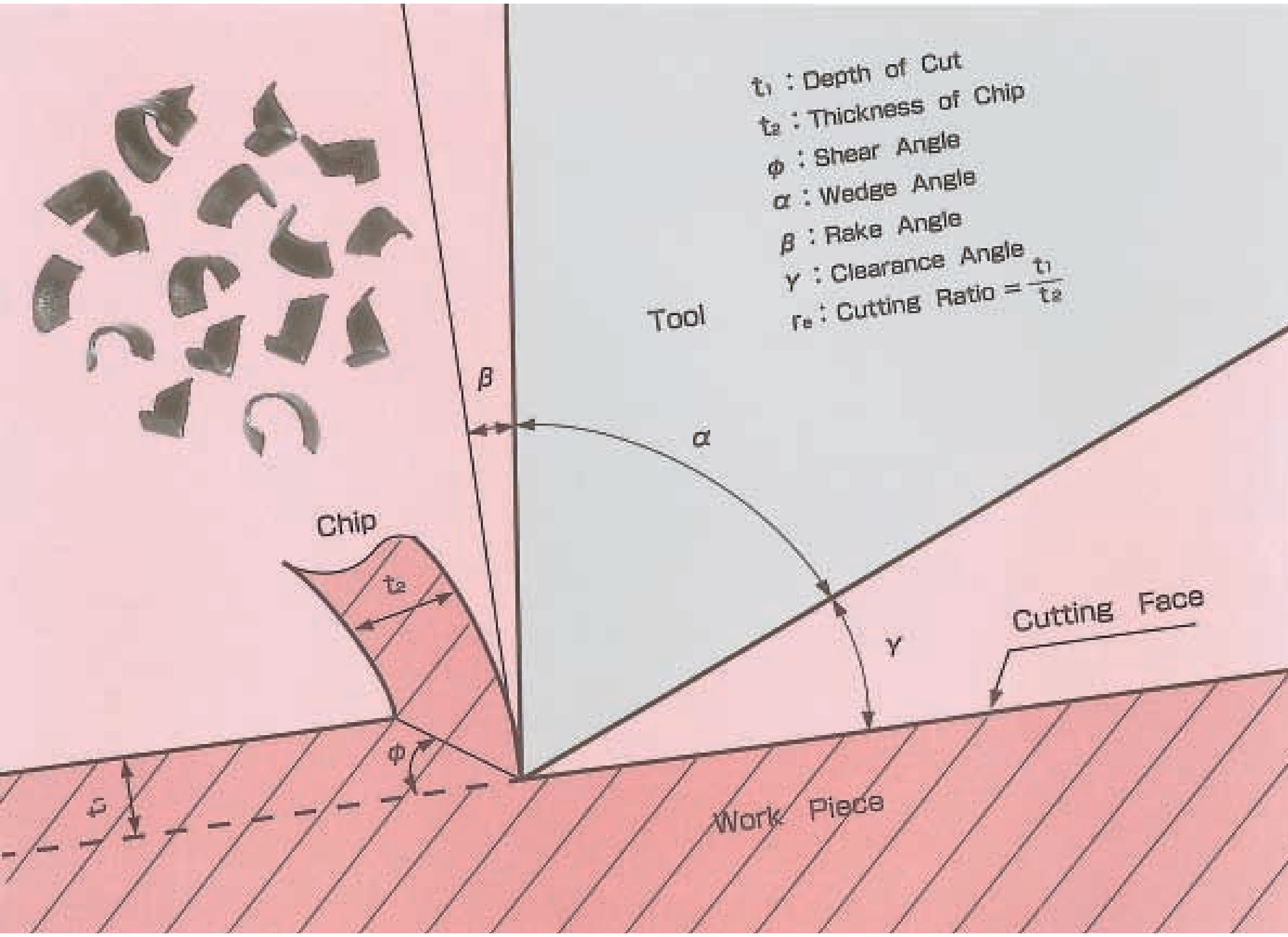
Technical Guidance



CENTRALA TECHNICZNA ELTECH®

Tw· j dystrybutor:

Centrala Techniczna ELTECH Sp. z o.o.
ul. Fabryczna 1-3, 58-100 ś widnica

tel. 74 858 27 00, fax 74 858 27 01

www.eltech.com.pl eltech@eltech.com.pl

SUMITOMO ELECTRIC

Reference

R1 ~ R7

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	—
SNCM240	8640	—
SNCM415	—	—
SNCM420	4320	—
SNCM439	4340	—
SNCM447	—	—

Cr Steels

SCr415	—	—
SCr420	—	—
SCr430	5130	34Cr4
SCr435	5135	37Cr4
SCr440	5140	41Cr4
SCr445	5147	—

Cr-Mo Steels

SCM415	—	—
SCM420	—	—
SCM430	4130	—
SCM435	4135	34CrMo4
SCM440	4140	42CrMo4
SCM445	4145	—

Mn Steels and Mn-Cr Steels for Structural Use

SMn420	1522	—
SMn433	1536	—
SMn438	1541	—
SMn443	1541	—
SMnC420	—	—
SMnC443	—	—

Cr-Mo Steels

SK1	W1-13	—
SK2	W1-11 1/2	—
SK3	W1-10	C105W1
SK4	W1-9	—
SK5	W1-8	C80W1
SK6	W1-7	C80W1
SK7	—	C70W2

High Speed Steels

JIS	AISI	DIN
SKH2	T1	—
SKH3	T4	—
SKH10	T15	—
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	—
SKS44	W2-8 1/2	—
SKD1	D3	X210Cr12
SKD11	D2	—

Grey Cast Iron

FC100	20	GG-10
FC150	25	GG-15
FC200	30	GG-20
FC250	35	GG-25
FC300	40	GG-30
FC350	50	GG-35

Nodular Cast Iron

FCD400	—	GGG-40
FCD450	60/40/ 8	GGG-40.3
FCD500	65/45/12	GGG-50
FCD600	80/55/06	GGG-60
FCD700	100/70/03	GGG-70

Ferritic Stainless Steels

SUS405	AISI 405	DINX6CrAl13
SUS429	AISI 429	
SUS430	AISI 430	DINX6Cr17
SUS430F	AISI 430F	DINX12CrMoS17
SUS434	AISI 434	

Martensitic Stainless Steels

SUS403	AISI 403	
SUS410	AISI 410	DINX10Cr13
SUS416	AISI 416	
SUS420JI	AISI 420	DINX20Cr13
SUS420F	AISI 420F	
SUS431	AISI 431	DINX20CrNi172
SUS440A	AISI 440A	
SUS440B	AISI 440B	
SUS440C	AISI 440C	

Austenitic Stainless Steels

JIS	AISI	DIN
SUS201	AISI 201	
SUS202	AISI 202	
SUS301	AISI 301	
SUS302	AISI 302	
SUS302B	AISI 302B	
SUS303	AISI 303	DINX10CrNiS189
SUS303Se	AISI 303Se	
SUS304	AISI 304	DINX5CrNi1810
SUS304L	AISI 304L	DINX2CrNi1911
SUS304NI	AISI 304N	
SUS305	AISI 305	DINX5CrNi1812
SUS308	AISI 308	
SUS309S	AISI 309S	
SUS310S	AISI 310S	
SUS316	AISI 316	DINX5CrNiMo17122
SUS316L	AISI 316L	DINX2CrNiMo17132
SUS316N	AISI 316N	
SUS317	AISI 317	DINX2CrNiMo18164
SUS317L	AISI 317L	
SUS321	AISI 321	
SUS347	AISI 347	DINX6CrNiNb1810
SUS384	AISI 384	

Heat Resisting Steels

SUH31		
SUH35		
SUH36		
SUH37		
SUH38		
SUH309	AISI 309	
SUH310	AISI 310	DINCrNi2520
SUH330	AISI 330	

Ferritic Heat Resisting Steels

SUH21		DINCrAl1205
SUH409	AISI 409	DINX6CrTi12
SUH446	AISI 446	

Martensitic Heat Resisting Steels

SUH1		
SUH3		
SUH4		
SUH11		
SUH600		

■ Steel and Non-Ferrous Metal Symbols Chart

● Classifications and Symbols of Steels

Class	Material	Symbol	Symbol's Rationale
Structural Steels	Rolled Steels for welded structures	SM	"M" for "Marine" - Usually used in welded marine structures
	Re-rolled Steels	SRB	"R" for "Re-rolled" and "B" for "Bar"
	Rolled Steels for general structures	SS	"S" for "Steel" and for "Structure"
	Light gauge sections for general structures	SSC	"C" for "Cold"
Steel Sheets	Hot rolled mild steel sheets / plates in coil form	SPH	"P" for "Plate" and "H" for "Hot"
Steel Tubes	Carbon steel tubes for piping	SGP	"GP" for "Gas Pipe"
	Carbon steel tubes for boiler and heat exchangers	STB	"T" for "Tube" and "B" for "Boiler"
	Seamless steel tubes for high pressure gas cylinders	STH	"H" for "High Pressure"
	Carbon steel tubes for general structures	STK	"K" for "Kozo"- Japanese word meaning "structure"
	Carbon steel tubes for machine structural uses	STKM	"M" for "Machine"
	Alloy steel tubes for structures	STKS	"S" for "Special"
	Alloy steel tubes for pipings	STPA	"P" for "Piping" and "A" for "Alloy"
	Carbon steel tubes for pressure pipings	STPG	"G" for "General"
	Carbon steel tubes for high temperature pipings	STPT	"T" for " Temperatures"
	Carbon steel tubes for high pressure pipings	SPS	"S" after "SP" is abbreviation for "Special"
	Stainless steel tubes for pipings	SUS-TP	"T" for "Tube" and "P" fpr "Piping"
Steel for Machine Structures	Carbon steels for machine structural uses	SxxC	"C" for "Carbon"
	Aluminium Chromium Molybdenum steels	SACM	"A" for "Al", "C" for "Cr" and "M" for "Mo"
	Chromium Molybdenum steels	SCM	"C" for "Cr" and "M" for "Mo"
	Chromium steels	SCr	"Cr" for "Chromium"
	Nickel Chromium steels	SNC	"N" for "Nickel" and "C" for "Chromium"
	Nickel Chromium Molybdenium steels	SNCM	"M" for "Molybdenium"
	Manganese steels for structural use Manganese Chromium steels	SMn SMnC	"Mn" for "Manganese" "C" for "Chromium"
Special Steels – Tool Steels	Carbon tool steels	SK	"K" for "Kogu"- Japanese word meaning "tool"
	Hollow drill steels	SKC	"C" for "Chisel"
	Alloy tool steel	SKS SKD SKT	"S" for "Special" "D" for "Die" "T" for "Tanzo"- Japanese word for "forging"
	High speed tool steels	SKH	"H" for "High speed"
Special Steels – Stainless Steels	Free cutting sulfuric steels	SUM	"M" for "Machinability"
	High Carbon Chromium bearing steels	SUJ	"J" for "Jikuuke"- Japanese word meaning "bearing"
	Spring steels	SUP	"P" for "Spring"
	Stainless steels	SUS	"S" after "SU" is abbreviation for "Stainless"
Special Steels – Heat-resistant Steels	Heat-resistant steels	SUH	"U" for "Special Usage" and "H" for "Heat"
	Heat-resistant steel bars	SUHB	"B" for "Bar"
	Heat-resistant steel sheets	SUHP	"P" for "Plate"
Forged Steels	Carbon steel forgings for general use	SF	"F" for "Forging"
	Carbon steel booms and billets for forgings	SFB	"B" for "Billet"
	Chromium Molybdenium steel forgings	SFCM	"C" for "Chromium" and "M" for "Molybdenium"
	Nickel Chromium Molybdenium steel forgings	SFNCM	"N" for "Nickel"
Cast Irons	Grey cast irons	FC	"F" for "Ferrous" and "C" for "Casting"
	Spherical graphite / Ductile cast irons	FCD	"D" for "Ductile"
	Blackheart malleable cast irons	FCMB	"M" for "Malleable" and "B" for "Black"
	Whiteheart malleable cast irons	FCMW	"W" for "White"
	Pearlite malleable cast irons	FCMP	"P" for "Pearlite"
Cast Steels	Carbon cast steels	SC	"C" for "Casting"
	Stainless cast steels	SCS	"S" for "Stainless"
	Heat-resistant cast steels	SCH	"H" for "Heat"
	High Manganese cast steels	SCMnH	"Mn" for "Manganese" and "H" for "High"

