
LP04	●	0,4	1,1	4,7			
LP06	●	0,4	1,1	6,0			
LP07	●	0,4	1,1	7,7			



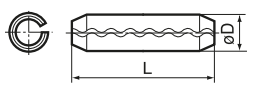
Cat. No.	Stock	Dimensions (mm)					
		d	H	L			
LSP3		5	3,5	5,5			
LSP3SD	●	5	3,5	5,5			
LSP4		6,7	4	7			
LSP4SD	●	6,7	4	7			
LSP5SD	●	7,7	4,5	8,5			
LSP6SD	●	9,85	5,9	11,1			
LSP8		13,05	10	12			
LSP10	●	5	3,3	6,5			
LSP16	●	6,6	4,5	9			
LSP20	●	8,2	5,5	9			
LSP25		9,8	6,5	11			
LSP32		13	10	12			



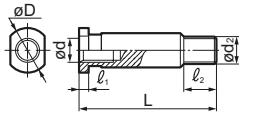
Cat. No.	Stock	Dimensions (mm)					
		d	Pitch	L	D	D_1	d_1
MP317	●	M4	0,7	15,5	6	4	3,7
MP320	●	M4	0,7	19,5	6	4	3,7
MP416	●	M5	0,8	14	7,5	6	5
MP420	●	M5	0,8	20	7,5	6	5
MP432	●	M5	0,8	32	7,5	6	5
MP531	●						
MP534	❑						



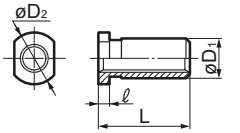
Cat. No.	Stock	Dimensions (mm)					
		d		L	D		θ°
SPP308	●	3,2		8	4,8		120



Cat. No.	Stock	Dimensions (mm)					
				L	D		
SPP3	●			14	3,2		

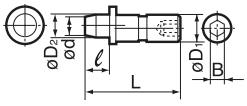


Cat. No.	Stock	Dimensions (mm)					
		d_1	d_2	L	D	ℓ_1	ℓ_2
VP20	●	M3,5	M4	12,0	5,0	≥4,5	≥4,5
VP25	●	M3,5	M4	17,0	5,0	≥4,5	≥4,5
VP32	●	M3,5	M4	24,0	5,0	≥4,5	≥4,5

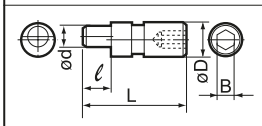


Cat. No.	Stock	Dimensions (mm)					
		d	Pitch	L	ℓ	D_1	D_2
VP32B	●	M3,5	0,6	8,0	1,4	5,0	6,5
VP40B	●	M3,5	0,6	11,5	1,4	5,0	6,5

■ Eccentric Pin



Cat. No.	Stock	Dimensions (mm)					
		d	D_1	D_2	L	ℓ	B
CPB34	●	3,4	4,1	5,5	14	5	2,5
CPB35	❑	3,4	4,1	5,5	17	5	2,5
CPB42	●	4,5	5,5	7	14	5	3
CPB43	●	4,5	5,5	7	16	5	3
CPB43S	●	4,5	5,5	7	19	5	3
CPB44T	❑	4,5	5,5	7	22	5	3
CPB45T	●	4,5	5,5	7	27	5	3
CPB64	●	6,8	8,2	10,5	24	6,6	4

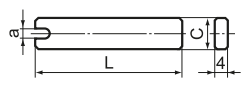


Cat. No.	Stock	Dimensions (mm)					
		d	D_1	D_2	L	ℓ	B
CPU304C	❑	3,3	5,5	-	10	3,5	3

Wrench

■ Wrench

Key Wrench



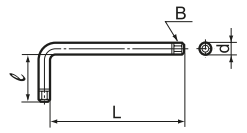
Cat. No.	Stock	Dimensions (mm)					
		L	a		C		
KY25		45	2,5		10		
KY40		60	4		13		

Hex Wrench (Hexagonal)

Cat. No.	Stock	Dimensions (mm)					
		B	L	ℓ			
LH020	●	2	50	16			
LH025	●	2,5	56	18			
LH030	●	3	63	20			
LH035	●	3,5	68	22			
LH040	●	4	70	25			
LH050	❑	5	80	28			
LH060		6	90	32			

Cat. No.	Stock	Dimensions (mm)					
LH035K	●						
LH045K	●						

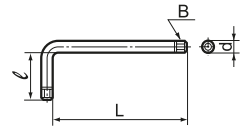
Torx Wrench



Cat. No.	Stock	Dimensions (mm)					
		B	d	L	ℓ		
LT0806		T8	2,3	45,0	6,0		
LT20	❑	T20	3,9	57,2	19,1		
LT25	❑	T25	4,4	60,3	20,2		
LT27	●	T27	4,96	63,5	21,5		
LT1510	❍	T15	3,26	62	10		

