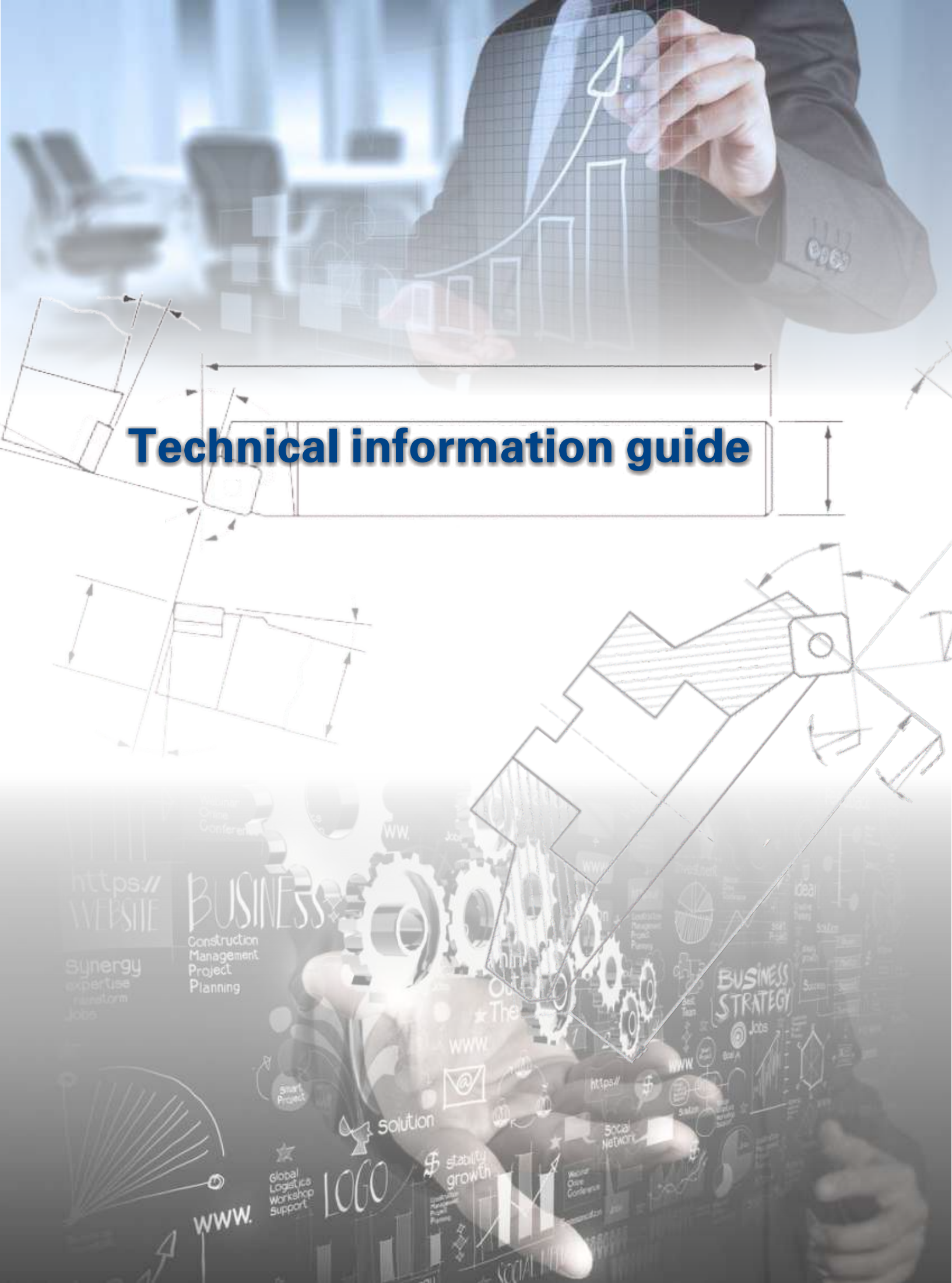
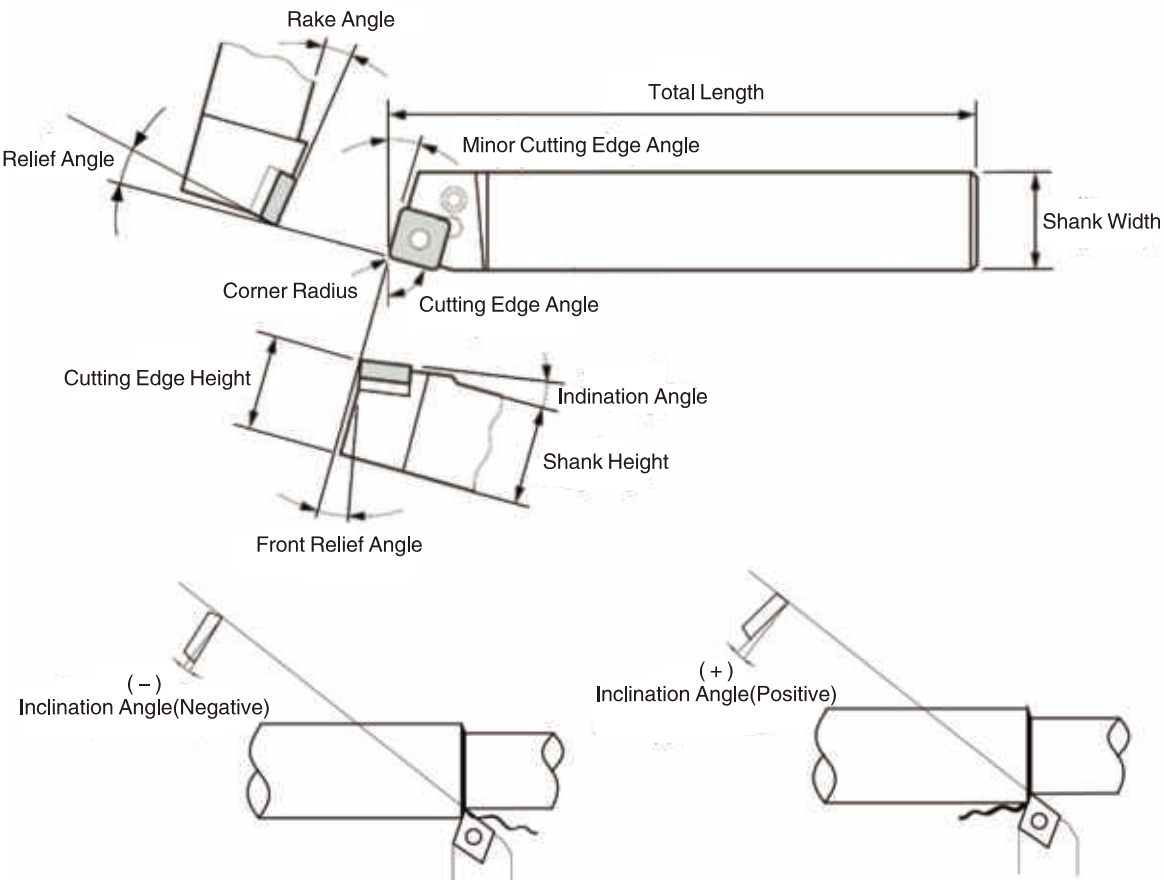