● Non-Ferrous Metals

Class	Material	Symbol
Copper and Copper Alloys	Copper and Copper alloys - Sheets, plates and strips	CxxxxP
		CxxxxPP
		CxxxxR
	Copper and Copper alloys - Welded pipes and tubes	CxxxxBD
		CxxxxBDS
		CxxxxBE
		CxxxxBF
Aluminium and Aluminium Alloys	Aluminium and Al alloys - Sheets, plates and strips	AxxxxP
		AxxxxPC
	Aluminium and Al alloys - Rods, bars and wires	AxxxxBE
		AxxxxBD
		AxxxxW
	Aluminium and Al alloys - Extruded shapes	AxxxxS
	Aluminium and Al alloy forgings	AxxxxFD
		AxxxxFH
Magnesium Alloys	Magnesium alloy sheets and plates	MP
Nickel Alloys	Nickel-Copper alloy sheets and plates	NCuP
	Nickel-Copper alloy rods and bars	NCuB
Wrought Titanium	Titanium rods and bars	TB
Castings	Brass castings	YBsCx
	High strength Brass castings	HBsCx
	Bronze castings	BCx
	Phosphorus Bronze castings	PCBx
	Aluminium Bronze castings	AlBCx
	Aluminium alloy castings	AC
	Magnesium alloy castings	MC
	Zinc alloy die castings	ZDCx
	Aluminium alloy die castings	ADC
	Magnesium alloy die castings	MDC
	White metals	WJ
	Aluminium alloy castings for bearings	AJ
	Copper-Lead alloy castings for bearings	KJ

■ Hardness Scale Comparision Chart

Brinell Hardness (HB) 3,000kgf	Rockwell Hardness				Vickers Hardness 50kgf	Shore Hardness	Traverse Rupture Strength (kg/mm^2)
	"A" Scale 60kgf (Brale)	"B" Scale 100kgf (1/10" Ball)	"C" Scale 150kgf (Brale)	"D" Scale 100kgf (Brale)			
—	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	69.7	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	210
534	77.8	—	53.5	65.8	569	71	202
514	76.9	—	52.1	64.7	547	70	193
495	76.3	—	51.0	63.8	528	68	186
477	75.6	—	49.6	62.7	508	66	177
461	74.9	—	48.5	61.7	491	65	170
444	74.2	—	47.1	60.8	472	63	162
429	73.4	—	45.7	59.7	455	61	154
415	72.8	—	44.5	58.8	440	59	149
401	72.0	—	43.1	57.8	425	58	142
388	71.4	—	41.8	56.8	410	56	136
375	70.6	—	40.4	55.7	396	54	129
363	70.0	—	39.1	54.6	383	52	124
352	69.3	(110.0)	37.9	53.8	372	51	120
341	68.7	(109.0)	36.6	52.8	360	50	115
331	68.1	(108.5)	35.5	51.9	350	48	112

Brinell Hardness (HB) 3,000kgf	Rockwell Hardness				Vickers Hardness 50kgf	Shore Hardness	Traverse Rupture Strength (kg/mm^2)
	"A" Scale 60kgf (Brale)	"B" Scale 100kgf (1/10" Ball)	"C" Scale 150kgf (Brale)	"D" Scale 100kgf (Brale)			
321	67.5	(108.0)	34.3	50.1	339	47	108
311	66.9	(107.5)	33.1	50.0	328	46	105
302	66.3	(107.0)	32.1	49.3	319	45	103
293	65.7	(106.0)	30.9	48.3	309	43	99
285	65.3	(105.5)	29.9	47.6	301	—	97
277	64.6	(104.5)	28.8	46.7	292	41	94
269	64.1	(104.0)	27.6	45.9	284	40	91
262	63.6	(103.0)	26.6	45.0	276	39	89
255	63.0	(102.0)	25.4	44.2	269	38	86
248	62.5	(101.0)	24.2	43.2	261	37	84
241	61.8	100.0	22.8	42.0	253	36	82
235	61.4	99.0	21.7	41.4	247	35	80
229	60.8	98.2	20.5	40.5	241	34	78
223	—	97.3	(18.8)	—	234	—	—
217	—	96.4	(17.5)	—	228	33	74
212	—	95.5	(16.0)	—	222	—	72
207	—	94.6	(15.2)	—	218	32	70
201	—	93.8	(13.8)	—	212	31	69
197	—	92.8	(12.7)	—	207	30	67
192	—	91.9	(11.5)	—	202	29	65
187	—	90.7	(10.0)	—	196	—	63
183	—	90.0	(9.0)	—	192	28	63
179	—	89.0	(8.0)	—	188	27	61
174	—	87.8	(6.4)	—	182	—	60
170	—	86.8	(5.4)	—	178	26	58
167	—	86.0	(4.4)	—	175	—	57
163	—	85.0	(3.3)	—	171	25	56
156	—	82.9	(0.9)	—	163	—	53
149	—	80.8	—	—	156	23	51
143	—	78.7	—	—	150	22	50
137	—	76.4	—	—	143	21	47
131	—	74.0	—	—	137	—	46
126	—	72.0	—	—	132	20	44
121	—	69.8	—	—	127	19	42
116	—	67.6	—	—	122	18	41
111	—	65.7	—	—	117	15	39

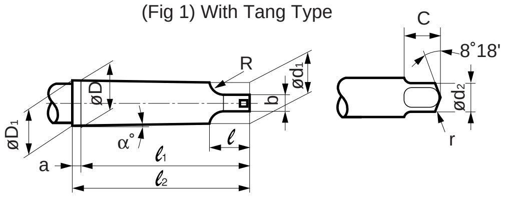
1) Figures within the ( ) are not commonly used

2) Rockwell A, C and D scales utilises a diamond brale

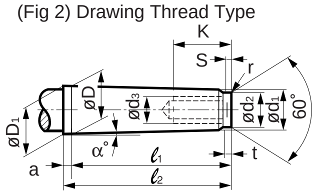
■ Standard of Tapers

● Morse Taper

(Fig 1) With Tang Type



(Fig 2) Drawing Thread Type



(Units in mm)

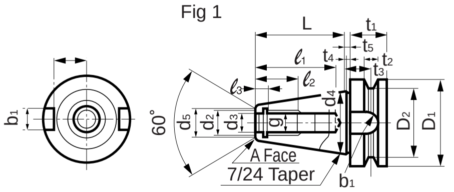
Morse Taper Number	Taper*		Taper Angle (α°)	Taper						Tang						Shape
				D	d	D1⁺ (Estimated)	d1⁺ (Estimated)	ℓ1 (Max)	ℓ2 (Max)	d2 (Max)	b	C (Max)	e (Max)	R	r	
0	$\frac{1}{19.212}$	0.05205	1°29'27"	9.045	3	9.2	6.1	56.5	59.5	6.0	3.9	6.5	10.5	4	1	Fig 1
1	$\frac{1}{20.047}$	0.04988	1°25'43"	12.065	3.5	12.2	9.0	62.0	65.5	8.7	5.2	8.5	13.5	5	1.2	
2	$\frac{1}{20.020}$	0.04995	1°25'50"	17.780	5	18.0	14.0	75.0	80.0	13.5	6.3	10	16	6	1.6	
3	$\frac{1}{19.922}$	0.05020	1°26'16"	23.825	5	24.1	19.1	94.0	99.0	18.5	7.9	13	20	7	2	
4	$\frac{1}{19.245}$	0.05194	1°29'15"	31.267	6.5	31.6	25.2	117.5	124.0	24.5	11.9	16	24	8	2.5	
5	$\frac{1}{19.002}$	0.05263	1°30'26"	44.399	6.5	44.7	36.5	149.5	156.0	35.7	15.9	19	29	10	3	
6	$\frac{1}{19.180}$	0.05214	1°29'36"	63.348	8	63.8	52.4	210.0	218.0	51.0	19	27	40	13	4	
7	$\frac{1}{19.231}$	0.05200	1°29'22"	83.058	10	83.6	68.2	286.0	296.0	66.8	28.6	35	54	19	5	

Morse Taper Number	Taper*		Taper Angle (α°)	Taper						Thread					Shape
				D	d	D1⁺ (Estimated)	d1⁺ (Estimated)	ℓ1 (Max)	ℓ2 (Max)	d2 (Max)	d3	K (Max)	t (Max)	r	
0	$\frac{1}{19.212}$	0.05205	1°29'27"	9.045	3	9.2	6.4	50	53	6	—	—	4	0.2	Fig 2
1	$\frac{1}{20.047}$	0.04988	1°25'43"	12.065	3.5	12.2	9.4	53.5	57	9	M 6	16	5	0.2	
2	$\frac{1}{20.020}$	0.04995	1°25'50"	17.780	5	18.0	14.6	64	69	14	M10	24	5	0.2	
3	$\frac{1}{19.922}$	0.05020	1°26'16"	23.825	5	24.1	19.8	81	86	19	M12	28	7	0.6	
4	$\frac{1}{19.254}$	0.05194	1°29'15"	31.267	6.5	31.6	25.9	102.5	109	25	M16	32	9	1	
5	$\frac{1}{19.002}$	0.05263	1°30'26"	44.399	6.5	44.7	37.6	129.5	136	35.7	M20	40	9	2.5	
6	$\frac{1}{19.180}$	0.05214	1°29'36"	63.348	8	63.8	53.9	182	190	51	M24	50	12	4	
7	$\frac{1}{19.231}$	0.05200	1°29'22"	80.058	10	86.6	70.0	250	260	65	M33	80	18.5	5	

* The fractional values are the taper standards.
⁺ Diameters (D_1) and (d_1) are calculated from the values of (D) and other values of the taper. (Values are rounded up to one decimal place)

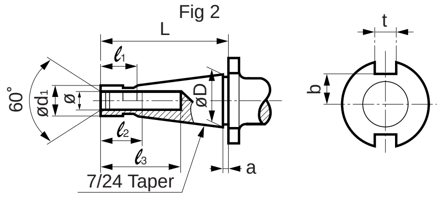
● Bottle Grip Taper

Fig 1



● American Standard Taper (National Taper)

Fig 2



● Bottle Grip Taper

(Units in mm)

Taper No.	D1	D2	t1	t2	t3	t4	t5	d1 (Standard)	d2	d3	d4	L	ℓ2	ℓ3	ℓ4	g	b1	t7	Reference		Shape
																			d5	ℓ1	
BT40	63	53	25	10	16.6	2	2	44.45	19	17	14	65.4	30	8	21	M16	16.1	22.6	25.3	70	Fig 1
BT45	85	73	30	12	21.2	3	3	57.15	23	21	17.5	82.8	38	9	26	M20	19.3	29.1	33.1	70	
BT50	100	85	35	15	23.2	3	3	69.85	27	25	21	101.8	45	11	31	M24	25.7	35.4	40.1	90	
BT60	155	135	45	20	28.2	3	3	107.95	33	31	26.5	161.8	56	12	34	M30	25.7	60.1	60.7	110	

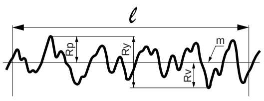
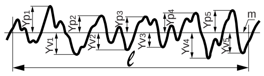
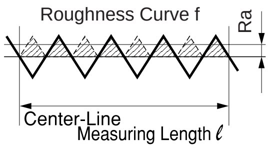
● American Standard Taper (National Taper)

(Units in mm)

Taper No.	Nominal Diameter	D	d1		L	ℓ1	ℓ2	ℓ3	g	a	t	b	Shape
30	1 1/4"	31.750	17.40	$^{-0.29}_{-0.36}$	70	20	24	50	1/2"	1.6	15.9	16	Fig 2
40	1 3/4"	44.450	25.32	$^{-0.30}_{-0.384}$	95	25	30	60	5/8"	1.6	15.9	22.5	
50	2 3/4"	69.850	39.60	$^{-0.31}_{-0.41}$	130	25	45	90	1"	3.2	25.4	35	
60	4 1/4"	107.950	60.20	$^{-0.34}_{-0.46}$	210	45	56	110	1 1/4"	3.2	25.4	60	

■ Finished Surface Roughness

● Types of Surface Roughness Measurements

Types	Symbol	Method of Determination	Descriptive Figure
Maximum Height	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	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.	
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.

