

# Turning Guidance

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# Turning Guidance

## ■ Selecting Cutting Conditions & Cutting Resistance

< Selection Of Cutting Conditions >

### ● Cutting Conditions & Their Influence

Item	Influencing Matters
Speed	Work Efficiency, Tool Life, Cutting Power Consumption & Surface Roughness
Feed	Work Efficiency, Chip Control, Tool Life, Cutting Power Consumption & Surface Roughness
Depth of Cut	Working Efficiency, Chip Control, Cutting Power Consumption & Dimensional Accuracy

### ● Selecting Cutting Parameters

#### Calculation of Cutting Speed, Table Feed & Cutting Time

Calculating Rotating speed given the Cutting speed:

$$N = \frac{1000 \times V}{\pi \times D}$$

N : Spindle Speed (rpm)  
V : Cutting Speed (m/min)  
D : Work Diameter (mm)  
 $\pi$  : 3.14

If extracting the Cutting Speed from the Rotating Speed:

$$V = \frac{\pi \times D \times N}{1000}$$

The symbols are as described in the above.

Calculating the actual Table Feed (F)

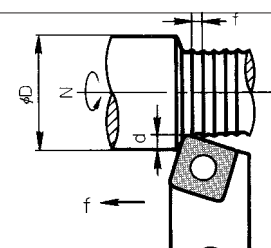
$$F = f \times N$$

Where F is in mm/min

Finally, Calculating the actual Cutting Time (T) in mins.

$$T = \frac{L}{F}$$

Where L is the total cutting length



N : Work Rotating speed (rpm)  
V : Cutting speed (m/min)  
f : Feedrate (mm/rev)  
d : Depth of cut (mm)  
D : Workpiece diameter (mm)

#### Tool Materials and Cutting Speed Ratio

HSS	Carbide	Coated	Cermet	Ceramic
1	3~6	5~15	5~10	10~25

#### Speed Ratio Related to Surface and Machining Conditions of The Work

Turned Surface	Casting & Forging Faces	Continuous Machining	Interuppted Machining
1	0.70	1	0.70

< Cutting Resistance >

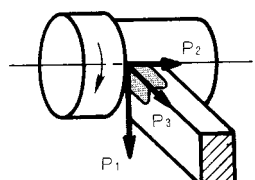
### ● Three Component Forces Of Cutting Resistance

### ● Factors Affecting Cutting Resistance

### ● Determination Of Cutting Resistance

### ● Determination Of Power Requirement

#### Three Component Forces:



P1: Principal or Tangential Component Force  
P2: Feed Component Force  
P3: Back Component Force

#### Determination of the Cutting Resistance

P1: Cutting Resistance (kg)  
Ps: Specific Cutting Resistance (kg/mm<sup>2</sup>)  
q: Area of the chip (mm<sup>2</sup>)

$$P1 = Ps \times q$$

#### Determination of Power Requirement

W : Power Requirement (kW)  
V : Speed (m/min)  
f : Feedrate (mm/rev)  
d : Depth of Cut (mm)  
 $\eta$  : Mechanical Efficiency  
H : Required Horsepower (HP)

$$W = \frac{V \cdot f \cdot d \cdot Ps}{6.12 \times 10^3 \cdot \eta}$$

$$H = \frac{W}{0.75}$$

#### Approximate Ps value

Normal Steel : 250~300 kg/mm<sup>2</sup>  
Cast Iron : 150kg/mm<sup>2</sup>

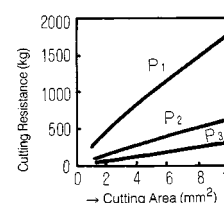
#### Factors Influencing Cutting Resistance

Factor	Decrease <- Cutting Resistance -> Increase
1. Workpiece	Low <- Tensile Strength -> High
2. Cutting Area	Small <- Cutting Area -> Large
3. Cutting speed	High <- Cutting Speed -> Low
4. Rake Angle	Large <- Rake Angle -> Small (Positive) (Negative)
5. Approach Angle	Small <- Approach angle -> Large