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Terms and Angles of Turning Toolholder



Function of Tool Angle

Tool Angle	Function	Effect
Rake Angle	●Affects cutting force, cutting heat, chip evacuation and tool life.	●When it is positive(+)angle,sharper cutting performance is obtained,less cutting resistance but less edge strength. ●Positive(+)angle is recommended for easy to machine workpieces or thin workpieces. ●Smaller rake angle or negative(–) angle is recommended when a stronger edge is required like scale cutting or interrupted cutting.

Tool Angle	Function	Effect
Inclination Angle	●The corner will bear a strong impact when heavy cutting. ●It needs a suitable cutting edge inclination angle to prevent fracture.	●When it is negative---Chip flows to the workpiece and vice versa. ●When it is positive---Cutting edge strength improves,but the back cutting force also increases and it is inclined to produce vibration. ●Recommended values:Turning 3° ~5° Milling 10° ~15° .
Relief Angle	●Prevents the tool's contact to the workpiece surface,except the cutting edge.	●When it is small,the cutting edge strength improves,but the wear at relief face increases,and tool life may decreases.
Cutting Edge Angle	●Affects chip control and the direction of cutting force.	●When it is large,chip thickness becomes thick and chip control improves.
Minor Cutting Edge Angle	●Prevents friction between cutting edge and work surface.	●When it is small,the cutting edge strength will improve,but the tip is heated. ●When it is small,back cutting force increases and it is inclined to produce cutting vibration. ●It should be smaller for rough finishing, while it can be larger for rough finishing . Recommended values:5° ~15° .
Corner Radius	●Affects tool nose strength and roughness of the finished surface.	●Recommended values:2~3 times of feed rate.