Cat. No.	Stock	Dimensions (mm)					
LT15K	●						

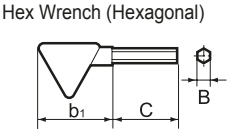
Torx Plus Wrench



Cat. No.	Stock	Dimensions (mm)					
		B	d	L	ℓ		
LT20IP		T20	4,0	57	18,5		
LT25IP		T25	4,5	60	19,5		

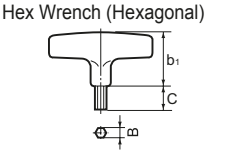
Cat. No.	Stock	Dimensions (mm)					
SDBSM	●						

Hex Wrench (Hexagonal)



Cat. No.	Stock	Dimensions (mm)					
		B	b_1	C			
TH015	●	1,5	35	30			
TH020	●	2	35	39			
TH025	●	2,5	35	39			

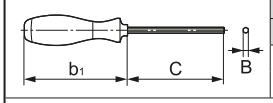
Hex Wrench (Hexagonal)



Cat. No.	Stock	Dimensions (mm)					
		B	b_1	C			
TH030	●	3	48	28			
TH040	●	4	48	37			
TH050	●	5	48	45			

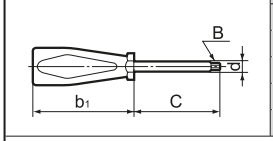
■ Wrench

Hex Wrench (Hexagonal)



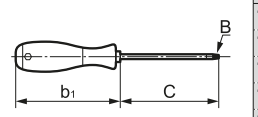
Cat. No.	Stock	Dimensions (mm)					
		B	C	b_1			
HD040	❍	4	75	111			

Torx Wrench



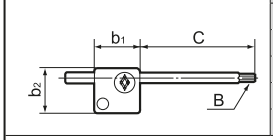
Cat. No.	Stock	Dimensions (mm)					
		B	d	C	B_1		
TRD07	●	T7	2,0	45	70		
TRD08	●	T8	2,3	55	70		
TRD15	❑	T15	3,3	70	100		
TRD20	●	T20	3,9	100	90		
TRD25	●	T25	5,3	80	110		

Torx Plus Wrench



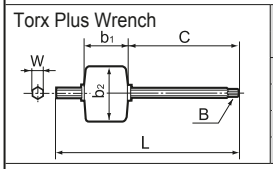
Cat. No.	Stock	Dimensions (mm)					
		B	C	b_1			
TRDR08IP	●	8IP	60	104			
TRDR10IP	●	10IP	80	111			
TRDR15IP	●	15IP	80	111			
TRDR20IP	●	20IP	100	118			
TRDR25IP	●	25IP	100	118			

Torx Wrench



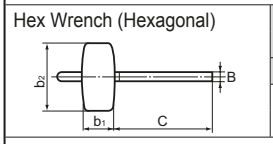
Cat. No.	Stock	Dimensions (mm)					
		B	C	b_1	b_2		
TRX06	●	T6	35,5	15	15		
TRX08	●	T8	38,5	19	19		
TRX10	●	T10	42,1	22	22		
TRX15	●	T15	46	22	27		
TRX20	●	T20	49	22	30		

Torx Plus Wrench



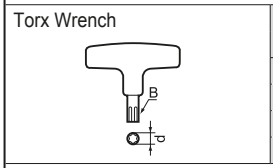
Cat. No.	Stock	Dimensions (mm)					
		B	W	L	C	b_1	b_2
TRX06IP	●						
TRX08IP	●						
TRX10IP	●						
TRX15IP	●	T15	3,5	85,5	47	23	29

Hex Wrench (Hexagonal)



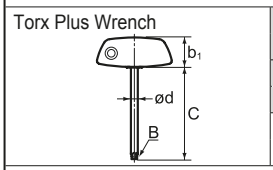
Cat. No.	Stock	Dimensions (mm)					
		B	C	b_1	b_2		
TSW040	●	4	60	20	40		

Torx Wrench



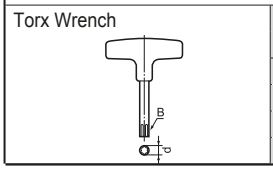
Cat. No.	Stock	Dimensions (mm)					
		B	d				
TT25	●	T25	4,4				
TT27	●	T27	5,0				

Torx Plus Wrench



Cat. No.	Stock	Dimensions (mm)					
		B	d	C	b_1		
TTR15IP	●	15IP	4,0	80	25,5		

Torx Wrench



Cat. No.	Stock	Dimensions (mm)					
		B	d				
TTX15W	●	T15	4,0				
TTX20	●	T20	3,9				

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P

P9 ~ P22

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AFBSM** ..... M38, M39 ..... Spare parts
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APET******PDFR-S ..... H31 ..... Indexable insert
APMT******PDER ..... H31 ..... Indexable insert
APMT******PDER-H ..... H31 ..... Indexable insert
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ASM****DL ..... J28 ..... Solid endmill
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B***-SDQC R/L ****-** ..... E17 ..... Boring bar
B***-SDUC R/L ****-** ..... E16 ..... Boring bar
B***-STUP R/L ****-** ..... E20 ..... Boring bar
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