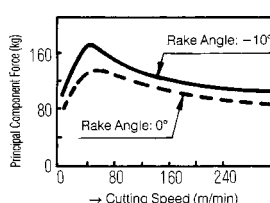
#### Relation Between Tensile Strength & Cutting Resistance

Tensile Strength (kg/mm <sup>2</sup> )	30~40	40~50	50~60	60~70	70~80	90~100
Cutting Resistance Ratio	1	1.10	1.18	1.29	1.45	1.70

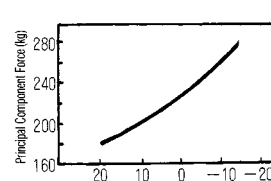
#### Cutting Area & Cutting Resistance



#### Cutting Speed & Cutting Resistance



#### Rake Angle & Cutting Resistance

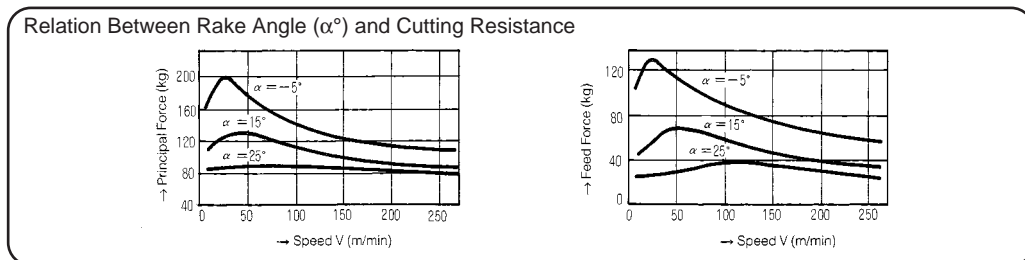


## ■ Influences of Cutting Edge Geometries

### ● Edge Forms & Their Influences

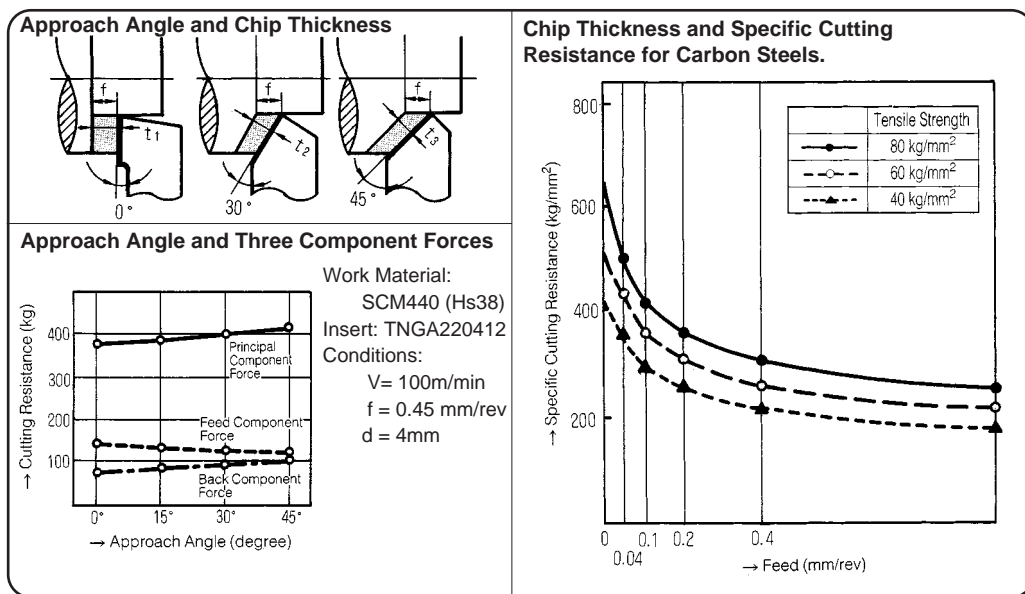
Kind Of Edge Forms	Strength Of Cutting Edge	Cutting Edge Temperature	Cutting Resistance	Cutting Ability	Tool Life	Surface Finished	Chatter	Chip Flow Direction
1. Back Rake	●		●					●
2. Top or Side Rake	●	●	●	●	●			●
3. Clearance Angle	●			●	●	●	●	
4. Trail Angle	●					●	●	
5. Approach Angle	●		●		●		●	●
6. Nose Radius	●		●		●	●	●	●