Basic Formulas of Turning

►Power Requirement

$$P_c = \frac{Ks \times Vc \times ap \times f}{6120 \times \eta}$$

$$P_{Hp} = \frac{Ks \times Vc \times ap \times f}{4500 \times \eta}$$

- P_c: Power Requirement(KW)
- P_{Hp}: Power Requirement (Horse Power)(HP)
- V_c: Cutting Speed(m/min)
- f: Feed Rate(mm/rev)
- a_p: Depth of Cut(mm)
- K_s: Specific Cutting Resistance(kgf/mm^2)
- η: Mechanical Efficiency(0.7~0.8)

$f = \frac{l}{n}$	l (mm/min) Length of cut per minute

approximate value of K_s

Aluminum:800MPa General Steel:2,500~3,000MPa Cast Iron:1500MPa

Low Carbon Steel	190	High Alloy Steel	245
Medium Carbon Steel	210	Cast Iron	93
High Carbon Steel	240	Malleable Cast Iron	120
Low Alloy Steel	190	Bronze,Brass	70

►Cutting Speed

$$V_c = \frac{\pi \times Dm \times n}{1000}$$

- V_c: Cutting Speed(m/min)
- n: Spindle Revolution(min^{-1})
- D_m: Woekpiece Diameter(mm)

►Surface Roughness

$$Rz = h = \frac{f^2}{8 \times R(\gamma\varepsilon)} \times 1000$$

- R_z=h:Theoretical Surface Roughness(μm)
- f:Feed Rate(mm/rev)
- R(γε):Corner Radius of Insert(mm)

Actual Surface Roughness	Steel:Theorrtical Surface Roughness (Rz)x1.5~3 Cast iron:Theoretical Surface Roughness (Rz)x3~5

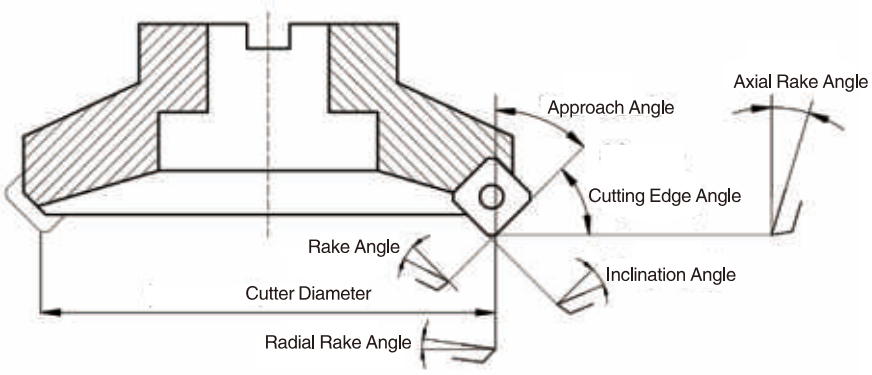
Trouble Shooting(Turning)