Designated values for **Ry**	Designated values for **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	0.40a 0.80a 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.

■ Tolerance Chart for Round Matching Parts

● Tolerance for Shank Sizes

Diameter, D(mm)		Tolerance Class (µm)																
>D	≤D	b9	c9	d8	d9	e7	e8	e9	f6	f7	f8	g5	g6	h5	h6	h7	h8	h9
–	3	−140 −165	−60 −85	−20 −34	−20 −45	−14 −24	−14 −28	−14 −39	−6 −12	−6 −16	−6 −20	−2 −6	−2 −8	0 −4	0 −6	0 −10	0 −14	0 −25
3	6	−140 −170	−70 −100	−30 −48	−30 −60	−20 −32	−20 −38	−20 −50	−10 −18	−10 −22	−10 −28	−4 −9	−4 −12	0 −5	0 −8	0 −12	0 −18	0 −30
6	10	−150 −186	−80 −116	−40 −62	−40 −76	−25 −40	−25 −47	−25 −61	−13 −22	−13 −28	−13 −35	−5 −11	−5 −14	0 −6	0 −9	0 −15	0 −22	0 −36
10	14	−150 −193	−95 −138	−50 −77	−50 −93	−32 −50	−32 −59	−32 −75	−16 −27	−16 −34	−16 −43	−6 −14	−6 −17	0 −8	0 −11	0 −18	0 −27	0 −43
14	18																	
18	24	−160 −212	−110 −162	−65 −98	−65 −117	−40 −61	−40 −73	−40 −92	−20 −33	−20 −41	−20 −53	−7 −16	−7 −20	0 −9	0 −13	0 −21	0 −33	0 −52
24	30																	
30	40	−170 −232	−120 −182	−80 −119	−80 −142	−50 −75	−50 −89	−50 −112	−25 −41	−25 −50	−25 −64	−9 −20	−9 −25	0 −11	0 −16	0 −25	0 −39	0 −62
40	50	−180 −242	−130 −192															
50	65	−190 −264	−140 −214	−110 −146	−100 −174	−60 −90	−60 −106	−60 −134	−30 −49	−30 −60	−30 −76	−10 −23	−10 −29	0 −13	0 −19	0 −30	0 −46	0 −74
65	80	−200 −274	−150 −224															
80	100	−220 −307	−170 −257	−120 −174	−120 −207	−72 −107	−72 −126	−72 −159	−36 −58	−36 −71	−36 −90	−12 −27	−12 −34	0 −15	0 −22	0 −35	0 −54	0 −87
100	120	−240 −327	−180 −267															
120	140	−260 −360	−200 −300	−145 −208	−145 −245	−85 −125	−85 −148	−85 −185	−43 −68	−43 −83	−43 −106	−14 −32	−14 −39	0 −18	0 −25	0 −40	0 −63	0 −100
140	160	−280 −380	−210 −310															
160	180	−310 −410	−230 −330															
180	200	−340 −455	−240 −355	−170 −242	−170 −285	−100 −146	−100 −172	−100 −215	−50 −79	−50 −96	−50 −122	−15 −35	−15 −44	0 −20	0 −29	0 −46	0 −72	0 −115
200	225	−380 −495	−260 −375															
225	250	−420 −535	−280 −395															

● Tolerance for Hole Sizes

Diameter, D(mm)		Tolerance Class (µm)																		
>D	≤D	B10	C9	C10	D8	D9	D10	E7	E8	E9	F6	F7	F8	G6	G7	H6	H7	H8	H9	H10
–	3	+180 +140	+85 +60	+100 +60	+34 +20	+45 +20	+60 +20	+24 +14	+28 +14	+39 +14	+12 +6	+16 +6	+20 +6	+8 +2	+12 +2	+6 0	+10 0	+14 0	+25 0	+40 0
3	6	+188 +140	+100 +70	+118 +70	+48 +30	+60 +30	+78 +30	+32 +20	+38 +20	+50 +20	+18 +10	+22 +10	+28 +10	+12 +4	+16 +4	+8 0	+12 0	+18 0	+30 0	+48 0
6	10	+208 +150	+116 +80	+138 +80	+62 +40	+76 +40	+98 +40	+40 +25	+47 +25	+61 +25	+22 +13	+28 +13	+35 +13	+14 +5	+20 +5	+9 0	+15 0	+22 0	+36 0	+58 0
10	14	+220 +150	+138 +95	+165 +95	+77 +50	+93 +50	+120 +50	+50 +32	+59 +32	+75 +32	+27 +16	+34 +16	+43 +16	+17 +6	+24 +6	+11 0	+18 0	+27 0	+43 0	+70 0
14	18																			
18	24	+244 +160	+162 +110	+194 +110	+98 +65	+117 +65	+149 +65	+61 +40	+73 +40	+92 +40	+33 +20	+41 +20	+53 +20	+20 +7	+28 +7	+13 0	+21 0	+33 0	+52 0	+84 0
24	30																			
30	40	+270 +170	+182 +120	+220 +120	+119 +80	+142 +80	+180 +80	+75 +50	+89 +50	+112 +50	+41 +25	+50 +25	+64 +25	+25 +9	+34 +9	+16 0	+25 0	+39 0	+62 0	+100 0
40	50	+280 +180	+192 +130	+230 +130																
50	65	+310 +190	+214 +140	+260 +140	+146 +146	+174 +100	+220 +146	+90 +60	+106 +60	+134 +60	+49 +30	+60 +30	+76 +30	+29 +10	+40 +10	+19 0	+30 0	+46 0	+74 0	+120 0
65	80	+320 +200	+224 +150	+270 +150																
80	100	+360 +220	+257 +170	+310 +170	+174 +120	+207 +120	+260 +120	+107 +72	+126 +72	+159 +72	+58 +36	+71 +36	+90 +36	+34 +12	+47 +12	+22 0	+35 0	+54 0	+87 0	+140 0
100	120	+380 +240	+267 +180	+320 +180																
120	140	+420 +260	+300 +200	+360 +200	+208 +145	+245 +145	+205 +145	+125 +85	+148 +85	+185 +85	+68 +43	+83 +43	+106 +43	+39 +14	+54 +14	+25 0	+40 0	+63 0	+100 0	+160 0
140	160	+440 +280	+310 +210	+370 +210																
160	180	+470 +310	+330 +230	+390 +230																
180	200	+525 +340	+355 +240	+425 +240	+242 +170	+285 +170	+355 +170	+146 +100	+172 +100	+215 +100	+79 +50	+96 +50	+122 +50	+44 +15	+61 +15	+29 0	+46 0	+72 0	+115 0	+185 0
200	225	+565 +380	+375 +260	+445 +260																
225	250	+605 +420	+395 +280	+465 +280																

Turning Guidance

T1 ~ T8

■ 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)
π : 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)

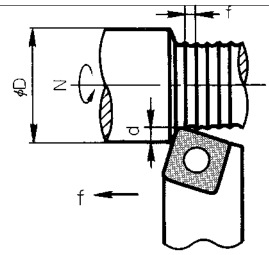
$$F = f \times N$$

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

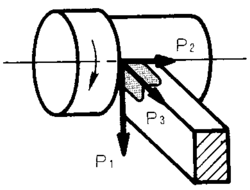
Speed Ratio Related to Surface and Machining Conditions of The Work

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

< Cutting Resistance >

● Three Component Forces Of Cutting Resistance

Three Component Forces:



P_1: Principal or Tangential Component Force
P_2: Feed Component Force
P_3: Back Component Force

● Factors Affecting Cutting Resistance

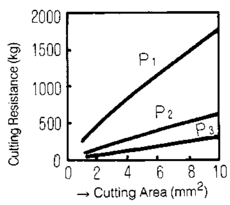
Factors Influencing Cutting Resistance

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 (Positive) <--	Rake Angle	--> Small (Negative)
5. Approach Angle	Small <--	Approach angle	--> Large

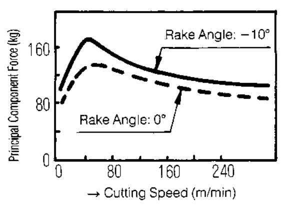
Relation Between Tensile Strength & Cutting Resistance

Tensile Strength (kg/mm²)	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

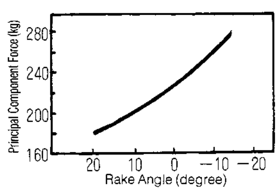
Cutting Area & Cutting Resistance



Cutting Speed & Cutting Resistance



Rake Angle & Cutting Resistance



● Determination Of Cutting Resistance

Determination of the Cutting Resistance

$$P_1 = P_s \times q$$

P_1: Cutting Resistance (kg)
P_s: Specific Cutting Resistance (kg/mm²)
q: Area of the chip (mm²)

● Determination Of Power Requirement

Determination of Power Requirement

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

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

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

Approximate Ps value

Normal Steel : 250~300 kg/mm²
Cast Iron : 150kg/mm²

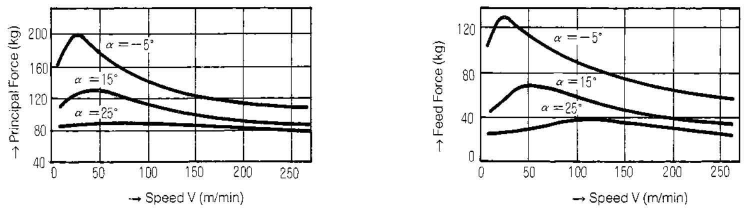
Influences of Cutting Edge Geometries

● 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

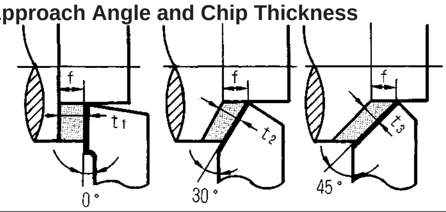
Relation Between Rake Angle (α°) and Cutting Resistance



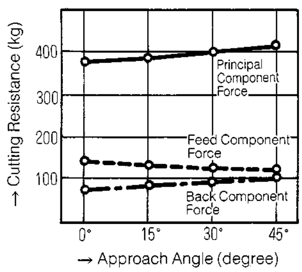
● Influence Of The Approach Angle :

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

Approach Angle and Chip Thickness

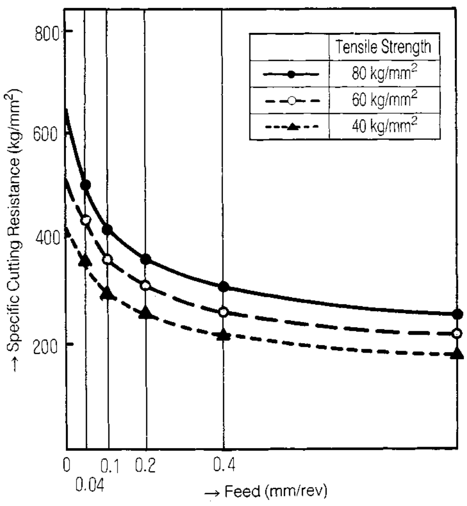


Approach Angle and Three Component Forces



Work Material:
SCM440 (Hs38)
Insert: TNGA220412
Conditions:
V= 100m/min
f = 0.45 mm/rev
d = 4mm

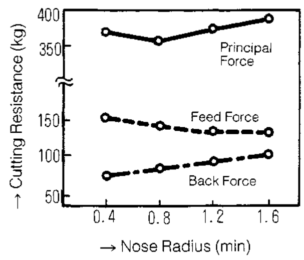
Chip Thickness and Specific Cutting Resistance for Carbon Steels.