### ● Relation Between Rake Angle & Cutting Resistance



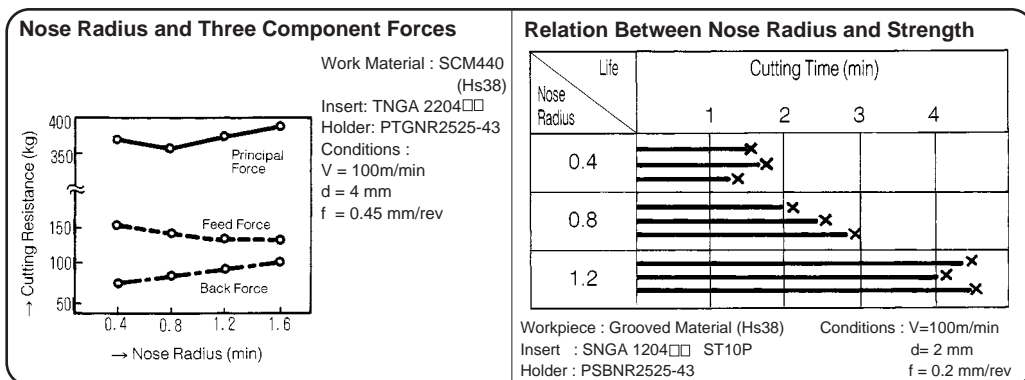
### ● Influence Of The Approach Angle :

- \*Relation To The Undeformed Chip Thickness.
- \*Chip Thickness & Specific Cutting Resistance.
- \*Approach Angle & 3 Component Forces.



### ● Influence Of the Nose Radius :

- \*Nose Radius & 3 Component Forces
- \*Nose Radius & Strength



# Turning Guidance

## General Guide Lines for Turning Tools

### Surface Roughness

**Theoretical (Geometric) Surface Roughness**

$$R_{max} = \frac{f^2}{8r}$$

$R_{max}$  : Surface Roughness (mm)  
 $f$  : Feed (mm/rev)  
 $r$  : Nose Radius (mm)

**Steps To Improve Finished Surfaces:**

1. Enlarge the nose radius.
2. Optimise the cutting speed and feed.  
(To set conditions so that the built-up edge may not occur.)
3. Optimise the insert grade

**Variation of Surface Roughness According To The Nose Radius & Feed**

Nose Radius \ Feed	0.4	0.8	1.2
0.15			
0.26			
0.46			

**Actual Surface Roughness:**

In Case of Steels,  
Theoretical Roughness x 1.5~3

In Case of Cast irons,  
Theoretical Roughness x 3~5

### Growth Of The Built-Up Edge & Its Remedies

Built-up edge is a state that while cutting, a portion of the workpiece piles up and adheres to the cutting edge due to work hardening. As an excessively harder degenerated substance than the base metal, the deposited material then acts as the cutting edge.

**Influence of Built-up Edge**

1. Deterioration of Surface Roughness And Accuracy.
2. Increase Edge Chipping

**Steps to Prevent Built-up Edge**

1. Raise the cutting temperature by increasing the speed and feed.
2. Apply cutting fluids that have a satisfactory EP performance.
3. Use coated or cermet tools.
4. Enlarge the rake angle.