Trouble	Troubl Item	Measures	Insert Grade: Change to Harder Grade	Insert Grade: Change to Tougher Grade	Insert Grade: More Thermal Shock Resistant Grade	Insert Grade: Change to More Welding Resistant Grade	Cutting Conditions: Vc Cutting Speed (Higher(Larger) ↑ Lower(Smaller) ↓)	Cutting Conditions: fz Feed Rate (Higher(Larger) ↑ Lower(Smaller) ↓)	Cutting Conditions: ap Depth of Cut (Higher(Larger) ↑ Lower(Smaller) ↓)	Cutting Conditions: ToolPath Review	Cutting Conditions: Coolant: Wet	Cutting Conditions: Coolant: Dry	Tool Geometry: Chipbreaker Review	Tool Geometry: Rake Angle (Increase ↑ Decrease ↓)	Tool Geometry: Comer-R(γε) (Increase ↑ Decrease ↓)	Tool Geometry: Approach Angle (Increase ↑ Decrease ↓)	Tool Geometry: Edge Strength/Honing (Increase ↑ Decrease ↓)	Tool Geometry: Change to Higher Tolerance(MG)	Tool Geometry: Toolholder Rigidity	Setting/Machine: Workpiece/Tool Installation	Setting/Machine: Overhang Length	Setting/Machine: Power,Rigidity
Unstable Dimension	Unstable Workpiece Dimension	Unsuitable Insert Tolerance																●				
		Tool or Workpiece Evacuation											●	●↑	●↓	●↓			●	●	●	●
	Frequent Offset during Cutting	Flank Wear Increase	●												●↑							
		Unsuitable Cutting Conditions					●↓	●↑														
		Built-up Edge				●	●↑															
Surface Roughness	Poor Surface Roughness	Poor Cutting by Tool Wear	●			●	●↓				●		●	●↑	●↑		●↓	●				
		Chipping		●				●↓	●↓				●		●↑		●↑			●	●	●
		Welding,Built-up Edge				●	●↑				●		●	●↑			●↓	●				
		Unsuitable Cutting Conditions					●↑	●↓	●↓		●											
		Unsuitable Tool Grade/Geometry											●		●↑		●↓	●				
		Vibration,Chattering		●			●↓	●↓ 1	●↓				●	●↑	●↓	●↓	●↓		●	●	●	●
Heat	Deterioration of Accuracy or Tool Life by Cutting Heat	Unsuitable Cutting Conditions					●↓	●↓	●↓		●											
		Unsuitable Tool Grade/Geometry	●										●	●↑			●↓					
Burr,Chipping,Scuffing	Steel,Aluminium→Burr	Unsuitable Cutting Conditions					●↓	●↑		●	●											
		Unsuitable Tool Grade/Geometry	●										●	●↑	●↓	●↓	●↓					
	Cast Iron→Workpiece Chip Off	Unsuitable Cutting Conditions						●↓	●↓	●												
		Unsuitable Tool Grade/Geometry	●										●	●↑	●↑	●↑	●↓		●	●	●	●
	Mild steel→Scuffing	Unsuitable Cutting Conditions					●↑	●↓2			●											
		Unsuitable Tool Grade/Geometry	●			●							●	●↑			●↓					
Edge Damage	Wear Increase at Relief Face,Rake Face	Flank Wear	●				●↓				●		●	●↑	●↑		●↓					
		Rake Face Wear	●				●↓	●↓	●↓		●		●	●↑		●↑						
	Notching	Notching				●	●↓				●											
	Chipping	Vibration,Chattering		●				●↓	●↓				●			●↑	●↑		●	●	●	●
	Crack	Unsuitable Tool Grade/ Cutting Conditions		●	●			●↓	●↓				●		●↑	●↑	●↑		●	●	●	●
	Thermal Crack	Unsuitable Tool Grade/ Cutting Conditions			●		●↓	●↓	●↓			●	●	●↑			●↓					
	Edge Nose Deformation	Edge Nose Deformation during Interrupted Cutting	●				●↓	●↓	●↓				●	●↓	●↑	●↑	●↑					
	Built-up Edge	Unsuitable Tool Grade/ Cutting Conditions				●	●↑	●↑			●		●	●↑			●↓	●				
Chip Control	Long,Tangling Chips	Unsuitable Cutting Conditions					●↓	●↑	●↑	●		●										
		Unsuitable Tool Geometry											●		●↓	●↓						
	Chips Scattering	Unsuitable Cutting Conditions						●↓	●↓			●										
		Unsuitable Tool Geometry											●		●↑	●↑						

(1)To prevent chattering,the higher f may be suitable.

(2)To prevent scuffing,the higher f may be suitable.