● Influence Of the Nose Radius :

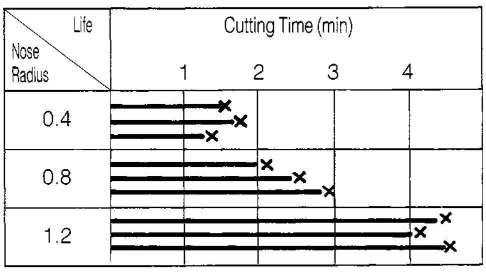
*Nose Radius & 3 Component Forces
*Nose Radius & Strength

Nose Radius and Three Component Forces



Work Material : SCM440 (Hs38)
Insert: TNGA 2204□□
Holder: PTGNR2525-43
Conditions :
V = 100m/min
d = 4 mm
f = 0.45 mm/rev

Relation Between Nose Radius and Strength



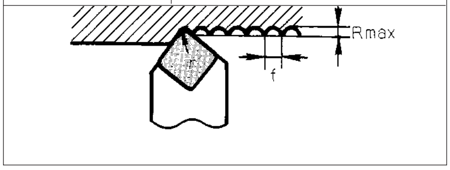
Workpiece : Grooved Material (Hs38)
Insert : SNGA 1204□□ ST10P
Holder : PSBNR2525-43
Conditions : V=100m/min
d= 2 mm
f = 0.2 mm/rev

■ General Guide Lines for Turning Tools

● Surface Roughness

Theoretical (Geometric) Surface Roughness

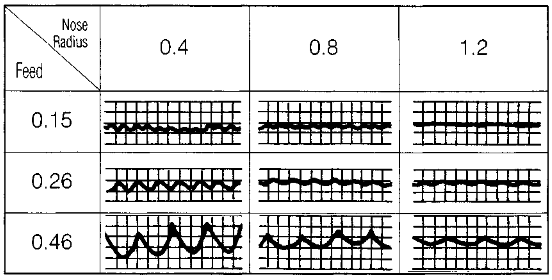
$Rmax = \frac{f^2}{8r}$	Rmax : Surface Roughness (mm) f : Feed (mm/rev) r : Nose Radius (mm)



Actual Surface Roughness:
In Case of Steels,
Theoretical Roughness x 1.5~3
In Case of Cast irons,
Theoretical Roughness x 3~5

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



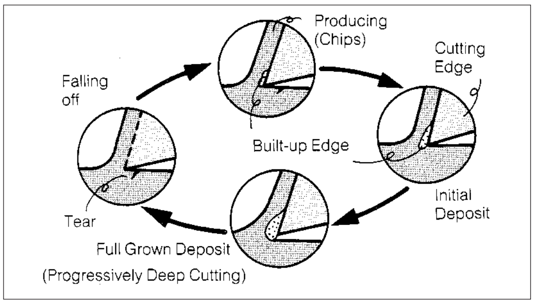
● Growth Of The Built-Up Edge & Its Remedies

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 than acts as the cutting edge.

Influence of Built-up Edge
1. Deterioration of Surface Roughness And Accuracy.
2. Increase Edge Chipping

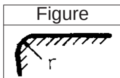
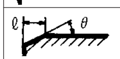
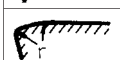
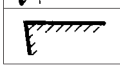
Steps to Prevent Built-up Edge
1. Raise the cutting temperature by increasing the speed and feed.
2. Apply cutting fluids that have a satisfactory EP performance.
3. Use coated or cermet tools.
4. Enlarge the rake angle.

Cycle of Built-up Edge



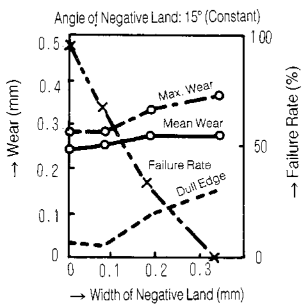
● Different Edge Treatments & Their Effects

Different Edge Treatments

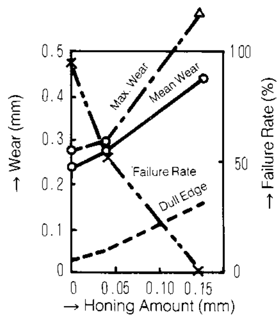
Figure	Description
	Honing
	Negative Land (Chamfer Honing)
	Combined Honing
	Sharp Edge (w/o Edge Treatment)

r : Honing Amount
θ : Angle Of Negative Land
ℓ : Width Of Negative Land

Influence of the Width of Negative Land



Influence of the Honing Amount



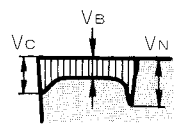
● Factors That Cause Chattering & Some Of Its Remedies

	Poor Workpiece Rigidity	Poor Tool Rigidity	Poor Machine Rigidity	Poor Cutting Conditions	Poor Edge Design
Remedies	- Improve clamping. - Use fixed steady. - Improve rigidity of the tail center.	- Use a thicker shank. - Reduce the overhang. - Use a carbide shank holder. - Check that toolholder is held properly.	- Reduce backlash in the main spindle Bearing - Eliminate backlash in machine slides	- Select correct cutting conditions. - Change speed to avoid the sympathetic vibration point.	- Reduce clearance angle. - Reduce approach angle. - Increase the end cutting edge angle. - Reduce the nose radius. - Make the rake angle larger. - Hone the cutting edge slightly.

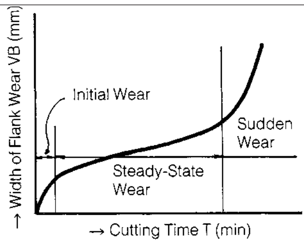
■ Tool Life

● Wear Process Curve

Flank Wear

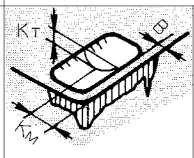


VB : Width of Flank Wear (Mean)
VC : Maximum Wear of Nose Radius
VN : Notch Wear

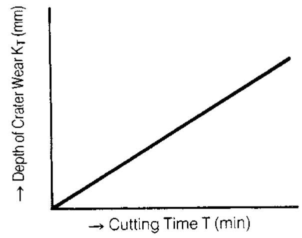


Initial wear is very fast. It then evens out to a more gradual pattern until a limit is reached. From that limit point, the wear increases substantially.

Crater Wear



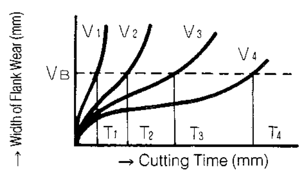
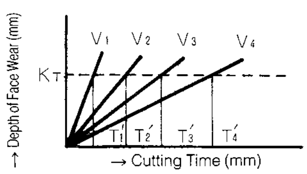
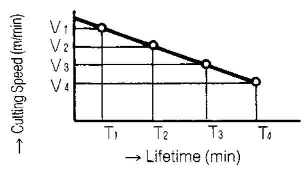
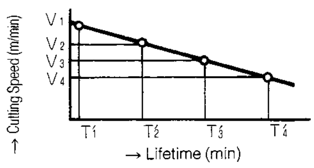
KT : Depth of Crater wear
B : Width of land
KM : Distance between the centre of the Crater wear and Cutting edge.



Crater wear is more progressive, there is no sudden breakdown pattern.

● Life Curve (V-T Lines)

At four speeds V1, V2, V3 and V4, the relative tool lives for a given flank wear VB or crater KT are indicated as T1, T2, T3 and T4 respectively, using log-log graph paper.

	Flank Wear	Flank Wear
Wearing Process		
Life Curve		

● 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

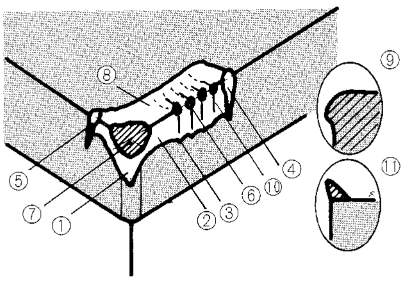
1. When surface finish deteriorates unacceptably.
2. When a fixed amount of tool wear is reached, (see the right hand table)
3. When work piece dimension is not tolerable.
4. When power consumption reaches a limit.
5. Sparking or chip discolouration and disfiguration.
6. Cutting Time or Number of components produced.

Width of flank wear for general life determination for cemented carbides.

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	Rough Cutting of Common Cast Irons.

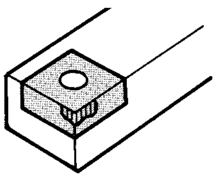
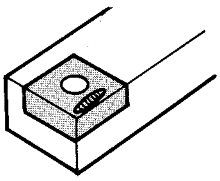
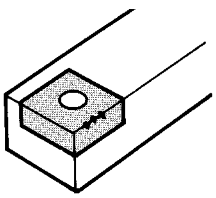
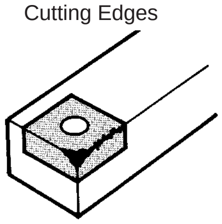
■ Tool Failures and Their Counter-Measures

● 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.

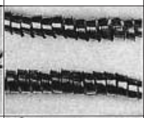
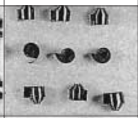
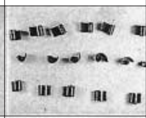
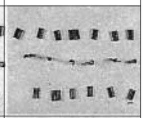
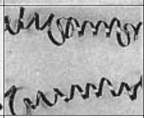
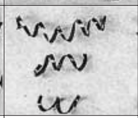
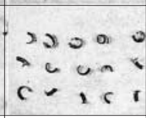
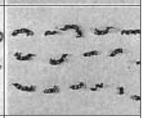
● Failure & Countermeasures

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

■ 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

Influence Of Chip Shapes

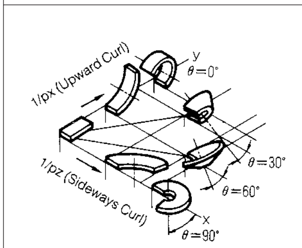
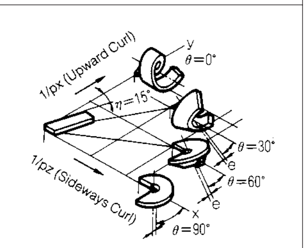
Influence \ Chip Shape		Type A	Type B	Type C	Type D	Type E
Tool life	Wear Resistance	O	O	O	O	O
	Chipping	X	X	O	O	X
Quality	Finished Surface	O	O	O	O	X
		O	O	O	O	X
		O	O	O	O	X
Transfer	Machining Part Chips	X	O	O	O	O
		X	X	O	O	O
Power Consumption Cutting Resistance Safety		O	O	O	O	X
		X	O	O	O	X
Overall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

O: Superior X:Inferior

- 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.

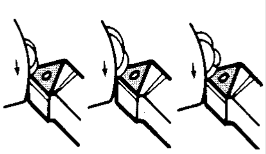
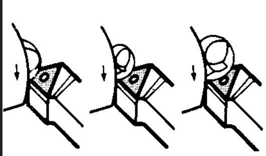
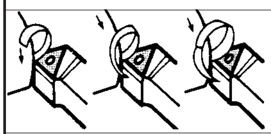
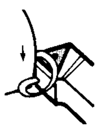
● Factors To Determine Chip Formation

(a) If Outlet Angle η = 0 °	(b) If Outlet Angle η = 15°
	

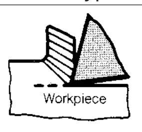
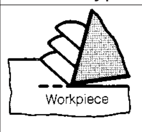
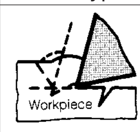
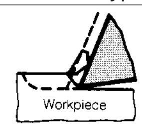
- Factors: Outlet Angle and Cutting Direction
- Chip Forms According to The Combination of Factors

Cutting Direction \ Outlet Angle	If n = 0	If n ≠ 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

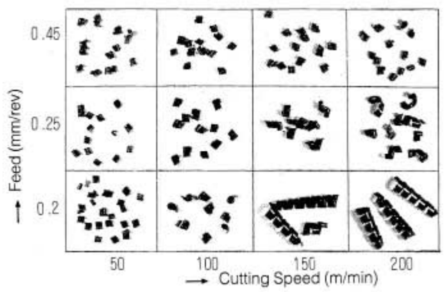
	Flow Type	Shear Type	Tear Type	Crack Type
Form	 Workpiece	 Workpiece	 Workpiece	 Workpiece
Condition	Continuous Chip and satisfactory surface finish	aA chip is sliced -off at the shear angle	Chip with the appearance of being torn off. The workpiece surface is damaged.	The swarf cracks before reaching 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 <-- Work Deformation --> Small Large <------- Rake Angle ------> Small Slight <------- Depth of cut ------> Excess High <----- Cutting Speed -----> Low			

Turning

■ 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.



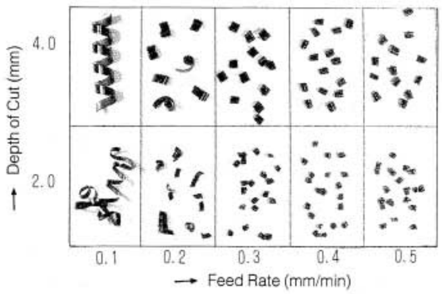
Workpiece : S45C (Hs38)

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.