**Cycle of Built-up Edge**

### Different Edge Treatments & Their Effects

**Different Edge Treatments**

Figure	Description
	Honing
	Negative Land (Chamfer Honing)
	Combined Honing
	Sharp Edge (w/o Edge Treatment)

$r$  : Honing Amount  
 $\theta$  : Angle Of Negative Land  
 $l$  : Width Of Negative Land

**Influence of the Width of Negative Land**

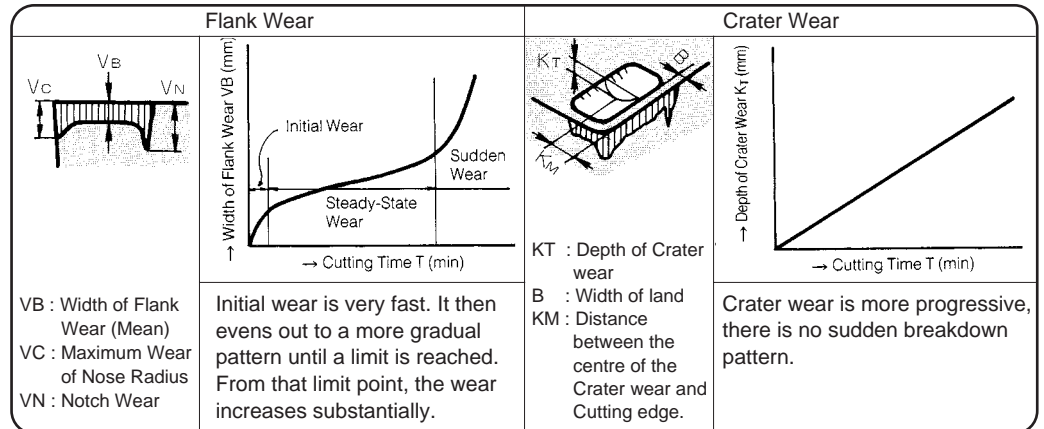
**Influence of the Honing Amount**

### Factors That Cause Chattering & Some Of Its Remedies

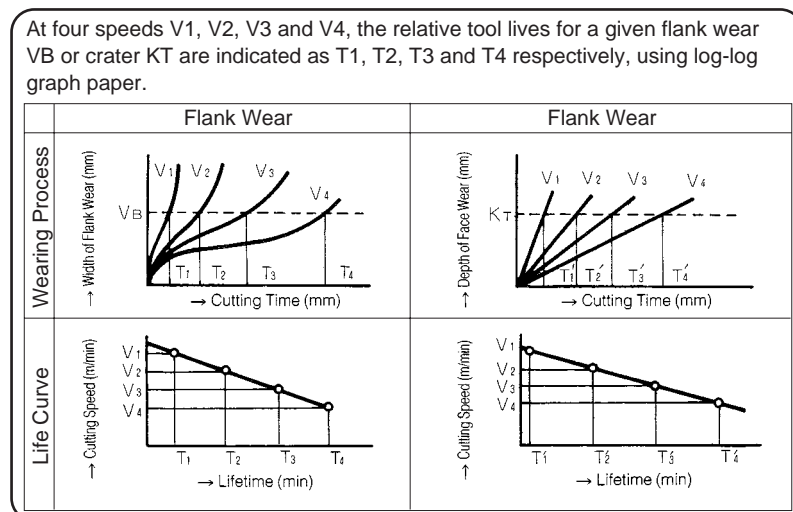
	Poor Workpiece Rigidity	Poor Tool Rigidity	Poor Machine Rigidity	Poor Cutting Conditions	Poor Edge Design
Remedies	<ul style="list-style-type: none"> <li>- Improve clamping.</li> <li>- Use fixed steady.</li> <li>- Improve rigidity of the tail center.</li> </ul>	<ul style="list-style-type: none"> <li>- Use a thicker shank.</li> <li>- Reduce the overhang.</li> <li>- Use a carbide shank holder.</li> <li>- Check that toolholder is held properly.</li> </ul>	<ul style="list-style-type: none"> <li>- Reduce backlash in the main spindle Bearing</li> <li>- Eliminate backlash in machine slides</li> </ul>	<ul style="list-style-type: none"> <li>- Select correct cutting conditions.</li> <li>- Change speed to avoid the sympathetic vibration point.</li> </ul>	<ul style="list-style-type: none"> <li>- Reduce clearance angle.</li> <li>- Reduce approach angle.</li> <li>- Increase the end cutting edge angle.</li> <li>- Reduce the nose radius.</li> <li>- Make the rake angle larger.</li> <li>- Hone the cutting edge slightly.</li> </ul>