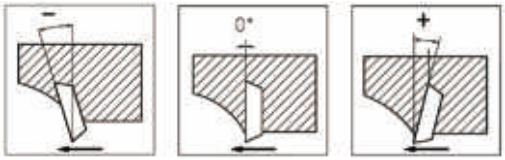
Terms and Angles of Turning Toolholder



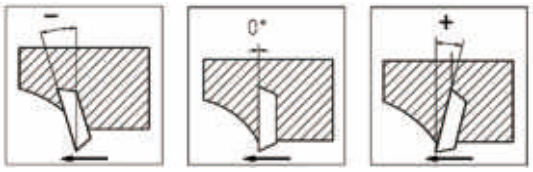
Function of Tool Angle

Tool Angle	Function	Effect
Axial Rake Angle	●Controls chip flow direction and cutting force.	●When it is positive---Good cutting performance and less chip welding.
Radial Rake Angle	●Controls chip flow direction and cutting force.	●When it is negative---Good chip evacuation.
Rake Angle	●Determines the real sharp degree of tool edge.	●When it is positive---Good cutting performance and less chip welding,but lower edge strength. ●When it is negative---Higher edge strength but easier to weld.
Approach Angle	●Controls chip thickness and chip flow direction.	●When it is large---Thinner chip thickness and lower cutting load.
Inclination Angle	●Controls chip flow direction .	●When it is positive---Good chip evacuation,less cutting resistance and lower edge stability of the part.

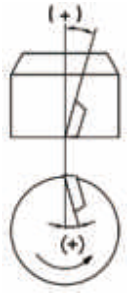
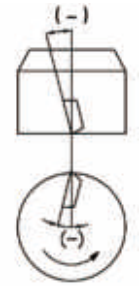
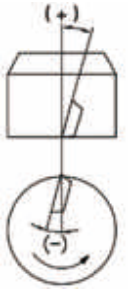
Positive/Negative Rake Angle



Positive/Negative Rake Angle



Characteristics Different Angle Combination

Combination of Rake Angles		Positive Axial Rake Angle (+)  Positive Radial Rake Angle (+) Double Positive	Negative Axial Rake Angle (−)  Negative Radial Rake Angle (−) Double Negative	Positive Axial Rake Angle (+)  Negative Radial Rake Angle (−) Positive + Negative
Axial Rake Angle		Positive (+)	Negative (−)	Positive (+)
Radial Raxe Angle		Positive (+)	Negative (−)	Negative (−)
Tool Style		Positive Angle (Single Side Used)	Negative Angle (Double Sides Used)	Positive Angle (Single Side Used)
Workpiece Material	**Steel**	●	—	●
	Cast Iron	—	●	●
	Light Alloy	●	—	—
	Difficult–to–machine Material	●	—	●

Basic Formulas of Milling

►Power Requirement

$$P_c = \frac{K_s \times Q}{6120 \times \eta}$$

$$= \frac{Ks \times ae \times Vf \times ap}{6120000 \times \eta}$$

$$= \frac{Ks \times ae \times fz \times Z \times n \times ap}{6120000 \times \eta}$$

$$P_{Hp} = \frac{6120}{4500} P_c$$

- P_c: Power Requirement(KW)
- P_{Hp}: Power Requirement (Horse Power)(HP)
- a_e: Width of Cut(mm)
- V_f: Table Feed(mm/min)
- f_z: Feed per Tooth(mm/t)
- Z: Number of Inserts(pcs)
- n: Spindle Revolution(min^{-1})
- a_p: Depth of Cut(mm)
- K_s: Specific Cutting Resistance(kgf/mm^2)
- η: Mechanical Efficiency(0.7~0.8)
- Q: Chip Removal Volume(cm^3/min)

approximate value of K_s

Aluminum:800MPa
General Steel:2,500~3,000MPa
Cast Iron:1500MPa

Low Carbon Steel	190	High Alloy Steel	245
Medium Carbon Steel	210	Cast Iron	93
High Carbon Steel	240	Malleable Cast Iron	120
Low Alloy Steel	190	Bronze,Brass	70

►Chip Removal Volume

$$P_c = \frac{a_e \times V_f \times a_p}{1000}$$

$$= \frac{ae \times fz \times Z \times n \times ap}{1000}$$

- Q: Chip Removal Volume(cm^3/min)
- a_e: Width of Cut(mm)
- V_f: Table Feed(mm/min)
- f_z: Feed per Tooth(mm/t)
- Z: Number of Inserts(pcs)
- n: Spindle Revolution(min^{-1})
- a_p: Depth of Cut(mm)