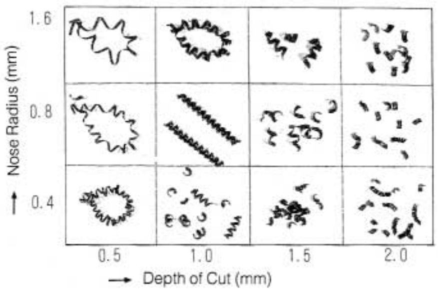
Workpiece : S45C (Hs38)

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.



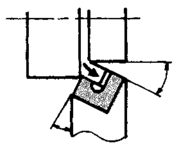
Workpiece : S45C (Hs38)

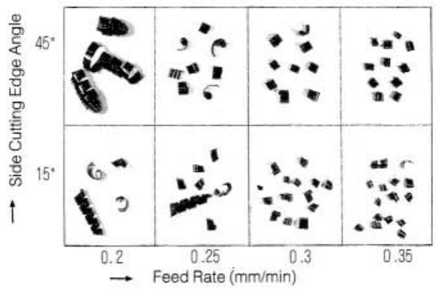
Insert : CNMG1204□□N-UX
Holder : PCLNR2525-43

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)

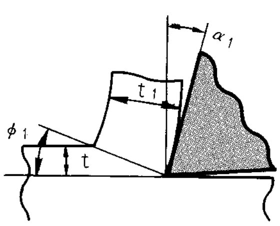
Insert : SNMG120408N-UX
Holder: PSBNR2525-43
(Side Cutting edge angle 15°)
PSSNR2525-43
(Side Cutting edge angle 45°)

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

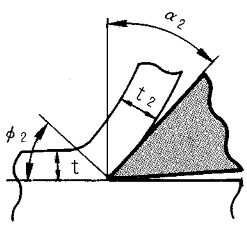
● Influence On The Rake Angle

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

For Small Top Rake Angle (α1)
- The shear angle is small (ϕ1)
- The chip is thick (t1)



For Large Top Rake Angle (α2)
- The shear angle is large (ϕ2)
- The chip is thin (t2)

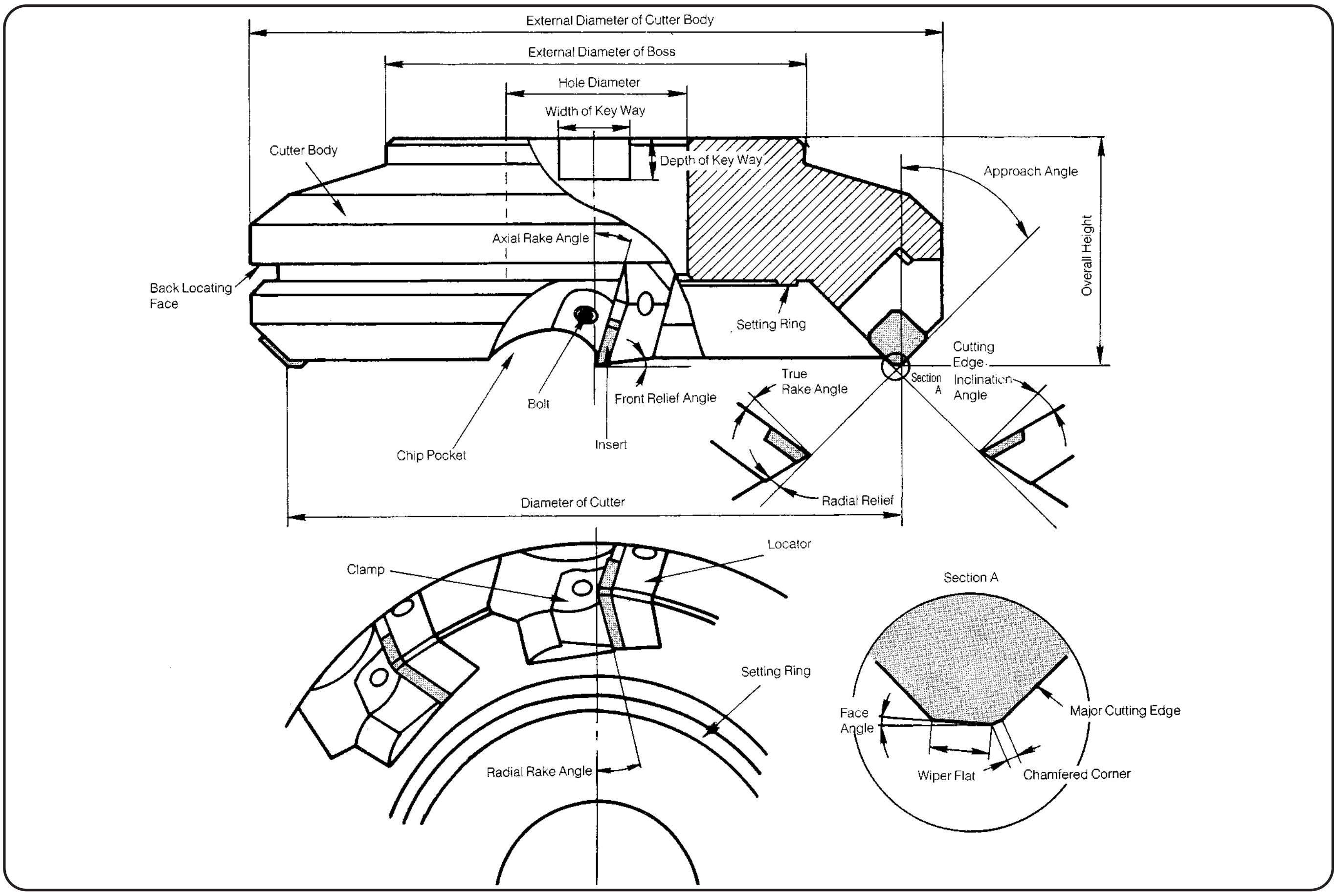


Milling Guidance

M1 ~ M7

■ Milling Cutter Nomenclature & Clamping Method

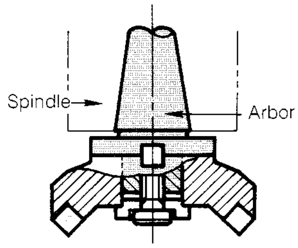
● Cutter Parts Name



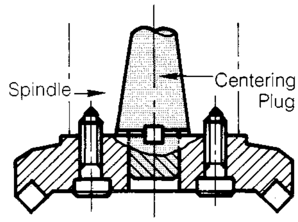
● Clamping Method for Each Cutter Size

Cutter Body			Adaptor	
External Diameter D (mm)	Internal Diameter d (mm)	Chart	Type	Figure (See diagram below)
80	25.4	Chart 1	Arbor	Type A
100	31.75	Chart 2	Arbor	Type A
125	38.1	Chart 2	Arbor	Type A
160	50.8	Chart 2	Arbor	Type A
200	47.625	Chart 3	Centering Plug	Type B
250	47.625	Chart 3	Centering Plug	Type B
315	47.625	Chart 4	Centering Plug	Type B

Clamping Method : Type A

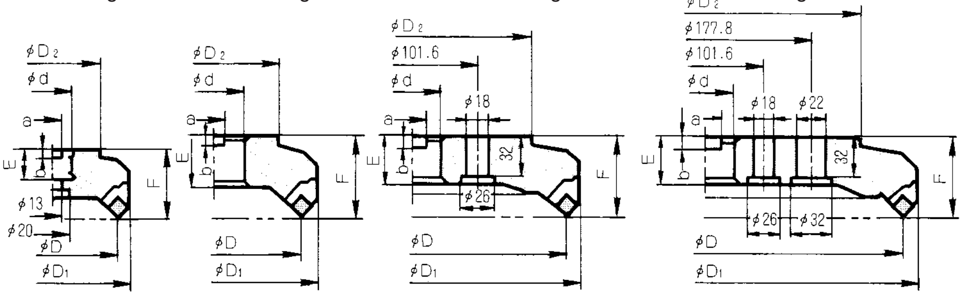


Clamping Method : Type B



Cutter Body Configuration Diagrams

Figure 1 Figure 2 Figure 3 Figure 4



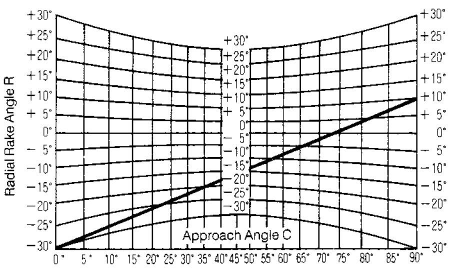
(D: External Diameter, D_1 : External Diameter of Body, D_2 :External Diameter of Boss, d: Hole Diameter, F: Height, E: Thickness, a: Width of Key Way, b: Depth of Key Way)

■ Influences of Cutting Edge Geometries

● Various Cutting Angles & Their Functions

	Description	Code	Functions	Influences
1. 2.	Axial Rake Angle Radial Rake Angle	A.R R.R	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	A.A	Controls chip thickness and chip removal direction	The effect of the large approach angle is to reduce the chip thickness and cutting force.
4.	True Rake Angle	T.A	Effective Rake Angle	- 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	I.A	Controls chip removal direction	- With a positive (large) angle, the chip removal is satisfactory with less cutting resistance but the strength of the corner is weaker.
6.	Wiper Flat Clearance Angle	F.A	Controls surface finish	A smaller clearance angle will produce a better surface finish.
7.	Clearance Angle		Controls edge strength, tool life and chattering, etc	

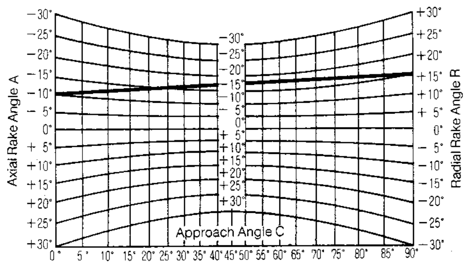
Ready Chart for True Rake Angles



Example in using the above chart :
Given: A(Axial Rake Angle) = +10°
R(Radial Rake Angle) = -30°
C(Approach Angle) = 60°
Solution: **T** (True Rake Angle) taken from the chart is = -8°

Formula: tan T = tan R.cos C + tan A.sin C

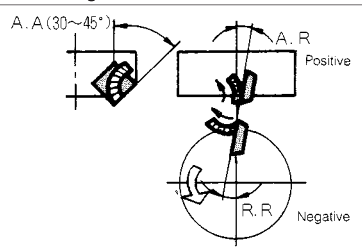
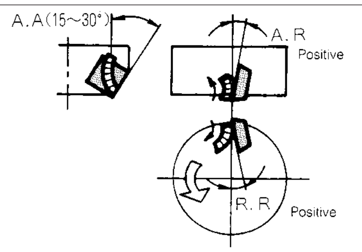
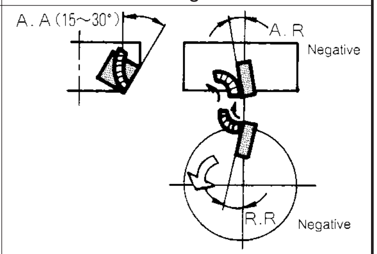
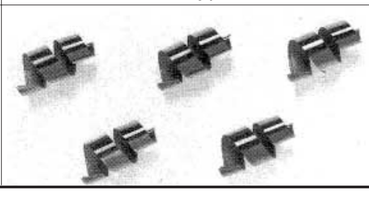
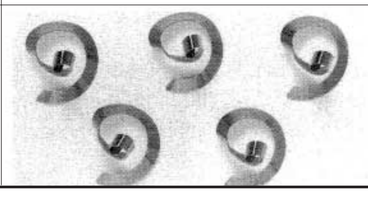
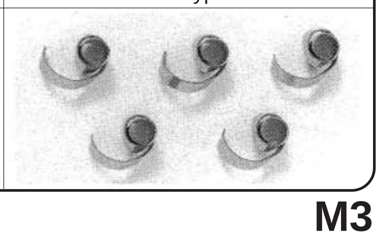
Ready Chart for Inclination Angles



Example in using the above chart:
Given: A(Axial Rake Angle) = -10°
R(Radial Rake Angle) = +15°
C(Approach Angle) = 25°
Solution: **I** (Inclination Angle) taken from the chart is = -15°

Formula: tan I = tan A.cos C - tan R.sin C

● Combinations Of Principal Angles & Their Features

	Negative - Positive Cutter	Double - Positive Cutter	Double - Negative Cutter
The effects of the various angle configurations with relation to chip formation and chip removal. A.R : Axial Rake angle R.R : Radial Rake angle A.A : Approach angle : Chip removal direction : Direction of cutter rotation			
Advantage	Best configuration for chip removal with good cutting action	Good Cutting Action	Economical using double sided inserts.
Disadvantage	Only single-sided inserts are available	Less Cutting Edge Strength Only single-sided inserts are available.	Poor Cutting Action
Applications	Suitable for Steels, Cast Irons Stainless Steels, Die Steels, etc.	General Milling of Steels Low rigidity workpiece	Milling of Cast Iron
Typical Cutter (Sample)	UFO Type	DPG Type	DNF Type
Chip forms Workpiece: SCM435 Condition : V= 130m/min f = 0.23 mm/tooth d = 3 mm			

Milling

■ Surface Finish

● Accuracy on Run-Out of teeth and Surface Finish

The cutting edges of a cutter with multiple cutting positions will inevitably have some slight deviations. This is defined as the accuracy or run-out of the teeth of which there are two kinds namely: the Axial Run-out of end cutting edges and Radial Run-out of peripheral cutting edges. Of these two the axial run-out of end cutting edges in particular is an influential factor of surface roughness.