## ■ Tool Life

### ● Wear Process Curve



### ● Life Curve (V-T Lines)



### ● Tool Life Equation

Tool Life Equation (Taylor's Equation)

$$VT^n = C$$

V : Cutting speed  
 T : Tool Life  
 n & C : Constants  
 Determined by the Work Material, Tool Material, Tool Design, etc.

### ● Alternative Tool Life Criteria

<ol style="list-style-type: none"> <li>When surface finish deteriorates unacceptably.</li> <li>When a fixed amount of tool wear is reached, (see the right hand table)</li> <li>When work piece dimension is not tolerable.</li> <li>When power consumption reaches a limit.</li> <li>Sparking or chip discolouration and disfiguration.</li> <li>Cutting Time or Number of components produced.</li> </ol>	Width of flank wear for general life determination for cemented carbides.									
	<table border="1"> <thead> <tr> <th>Width of Wear (mm)</th> <th>Applications</th> </tr> </thead> <tbody> <tr> <td>0.2</td> <td>Finish Cutting of Nonferrous Alloys, Fine and Light Cut, etc.</td> </tr> <tr> <td>0.4</td> <td>Cutting of Special Steels and The Like.</td> </tr> <tr> <td>0.7</td> <td>Normal Cutting of Cast Irons, Steels, etc.</td> </tr> <tr> <td>1- 1.25</td> <td>Rough Cutting of Common Cast Irons.</td> </tr> </tbody> </table>	Width of Wear (mm)	Applications	0.2	Finish Cutting of Nonferrous Alloys, Fine and Light Cut, etc.	0.4	Cutting of Special Steels and The Like.	0.7	Normal Cutting of Cast Irons, Steels, etc.	1- 1.25
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1- 1.25	Rough Cutting of Common Cast Irons.									

# Turning Guidance

## ■ Tool Failures and Their Counter-Measures

### ● Characteristic Of Tool Failure

No.	Failure	Cause	
1~5	Flank Wear	Physical	Due to the scratching effect of hard grains contained within the work material.
6	Chipping		Fine breakages caused by high pressure cutting, chatter and vibration, etc.
7	Partial Fracture		Due to mechanical impact when an excessive force is applied to the cutting edge.
8	Crater Wear	Chemical	Due to a combination of galling and welding between the chips and the top rake.
9	Plastic Deformation		The cutting edge is deformed due to its softening at high temperature.
10	Thermal Crack		Thermal fatigue from the heating and cooling cycle during interrupted cutting.
11	Built-up Edge		The deposition and adhesion of the hardened work material on the cutting edge.