►Table Feed & Feed Per Tooth

$$f_z = \frac{V_f}{Z \times n}$$

- f_z: Feed per Tooth(mm/t)
- V_f: Table Feed(mm/min)
- Z: Number of Inserts(pcs)
- n: Spindle Revolution(min^{-1})

►Cutting Speed

$$V_c = \frac{\pi \times D_m \times n}{1000}$$

- V_c: Cutting Speed(m/min)
- n: Spindle Revolution(min^{-1})
- D_s: Cutter Diameter(mm)

Trouble Shooting(Milling)

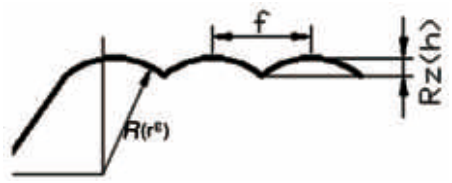
Trouble	Troubl Item	Measures	Insert Grade: Change to Harder Grade	Insert Grade: Change to Tougher Grade	Insert Grade: More Thermal Shock Resistant Grade	Insert Grade: Change to More Welding Resistant Grade	Cutting Conditions: Vc Cutting Speed (Higher(Larger) ↑ Lower(Smaller) ↓)	Cutting Conditions: fz Feed Rate (Higher(Larger) ↑ Lower(Smaller) ↓)	Cutting Conditions: ap Depth of Cut (Higher(Larger) ↑ Lower(Smaller) ↓)	Cutting Conditions: Cutter Dia. Cutting Width Review	Cutting Conditions: ToolPath Review	Cutting Conditions: Coolant: Wet	Cutting Conditions: Coolant: Dry	Tool Geometry: Insert with Chipbreaker	Tool Geometry: Relief Angle (Increase ↑ Decrease ↓)	Tool Geometry: Corner Angle (Increase ↑ Decrease ↓)	Tool Geometry: Edge Strength/Honing (Increase ↑ Decrease ↓)	Tool Geometry: Insert Number (Increase ↑ Decrease ↓)	Tool Geometry: Insert Pocket	Tool Geometry: Wiper Edge(Relief Angle)Review	Tool Geometry: Insert Runout Check	Tool Geometry: Cutter Rigidity	Setting/Machine: Workpiece/Tool Installation	Setting/Machine: Overhang Length	Setting/Machine: Power, Rigidity
Edge Damage	Flank Wear Increase	Unsuitable Cutting Conditions					●↓						●												
		Unsuitable Tool Geometry	●													●↑		●↓				●				
	Rake Face Wear Increase	Unsuitable Cutting Conditions					●↓	●↓	●↓				●												
		Unsuitable Tool Geometry	●													●↑	●↑	●↓							
	Chipping, Cracking	Unsuitable Cutting Conditions						●↓	●↓	●		●													
		Unsuitable Tool Geometry		●												●↓	●	●↑				●	●	●	●	●
	Edge Breakage by Thermal Shock	Unsuitable Cutting Conditions					●↓	●↓	●↓					●											
		Unsuitable Tool Geometry			●											●↑		●↓							
	Built–up Edge	Unsuitable Cutting Conditions					●↑	●↑					●												
		Unsuitable Tool Geometry				●										●↑		●↓							
Machining Accuracy	Poor Surface Finish	Unsuitable Cutting Conditions					●↑	●↓	●↓				●												
		Unsuitable Tool Geometry	●			●												●↓	●↓			●	●		●	●
	Burr	Unsuitable Cutting Conditions					●↓	●↓	●↓	●		●													
		Unsuitable Tool Geometry														●↑	●↓	●↓				●				
	Workpiece Chip Off	Unsuitable Cutting Conditions																							
		Unsuitable Tool Geometry														●↑	●↑	●↓	●↑			●				
	Poor Planeness/ Parellelness	Tool or Workpiece Evacuation						●↓	●↓				●1		●	●↑	●↓	●↓	●↓			●	●	●	●	●
Others	Heavy Chattering, Vibration	Unsuitable Cutting Conditions, Installation					●↓	●↓2	●↓3	●		●4			●	●↑	●↓	●↓	●↓					●	●	●
	Damaging Chips	Unsuitable Cutting Conditions					●↑	●↓5		●			●6	●												
		Unsuitable Tool Geometry													●	●↑			●↓	●						

(1) If the surface is warped by cutting heat.
(2) To prevent chattering,the higher fz may be suitable.
(3) To prevent chattering,the larger ap may be suitable.
(4) Down–cut method is recommended for Helical Endmilling.
(5) Higher fz may be suitable.
(6) Compressed air is recommended.