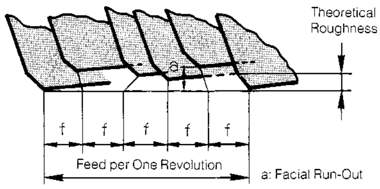
a. Axial Run-Out of The End Cutting Edges

A difference between the maximum and minimum cutting edge positions projected in the axial direction when rotating with reference at the cutter center.

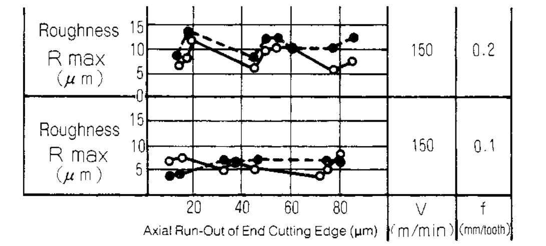
b. Radial Run-Out of The Peripheral Cutting Edges

A difference between the maximum and minimum cutting edge positions projected in the radial direction, when rotating with reference at the cutter center.

- Comparison With Theoretical and Actual Roughness When Cutting With A General Cutter (Example):



a: Axial Run-Out of End Cutting Edge
f: Feed per Tooth



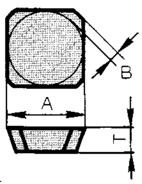
Theoretical Roughness
Actual Roughness

- Workpiece: Carbon Steel
- Cutter dia. :160 mm   No. of Teeth: 6
- Depth of Cut : 1mm

● Improving Run-Out of teeth:

1. Improve the dimensional tolerance of the inserts.
2. Improve the dimensional accuracy of the cutter body and its various components.

- Accuracy of the inserts: (Units: mm)



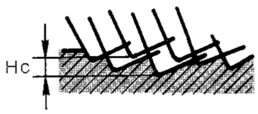
Class	A	B	T
F	0.013	0.005	0.025
C	0.025	0.013	0.025
K	0.075	0.013	0.025

● Improving Surface Finish:

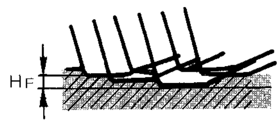
1. Milling inserts with wiper flat

Projecting one of the inserts more than the others so as to act as a wiper.
- Inserts with Linear Wiper Flat (Face Angle: approx. 15'~1º)
- Inserts with Curved Wiper Flat (Curvature is about 500 mm in radius)

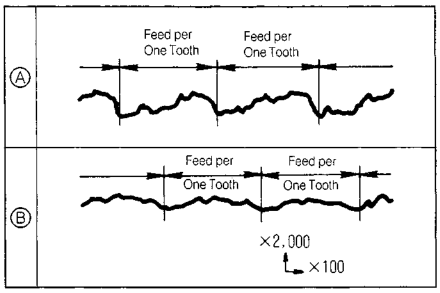
- Surface roughness by cutting edges without wiper flat:



- Surface roughness by cutting edges with linear wiper flat:



- Surface Roughness by The Wiper Flat System (Depending On Face Angles) :

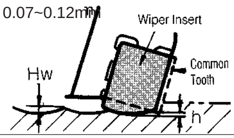


- Workpiece: Alloy Steel
- Cutter: DPG5160R (Single tooth)
- V = 154 m/min
  f = 0.234 mm/tooth
  d = 2 mm
- Face angles:
  A = 28'
  B = 6'

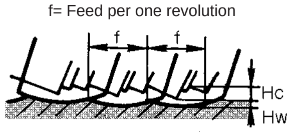
2. Built-in Wiper Insert System

A method in which 1 or 2 inserts with a smooth curved edge (wiper inserts) are projected fractionally more than the others so that the working surfaces are wiped flat.
(UFO Type, DNF Type, etc.)

h : Projected Amount of Wiper Insert
Steels : 0.03~0.07 mm
Cast Irons : 0.07~0.12mm

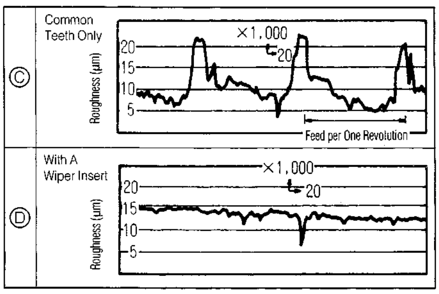


f= Feed per one revolution



Hc: Surface Roughness by Standard inserts
Hw: Surface Roughness by Wiper Inserts

- Example Of The Wiper Chip's Effect :



- Workpiece: Cast Iron
- Cutter: DPG4100R
- Insert: SPCH42R
- Axial run-out: 0.015 mm
- Radial run-out: 0.04 mm

V = 105 m/min
f = 0.29 mm/tooth
(1.45 mm/rev)

C: Standard inserts only
D: With one wiper insert

3. Where No Wiper Inserts Are Available

Reposition inserts to achieve highest 2, 3 or 4 inserts equispaced around the cutter body so that each such high inserts can precede whatever number of lower inserts. Total feedrate/tooth should not bemore than 80% of wiper flat width.

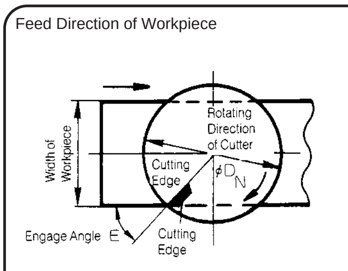
■ Cutter Size & Number of Teeth

● Selection of Cutter Size

1. Engage Angle

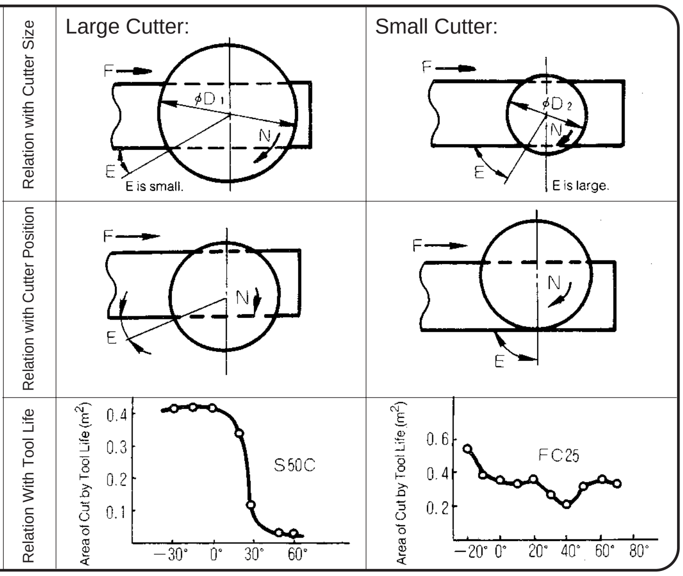
Workpiece	Optimum Engage Angle	Ratio between the diameter of the cutter and the width of the workpiece
Steel	+20 ~ -10	3 : 2
Cast Iron	Below +50	5 : 4
Light Alloy	Below +40	5 : 3

The above recommendations are based on a ϕ150mm cutter of on a 100mm wide steel block.



The engage angle (E) is defined as depicted above.
- As tool life will be shortened if E is large therefore a smaller E is preferable.

- In order to change E :
  1. Enlarge the size of the milling cutter.
  2. Re-position of milling cutter.

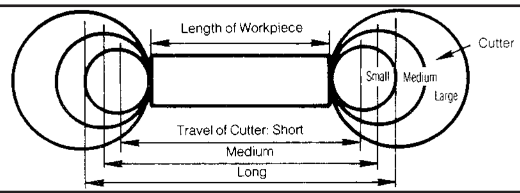


2. Mechanical Rigidity

Machine Horsepower	Adaptive Cutter Size
3~5 PS	80 ~ 100 mm
7.5~10 PS	100 ~ 160 mm
15~30 PS	160 ~ 200 mm

3. Processing Time

It is more efficient to select a correct cutter diameter as time can be wasted waiting for the cutter to run off the workpiece if too large a diameter is used.

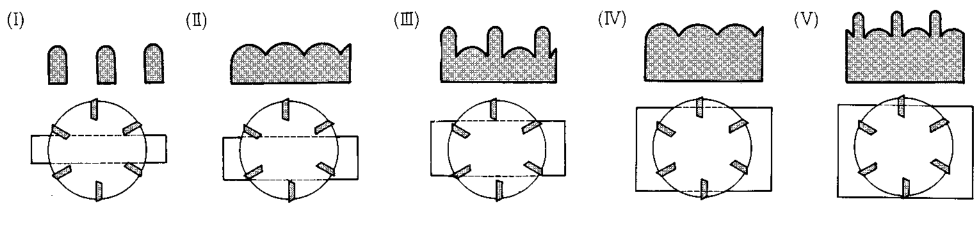


● Selecting The Number of Teeth

1. Number of Simultaneous Cutting Edges

- The minimum number of cutting edges simultaneously engaged in the workpiece should be about 2~4 teeth.
- Less than this requirement will cause the work to shift due to impacts which may lead to insert failure or more inferior surface roughness.
- More than the requirement may cause deformation of the work, chattering and vibration.

- Relationship Between The Number of Simultaneous Cutting Edges and Cutting Force:



(I)	(II)	(III)	(IV)	(V)
0 or 1 tooth in contact	1 tooth constantly in contact	1 or 2 teeth in contact	Constantly 2 teeth in contact	2 to 3 teeth in contact.

2. Work Materials

Workpiece	Number of Teeth	Cutter example and number of teeth
Steel	Dx1~1.5	UFO4160 (8 teeth)
Cast Iron	Dx2-1~Dx4	DHGF4160 (11 teeth)
Light Alloy	Dx1+α	APG4160 (8 teeth)

D: Nominal diameter of the cutter

- Considerations of Work Materials:

- Maximize the number of teeth for high feed milling of Cast Irons. (Rigidity of the machine and clamping must be sufficient.)
- For steels, the number of teeth should be reduced but feed per tooth should be increased. (Wide chip pockets and rigid cutter body are necessary)
- Improve the efficiency of milling non-ferrous alloys by increasing the speed.

- Examples Of The Combination Of Typical Cutters & Number Of Teeth

Application / Cutter / Nominal Size	Steel	Cast Iron	Light Alloy	High Feed
	UFO	DHGF	APG	DPV (Z)
100mm (4")	5	7	5	10
160mm (6")	8	11	8	18
200mm (8")	10	15	10	24
315mm(12")	14	23	16	36

3. Other Conditions

1. For narrow workpieces, increase the number of teeth so that at least one tooth is always cutting.
2. When using unsteady machines and workpieces, the number of teeth should be reduced.