### ● Failure & Countermeasures

Failure	Basic Counter-measures		Application Example										
Edge Failure	Excessive Flank Wear	Tool Material - Use a more wear-resistant grade Carbide --> { Coated Carbide / Cermet Cutting Conditions - Decrease Speed	Recommended Insert Grade: <table border="1"> <thead> <tr> <th></th> <th>Steel</th> <th>Cast Iron</th> </tr> </thead> <tbody> <tr> <td>Finishing</td> <td>T110A (Cermet)</td> <td>BN250 (CBN)</td> </tr> <tr> <td>Rough</td> <td>AC2000 (Alumina Coated)</td> <td>AC500G (Alumina Coated) NS260C (Ceramic)</td> </tr> </tbody> </table>			Steel	Cast Iron	Finishing	T110A (Cermet)	BN250 (CBN)	Rough	AC2000 (Alumina Coated)	AC500G (Alumina Coated) NS260C (Ceramic)
		Steel	Cast Iron										
	Finishing	T110A (Cermet)	BN250 (CBN)										
	Rough	AC2000 (Alumina Coated)	AC500G (Alumina Coated) NS260C (Ceramic)										
	Excessive Crater Wear	Tool Material - Use a crater-resistant grade. Carbide --> Coated (K--> M--> P) Cermet Tool design - Enlarge the rake angle Cutting Conditions - Select the correct chip breaker - Decrease speed, reduce the depth of cut and feedrate.	Recommended Insert Grade: <table border="1"> <thead> <tr> <th></th> <th>Steel</th> <th>Cast Iron</th> </tr> </thead> <tbody> <tr> <td>Finishing</td> <td>T110A (Cermet)</td> <td>BN250 (CBN)</td> </tr> <tr> <td>Rough Machining</td> <td>AC2000 (Alumina Coated)</td> <td>AC500G (Alumina Coated)</td> </tr> </tbody> </table> ●Use MU Type Chip Breaker			Steel	Cast Iron	Finishing	T110A (Cermet)	BN250 (CBN)	Rough Machining	AC2000 (Alumina Coated)	AC500G (Alumina Coated)
		Steel	Cast Iron										
Finishing	T110A (Cermet)	BN250 (CBN)											
Rough Machining	AC2000 (Alumina Coated)	AC500G (Alumina Coated)											
Cutting Edge Chipping	Tool Material - Use tougher grades. If carbides: P10 -> P20 -> P30 K01 -> K10 -> K20 Tool design - If built-up edge occurs, change to a less susceptible grade eg. cermet. - Reinforce the cutting edge eg. Honing. - Reduce the rake angle. Cutting Conditions - Increase speed (If there is edge build-up).	Recommended Insert Grade: <table border="1"> <thead> <tr> <th></th> <th>Steel</th> <th>Cast Iron</th> </tr> </thead> <tbody> <tr> <td>Finishing</td> <td>T1200A (Cermet)</td> <td>AC500G (Coated)</td> </tr> <tr> <td>Rough Machining</td> <td>AC3000 (Alumina Coated)</td> <td>AC500G (Alumina Coated) NS260 (Ceramic)</td> </tr> </tbody> </table> ● Edge Treatment : All of our inserts have been honed in advance.			Steel	Cast Iron	Finishing	T1200A (Cermet)	AC500G (Coated)	Rough Machining	AC3000 (Alumina Coated)	AC500G (Alumina Coated) NS260 (Ceramic)	
	Steel	Cast Iron											
Finishing	T1200A (Cermet)	AC500G (Coated)											
Rough Machining	AC3000 (Alumina Coated)	AC500G (Alumina Coated) NS260 (Ceramic)											
Partial Fracture Of Cutting Edges	Tool Material - Use tougher grades. For carbides: P10 -> P20 -> P30 K01 -> K10 -> K20 Tool design - Use the holder with a larger approach angle. - Use a holder with a larger shank size. Cutting Conditions - Reduce the depth of cut and feedrate.	Recommended Insert Grade: <table border="1"> <thead> <tr> <th></th> <th>Steel</th> <th>Cast Iron</th> </tr> </thead> <tbody> <tr> <td>Rough Machining</td> <td>AC2000 /AC3000</td> <td>AC500G (Coated) NS260C (Ceramic)</td> </tr> </tbody> </table> ● Insert : Use UX Type Breaker ● Holder : Use Lever-lock Type			Steel	Cast Iron	Rough Machining	AC2000 /AC3000	AC500G (Coated) NS260C (Ceramic)				
	Steel	Cast Iron											
Rough Machining	AC2000 /AC3000	AC500G (Coated) NS260C (Ceramic)											
Built-up Edge	Tool Material - Change to a grade which is more adhesion resistant. Cutting Conditions - Increase the cutting speed and feed. - Use cutting fluids.	Recommended Insert Grades : Cermet											
Plastic Deformation	Tool Material - Change to high thermal resistant grades. Cutting Conditions - Reduce the cutting speed and feed.	Recommended Insert Grades : AC2000 or AC3000											