Surface Roughness

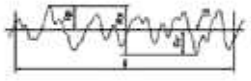
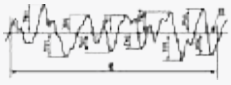
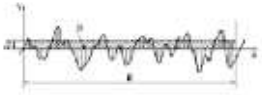
The oretical(Geometrical)Surface Rougness

$$-R_z(h)=\frac{f^2}{8\times R(\gamma\varepsilon)}\times 1000$$

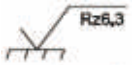
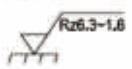


- $R_z(h)$: Theoretical Surface Roughness(μ m)
- f :Feed Rate(mm/rev)
- R(γ ε):Corner Radius of Insert(mm)

How to Obtain Surface Roughness Values

Type	Symbol	How to Obtain	Explanation
Max.Height Roughness	R_z	Ry is a mean value in micron meter obtained from the distance of the highest peaks and the lowest valleys within the range of sampled reference lengths(l)in the direction of the center line of the roughness curve. $R_z=R_p+R_v$	
Ten Points Mean Roughness	R_{ZJIS}	Rz is a mean value in micron meter obtained form the distances of 5 highest peaks(Yp)and the 5 lowest valleys(Yv)measured from the center line of the roughness curve within the range of sampled reference length(l). $R_{ZJIS}=\frac{(Yp1+Yp2+Yp3+Yp4+Yp5)+(Yv1+Yv2+Yv3+Yv4+Yv5)}{5}$	 Yp1,Yp2,Yp3,Yp4,Yp5: Distance from the mean line to highest 5 peaks in the range of sampled reference length(l) v1,Yv2,Yv3,Yv4,Yv5: Distance from the mean line to lowest 5 valleys in the range of sampled reference length(l)
Arithmetical Mean Roughness	Ra	Ra is obtained from the following formula inmicron meter,the roughness curve is expressed by y=f(x), the X–axis is in the direction of the center line and the Y–axis is the vertical magnification of the roughness curve in the range of sampled reference lengths(l). $Ra=\frac{1}{l}\int_0^l[f(x)]dx$	

Indication in JIS Standard

Example of Ra Indication	Example of Rz Indication
①When indicating the upper limit only (when upper limit is 6.3 μ mRa)  ②When indicating both lower and upper limit (when upper limit is 6.3 μ mRa,lower limit is 1.6 μ mRa) 	①When indicating upper limit only indicate surface roughness following the parameter symbol.  ②When indicating both lower and upper limit indicate surface roughness as(upper limit–lower limit) following the parameter symbol. 