■ Power Requirement, Cutting Conditions & Grades Selection

● Power & Cutting Resistance

1. Determination of Power Requirement
(Refer to the chart on the right)

- Determination Of The Power Requirement

$$W = \frac{Ps \times Q}{6.12 \times 10^3}$$

2. Chip Removal

- Determination Of Horse Power Requirement

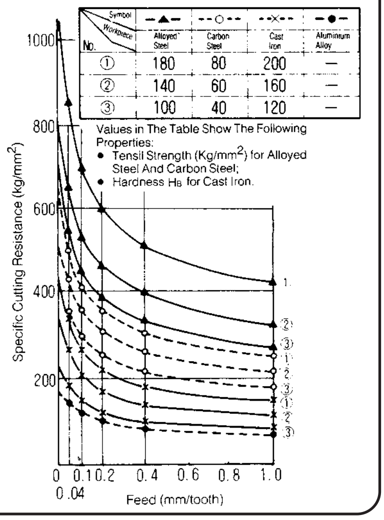
$$H = \frac{W}{0.75}$$

W: Power Requirement (Kw)
H: Horsepower Requirement (HP)
Q: Chip Removal Amount (cm^3/min)
L : Width of cut (mm)
F : Feed per minute (mm/min)
d : Depth of Cut (mm)
Ps: Specific Cutting Resistance
eg.Steel : 250~300
Cast Iron:150
(Refer to chart on the right)

- Calculation Of Chip Removal Amount

$$Q = \frac{L \times F \times d}{1000}$$

- Specific cutting resistance based on feed in relation to the work material.

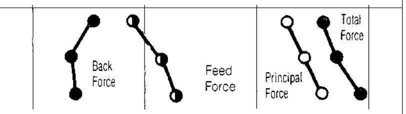


No.	Alloyed Steel	Carbon Steel	Cast Iron	Aluminum Alloy
①	180	80	200	—
②	140	60	160	—
③	100	40	120	—

3. Factors Influencing Cutting Resistance

Factor	Cutting Resistance will be ...
- If the inclination angle becomes large,	Reduced
- If the true rake angle becomes large,	Reduced
- If the cutting edge is excessively honed,	Increased
- If the approach angle becomes large,	Slightly Increased

4. Comparison of Cutting Resistance Among Typical SEC-ACE MILLS

Cutter Type	Edge angle			Cutting Resistance (kg)
	A.R.	R.R.	A.A	0 50 100 150
UFO	15°	-4°	45°	
APG	18°	-2°	25°	
DPG	8°	0°	15°	

Work : Alloy Steel (HB250)
Machine : Machining Center (15 HP)
Conditions: V =120m/min
f = 0.3mm/tooth
d = 3mm

● Calculation Method of Cutting Conditions

- Calculation Of Cutting Speed

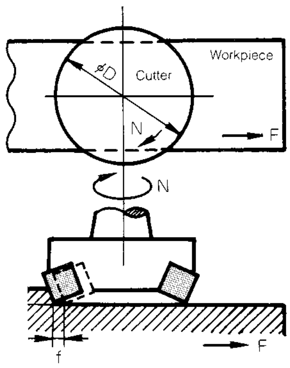
$$V = \frac{\pi \times D \times N}{1000}$$

- Calculation Of The Feed

$$F = f \times Z \times N$$

$$f = \frac{F}{Z.N}$$

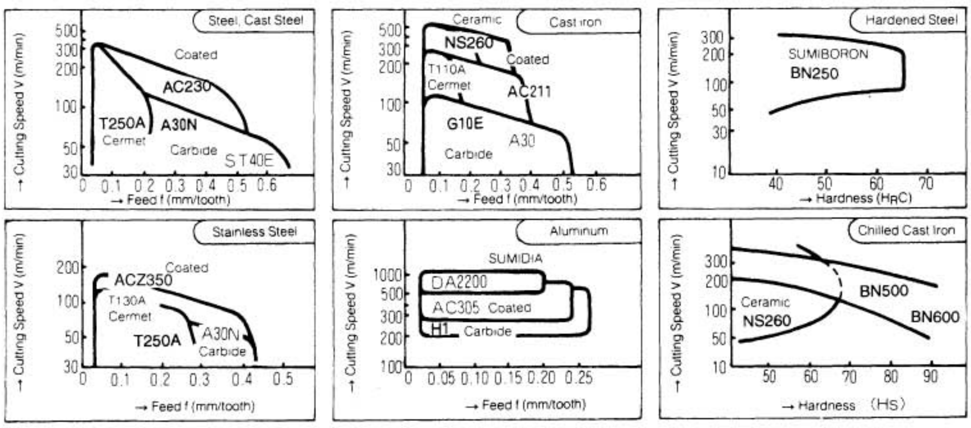
V: Cutting Speed (m/min)
π : 3.14
D: Cutter Diameter (mm)
N: Revolution (rpm)
F: Feed (mm/min)
f : Feed per tooth (mm/tooth)
Z: Number of Teeth



● Selection of Insert Grade

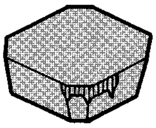
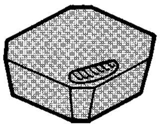
1. Requirements:
- Good Wear Resistant
  eg. Coated grade
- Good Toughness
  eg. Tough carbide grade
- Good Resistance to Thermal cracks eg. Tough carbide grade
- Adhesion resistant
  eg. Cermet grade

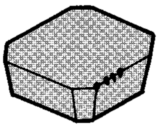
2. Recommended Insert Grade Depends on Work Material



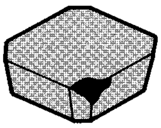
■ Trouble Shooting Guide for Milling

● Suggested Remedies for Common Faults

<table>
<tr><th></th><th>Trouble</th><th colspan="2">Basic Remedies</th><th>Proven Remedies</th></tr>
<tr><td rowspan="4">Edge Failure</td><td rowspan="2">Excessive Flank Wear
</td><td>Insert Grade</td><td>- Use more wear-resistant Grade.
Carbide P30 ---> P20 / K20 ---> K10 ---> Coated / Cermet</td><td rowspan="2">- Recommended Insert Grade
<table><tr><th></th><th>Steel</th><th>Cast Iron</th><th>Light Alloy</th></tr><tr><td>Finishing</td><td>T250A (Cermet)</td><td>G10E (Carbide)</td><td>DA2200 (SumiDia)</td></tr><tr><td>Roughing</td><td>A30N (Carbide)
AC230 (Coated)</td><td>G10E (Carbide)</td><td>EH20Z (Coated)</td></tr></table></td></tr>
<tr><td>Cutting Conditions</td><td>- Decrease speed and increase feed.</td></tr>
<tr><td>Excessive Crater Wear
</td><td>Insert Grade

Cutting Conditions</td><td>- Use more crater-resistant grade.
Carbide (K ---> M ---> P) ---> Cermet / Coated
- Decrease speed and reduce tahe depth of cut and feed.</td><td>- Recommended Insert Grade
<table><tr><th></th><th>Steel</th><th>Cast Iron</th><th>Light Alloy</th></tr><tr><td>Finishing</td><td>T250A (Cermet)</td><td>G10E (Carbide)</td><td>DA2200(SumiDia)</td></tr><tr><td>Roughing</td><td>AC230 (Coated)</td><td>AC211 (Carbide)</td><td>EH20Z (Coated)</td></tr></table></td></tr>
<tr><td>Cutting Edge Chipping
</td><td>Insert Grade

Insert Design

Cutting Conditions</td><td>- Use tougher grade.
Carbide P30 ---> P20 ---> P30 / K01 ---> K10 ---> K20
- Use negative-positive edge type cutter with a large approach angle.
- Reinforce the cutting edges (by honing).
- Reduce feed.</td><td>- Recommended Insert Grade :
<table><tr><th></th><th>Steel</th><th>Cast Iron</th><th></th></tr><tr><td>Roughing</td><td>A30N (Carbide)</td><td>G10E (Carbide)</td><td></td></tr></table>
- Recommended Cutter : SEC-UFO Type</td></tr>
<tr><td></td><td>Partial Fracture of Cutting Edges
</td><td>Insert Grade

Insert Design

Cutting Conditions</td><td>- Excessively low speed or feed, use a grade which is more adhesion resistant.
- Thermal cracking, use a more thermal resistant grade.
- Use negative-positive (or negative) edge type cutter with a large approach angle.
- Enlarge the insert size (thickness in particular)
- Select conditions suitable to applications.</td><td>- Recommended Insert Grades :
<table><tr><th></th><th>Steel</th><th>Cast Iron</th><th></th></tr><tr><td>Finishing</td><td>T250A (Cermet)</td><td>G10E (Carbide)</td><td></td></tr><tr><td>Roughing</td><td>AC325 (Coated)</td><td>ACZ310 (Coated)</td><td>EH20Z (Coated)</td></tr></table>- Recommended Cutters : SEC-UFO Type
- Insert Thickness : From 3.18mm to 4.76mm</td></tr>
<tr><td rowspan="5">Others</td><td>Unsatisfactory Surface Finish</td><td>Insert Grade
Tool Design

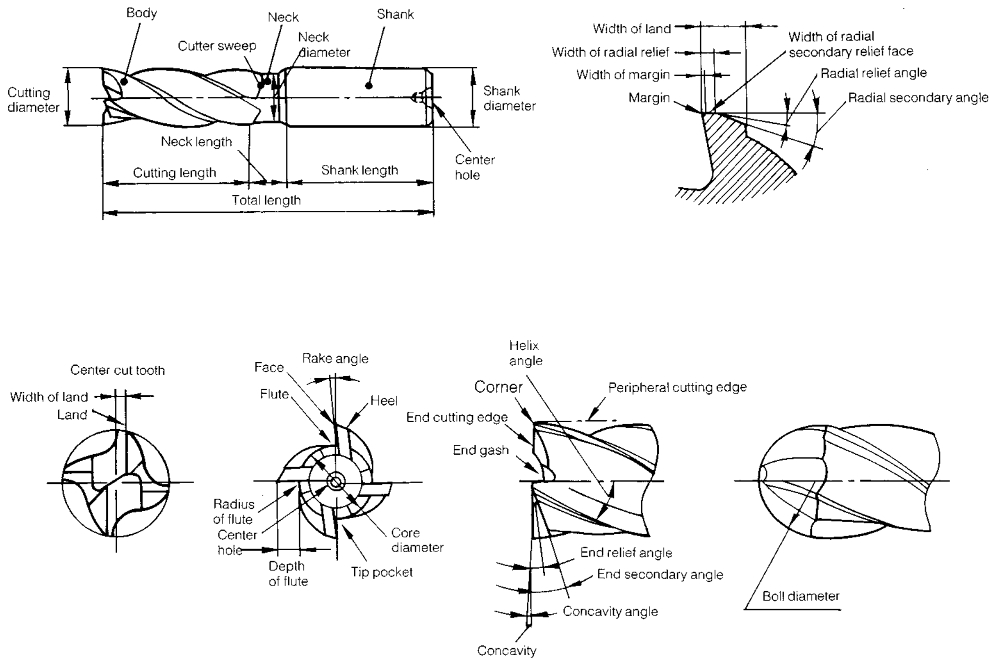
Cutting Conditions</td><td>- Use a more adhesion resistant grade. Carbide ---> Cermet
- Improve axial run-out of the cutting edges. (Use cutter with less run-out on edges with proper setting of the inserts)
- Use wiper insert.
- Use a special purpose cutter for finishing.
- Increase speed.</td><td>- Recommended Cutters & Insert Grades :
<table><tr><th></th><th></th><th>Steel</th><th>Cast Iron</th><th>Light Alloy</th></tr><tr><td>General Purpose</td><td>Cutter
Insert</td><td>UFO Type
T250A (Cermet)</td><td>DHGF Type
G10E (Carbide)</td><td>APG Type
EH20Z</td></tr><tr><td>For Finishing Only</td><td>Cutter
Insert</td><td>PF Type
T12A (Cermet)</td><td>PF Type
Ceramic Insert</td><td>APG Type
(With Wiper Chip)
DA200 (SumiDia)</td></tr></table></td></tr>
<tr><td>Chattering</td><td>Tool Design
Cutting Conditions
Others</td><td>- Use positive cutter with a large rake angle.
- Use irregular pitched cutter.
- Reduce feed.
- Improve clamping of the workpiece and cutter.</td><td>- Recommended Cutters :
For Steel : UFO Type, EHG Type
For Light Alloys : APG Type
For Cast Iron : DHG Tyoe</td></tr>
<tr><td>Unsatisfactory Chip Control</td><td>Tool Design</td><td>- Use Negative (R.R)-Positive (A.R) Cutter
- Reduce the number of teeth
- Enlarge the chip pocket</td><td>- Recommended Cutters : UFO Type, EHG Type</td></tr>
<tr><td>Edge Chipping on Workpiece</td><td>Tool Design
Cutting Conditions</td><td>- Enlarge the approach angle
- Reduce feed</td><td>- Recommended Cutters : UFO Type, EHG Type</td></tr>
<tr><td>Burr on Workpiece</td><td>Tool Design
Cutting Conditions</td><td>- Use a positive cutter
- Increase speed</td><td>- Recommended Cutters : UFO Type, EHG Type</td></tr>
</table>