## ■ Analysis of Chip Control on Turning

### ● Classification Of Chip Formation & Their Influences

#### Shape Categories for Chips

Depth of Cut	A	B	C	D	E
Excess					
Slight					
Curled Length	No Curling	Over 50 mm	Up to and including 50 mm 1 to 5 Turns	Below 1 Turn	Half Turn
Remarks	Continuous Random Shape	Continuous Regular Shape	Good	Good	Excessively Broken Chip

- Good chip control : Types C and D
- Unsatisfactory chip control: -  
 Type A : Twines around the tool and work material, causes the machine to stop, quality impairment on the machined surface or problems in safety.  
 Type B : Causes performance reduction of the chip's automatic transfer system or even edge chipping.  
 Type E : Causes such troubles as spray of chips, unsatisfactory finished surface due to chattering, chipping of the cutting edges or increase in cutting resistance and heat generation.

#### Influence Of Chip Shapes

Influence		Chip Shape				
		Type A	Type B	Type C	Type D	Type E
Tool life	Wear Resistance	O	O	O	O	O
	Chipping	X	X	O	O	X
Quality	Finished Surface	O	O	O	O	X
		O	O	O	O	X
Transfer	Machining Part Chips	X	O	O	O	O
		X	X	O	O	O
Power Consumption	Cutting Resistance	O	O	O	O	X
	Safety	X	O	O	O	X
Overall Evaluation		X	O	Excellent	Excellent	X

O: Superior X: Inferior

### ● Factors To Determine Chip Formation

(a) If Outlet Angle  $\eta = 0^\circ$

(b) If Outlet Angle  $\eta = 15^\circ$

- Factors: Outlet Angle and Cutting Direction
- Chip Forms According to The Combination of Factors

Cutting Direction	Outlet Angle	
	If $n = 0$	If $n \neq 0$
Upward Only	Cylindrical Form	Spiral Form
Sideways Only	Washer-Like Form	
Upward + Sideways	Conical Form	

### ● Types Of Chip Breaking

Figure of Chip Breaking	Type	Meanings
	Work Obstructive Type	- Cause by the effect of the upward curl only, if the rake is too small. - Chip broken because it struck against the work end face.
	Scroll Type	- Caused by the upward curling force when the rake angle is large. - Rolls in without breaking after striking against the work end face.
	Flank Obstructive Type	- Removed spirally by the mixing of upward and sideways curls. - Strikes against the flank and breaks.
	Side Curl Type	- Occurs if the sideways curling factor is superior. - Strikes against the flank of the tool and breaks.

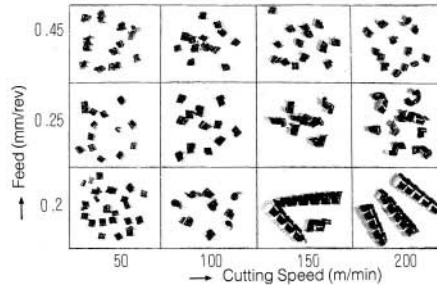
### ● Formation Of Chips

	Flow Type	Shear Type	Tear Type	Crack Type
Form				
Condition	Continuous Chip and satisfactory surface finish	aA chip is sliced -off at the shear angle	Chip with the appearance of being torn off. The workpiece surface is damaged.	The swarf cracks before reaching cutting edge, which then separates it from parent work piece body.
Examples	Normal Cutting for Steels, Light Alloys, and Alloyed Cast Irons	Low speed cutting for Steels and Stainless Steels	Fine Cutting for Steels and Cast Irons at Excessively Low Speed	Cutting for General Purpose Cast Irons, Rocks, and Carbonous Materials
Influence	Large $\leftarrow$ Work Deformation $\rightarrow$ Small Large $\leftarrow$ Rake Angle $\rightarrow$ Small Slight $\leftarrow$ Depth of cut $\rightarrow$ Excess High $\leftarrow$ Cutting Speed $\rightarrow$ Low			