Hardness Conversion Table

Vickers Hardness (HV)	Brinell Hardness (HB)		Rockwell Hardness			Shore Hardness (HS)	Tensile Strength Mpa*
	Standard Ball	Tungsten Carbide Ball	A Scale Load: 60kgf Diamond Point(HRA)	B Scale Load:100kgf 1.6mm Dia.Ball (HRB)	C Scale Load: 150kgf Diamond Point(HRC)		
940	–	–	85.6	–	68.0	97	–
920	–	–	85.3	–	67.5	96	–
900	–	–	85.0	–	67.0	95	–
880	–	(767)	84.7	–	66.4	93	–
860	–	(757)	84.4	–	65.9	92	–
840	–	(745)	84.1	–	62.3	91	–
820	–	(733)	83.8	–	64.7	90	–
800	–	(722)	83.4	–	64.0	88	–
780	–	(710)	83.0	–	63.3	87	–
760	–	(698)	82.6	–	62.5	86	–
740	–	(684)	82.2	–	61.8	84	–
720	–	(670)	81.8	–	61.0	83	–
700	–	(656)	81.3	–	60.1	81	–
690	–	(647)	81.1	–	59.7	–	–
680	–	(638)	80.8	–	59.2	80	–
670	–	630	80.6	–	58.8	–	–
660	–	620	80.3	–	58.3	79	–
650	–	611	80.0	–	57.8	–	–
640	–	601	79.8	–	57.3	77	–
630	–	591	79.5	–	56.8	–	–
620	–	582	79.2	–	56.3	75	–
610	–	573	78.9	–	55.7	–	–
600	–	564	78.6	–	55.2	74	–
590	–	554	78.4	–	54.7	–	2055
580	–	545	78.0	–	54.1	72	2020
570	–	535	77.8	–	53.6	–	1985
560	–	525	77.4	–	53.0	71	1950
550	505	517	77.0	–	52.3	–	1905
540	496	507	76.7	–	51.7	69	1860
530	488	497	76.4	–	51.1	–	1825
520	480	488	76.1	–	50.5	67	1795
510	473	479	75.7	–	49.8	–	1750
500	465	471	75.3	–	49.1	66	1705
490	456	460	74.9	–	48.4	–	1660
480	448	452	74.5	–	47.7	64	1620
470	441	442	74.1	–	46.9	–	1570
460	433	433	73.6	–	46.1	62	1530
450	425	425	73.3	–	45.3	–	1495
440	415	415	72.8	–	44.5	59	1460
430	405	405	72.3	–	43.6	–	1410
420	397	397	71.8	–	42.7	57	1370
410	388	388	71.4	–	41.8	–	1330
400	379	379	70.8	–	40.8	55	1290
390	369	369	70.3	–	39.8	–	1240
380	360	360	69.8	110.0	38.8	52	1205
370	350	350	69.2	–	37.7	–	1170
360	341	341	68.7	109.0	36.6	50	1130
350	331	331	68.1	–	35.5	–	1095
340	322	322	67.6	108.0	34.4	47	1070
330	313	313	67.0	–	33.3	–	1035

Hardness Conversion Table

Vickers Hardness (HV)	Brinell Hardness (HB)		Rockwell Hardness			Shore Hardness (HS)	Tensile Strength Mpa*
	Standard Ball	Tungsten Carbide Ball	A Scale Load: 60kgf Diamond Point(HRA)	B Scale Load:100kgf 1.6mm Dia.Ball (HRB)	C Scale Load: 150kgf Diamond Point(HRC)		
320	303	303	66.4	(107.0)	32.2	45	1005
310	294	294	65.8	–	31	–	980
300	284	284	65.2	–105.5	29.8	42	950
295	280	280	64.8	–	29.2	–	935
290	275	275	64.5	–104.5	28.5	41	915
285	270	270	64.2	–	27.8	–	905
280	265	265	63.8	–103.5	27.1	40	890
275	261	261	63.5	–	26.4	–	875
270	256	256	63.1	102	25.6	38	855
265	252	252	62.7	–	24.8	–	840
260	247	247	62.4	(101.0)	24.0	37	825
255	243	243	62.0	–	23.1	–	805
250	238	238	61.6	99.5	22.2	36	795
245	233	233	61.2	–	21.3	–	780
240	228	228	60.7	98.1	20.3	34	765
230	219	219	–	96.7	(18.0)	33	730
220	209	209	–	95.0	(15.7)	32	695
210	200	200	–	93.4	(13.4)	30	670
200	190	190	–	91.5	(11.0)	29	635
190	181	181	–	89.5	(8.5)	28	605
180	171	171	–	87.1	(6.0)	26	580
170	162	162	–	85.0	(3.0)	25	545
160	152	152	–	81.7	(0.0)	24	515
150	143	143	–	78.7	–	22	490
140	133	133	–	75.0	–	21	455
130	124	124	–	71.2	–	20	425
120	114	114	–	66.7	–	–	390
110	105	105	–	62.3	–	–	–
100	95	95	–	56.2	–	–	–
95	90	90	–	52.0	–	–	–
90	86	86	–	48.0	–	–	–
85	81	81	–	41.0	–	–	–

Extracted from JIS Handbook "Iron & Steel"(SAE J 417)

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

(2)Value in ( ) is not in practical use,but reference only