## Factors on Chip Control & Their Influences

### ● Influence On The Cutting Speed & Feed

- The effective range of the chip breaker is reduced with the cutting speed being increased.
- At high speeds and small feedrates, lengthened chips will result.
- At high speeds and large feedrates, packed chips will result.



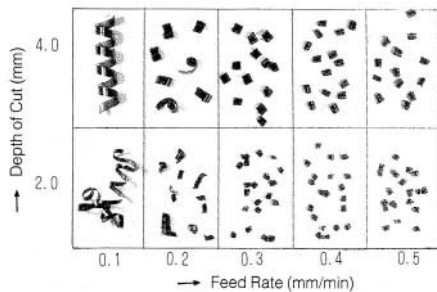
Workpiece : S45C (Hs38)

Insert : SNMG120408N-UX  
Holder : PSBNR2525-43

Cutting Conditions:  
d = 3 mm

### ● Influence Of The Feed & Cutting Depth

- With small depths and small feeds, longer chips will be formed.
- With deeper depths and larger feeds, short chips will result.



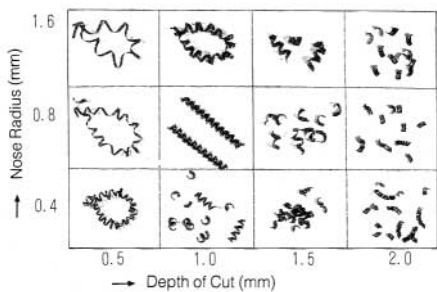
Workpiece : S45C (Hs38)

Insert : SNMG120408N-UX  
Holder : PSBNR2525-43

Cutting Conditions:  
V = 150 m/min

### ● Influence Of The Nose Radius

- Chips become unsusceptible to breakage when the nose radius is larger and the cutting depth is less.
- Chips become thinner as the nose radius gets larger but their control is poor.



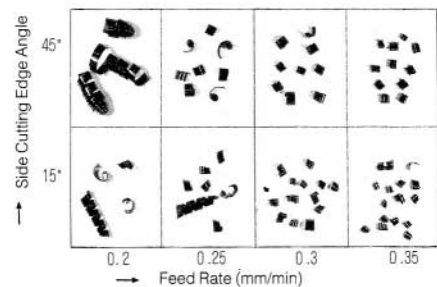
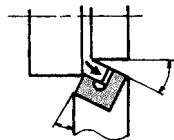
Workpiece : S45C (Hs38)

Insert : CNMG1204□□N-UX  
Holder : PCLNR2525-43

Cutting Conditions:  
V = 120 m/min  
f = 0.3 mm/rev

### ● Influence Of The Side Cutting Edge Angle

- If the side cutting edge angle becomes larger, the outlet angle and chips become larger and thinner respectively which makes the difficult to control.



Workpiece : S45C (Hs38)

Insert : SNMG120408N-UX  
Holder : PSBNR2525-43

(Side Cutting edge angle 15°)  
PSSNR2525-43  
(Side Cutting edge angle 45°)

Cutting Conditions:  
V = 150 m/min  
d = 3 mm

### ● Influence On The Rake Angle

- Chips become thicker when the rake angle gets smaller but they are easier to control.

For Small Top Rake Angle ( $\alpha_1$ )  
- The shear angle is small ( $\phi_1$ )  
- The chip is thick ( $t_1$ )

For Large Top Rake Angle ( $\alpha_2$ )  
- The shear angle is large ( $\phi_2$ )  
- The chip is thin ( $t_2$ )