Endmilling Guidance

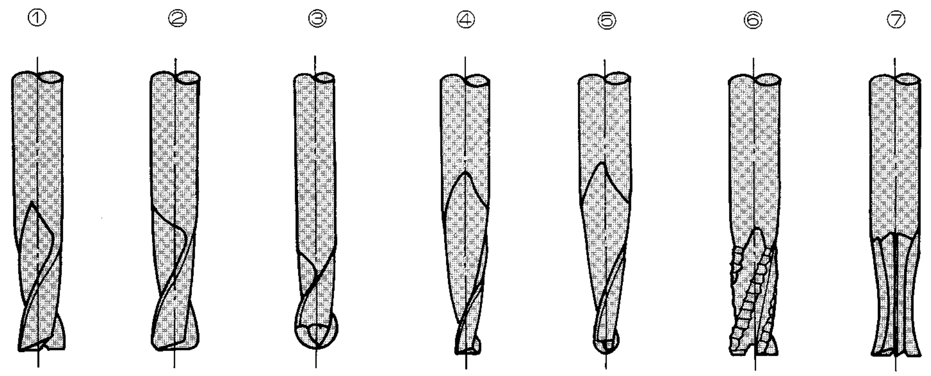
E1 ~ E10

■ Endmill Nomenclature

● Technical Terms



● Edge Shapes

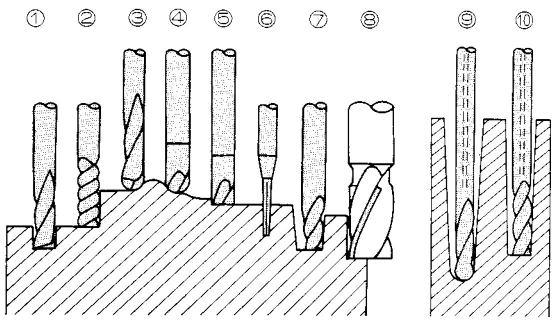


No.	Endmill Type	Feature of The Type of Endmills	Applications
1	Square Endmills	- Angle of its peripheral cutting edges is 90º	- For milling key ways and "i"-shaped grooves.
2	Radius Endmills	- Corners between peripheral cuting edges and end cutting edges have a radius.	- For applications between 1 & 3.
3	Ball Nose Endmills	- End cutting edges are spherical in shape.	- For copying operations of die moulds, etc.
4	Taper Endmills	- Side cutting edges are tapered at an angle.	- For milling die punches.
5	Taper Ball Nose Endmills	- Combination of 3 and 4.	- For copying operations on die moulds, etc.
6	Roughing Endmills	- Side cutting edges have jaggered teeth	- For roughing operations.
7	Formed Endmills	- Side cutting edges have a pre-formed profile	- For special side profiles.

■ Sumitomo's Endmills & Cutting Conditions

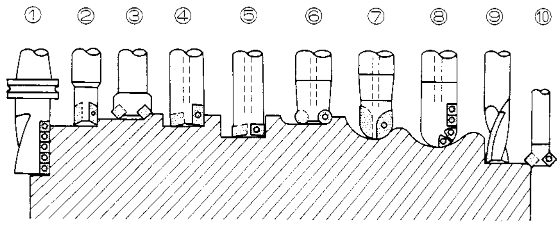
● Sumitomo's Endmills

- Solid Endmills



1. **Spiral Endmill** - SSM,HHM,HHMR,SSHE
2. **High Helix Endmill** - HSM
3. **Ballnose Endmill** - SSB,SHB
4. **Cermet Ballnose Endmill** - SFB-T
5. **Cermet Endmill** - SFM-T
6. **Tapered Endmill** - STRM
7. **Tapered Endmill** - STM
8. **Brazed Endmill** - MES
9. **Endmill for Graphite (Ballnose)** - GBM
10. **Endmill for Graphite (Square)** - GSM

- Indexable Type



1. **SEC-Repeater Wavemill** - WRM
2. **SEC-Wavemill** - WEM
3. **SEC-Multi Mill** - UFO
4. **SEC-Wavemill** - WMM
5. **SEC-Bore Endmill** - HKE
6. **SEC-ACE Ballnose Endmill** - RBM 6000
7. **SEC-Wavemill** - WBMR
8. **SEC-Wavemill** - WBMR
9. **SEC Helical Endmill** - CMS
10. **SEC Chamfering Endmill** - SCP

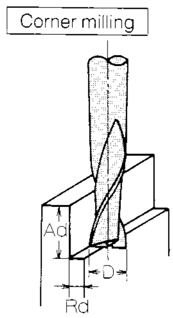
● Calculation Of Cutting Conditions for Normal Endmills

1. Cutting Conditions

- Calculation of Cutting Speed

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

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



V: Cutting speed
π : 3.14
D: Endmill diameter (mm)
N: Spindle speed (rpm)
F: Feedrate (mm/min)
fr: Feed per revolution (mm/rev)
ft: Feed per tooth (mm/teeth)
Z: Number of teeth

2. Feed

- Feed Calculation

$$F = N \times fr$$

$$fr = \frac{F}{N}$$

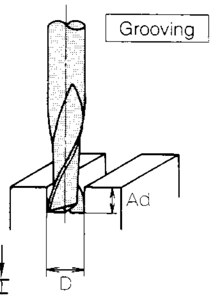
$$F = N \times ft \times Z$$

$$ft = \frac{fr}{Z} = \frac{F}{N \times Z}$$

3. Depth of Cut

- Depth of Cut

Ad = Axial depth of cut
Rd = Radial width of cut

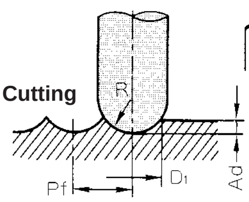


● Calculation Of Cutting Conditions for Ballnose Endmills

1. Boundary of Cutting

- Calculation of Boundary of Cutting

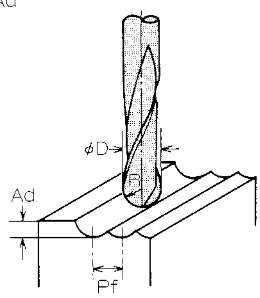
$$D_1 = 2 \times \sqrt{2 \times R \times Ad - Ad^2}$$



2. Cutting Speed

3. Feed

- Calculation of Speeds and Feedrate for the Ballnose endmills are the same as those for Normal endmills



Endmilling Guidance

■ Cutting Profile & Performance

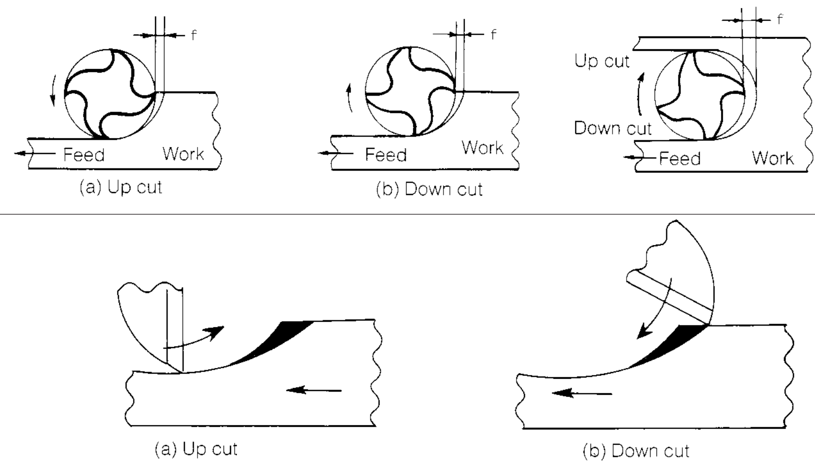
● Cutting Directions

1. Up cut

2. Down cut

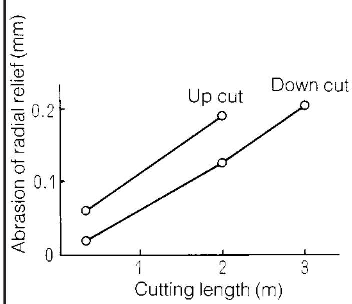
- Corner Milling

- Grooving

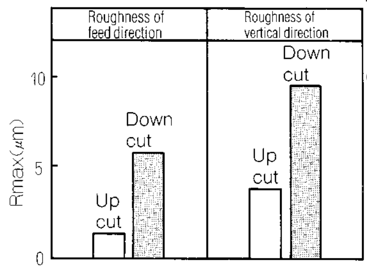


● Performance Comparison

- Abrasion Rate of Teeth



- Surface Roughness



- Cutting Conditions

Work : SCM435 (Hs 36~37)
Tool : SSM2100
(ϕ10mm, 2 teeth)

Conditions: V = 50 m/min
f = 0.05 mm/tooth
Ad = 15 mm
Rd = 5 mm
Corner Milling
Dry cut

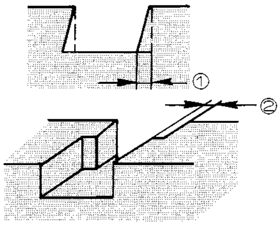
● Chip Control

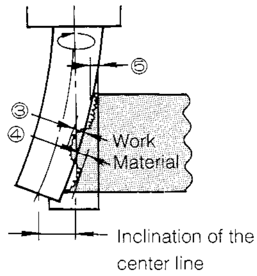
		SSM2080	SSM4080	KSM2080	SFM2080	HSM3080	
Corner Milling	Up Cut						Work: Pre-hardened Steel (HRC40) Cutting Conditions - Corner milling : V = 25 m/min f = 0.16 mm/rev Ad = 12 mm Rd = 0.8 mm
	Down Cut						
Grooving							Cutting Conditions - Grooving: V = 25 m/min f = 0.05 mm/rev Ad = 8 mm Rd = 8 mm

Cutting Profile & Accuracy

● Precision

1. Bending of machined surface
2. Straightness
3. Roughness
4. Waviness
5. Displacement

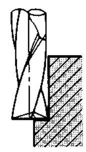




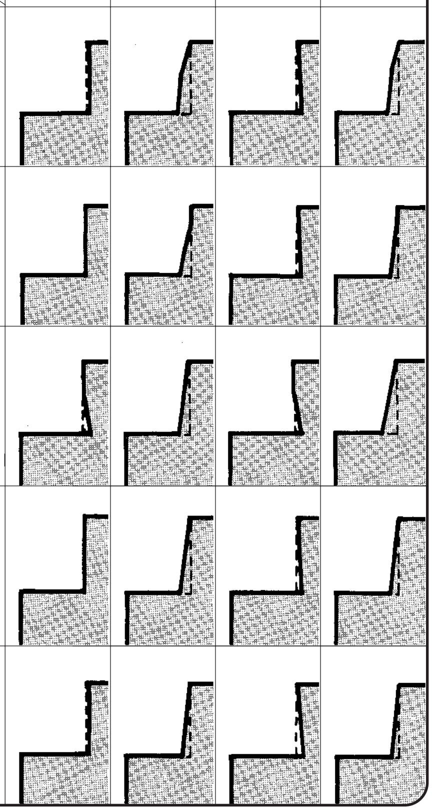
● Relation Between Cutting Condition and Bending of Machined Surface

Corner Milling

Work: Pre-Hardened steel
Condition: V = 25 m/min
Ad = 12 mm
Rd = 0.8 mm

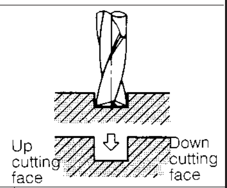


Feed / Direction / Cat. No.	0.16 mm/rev		0.11 mm/rev	
	Up Cut	Down Cut	Up Cut	Down Cut
SSM2080				
SSM4080				
KSM2080				
SFM2080				
HSM3080				

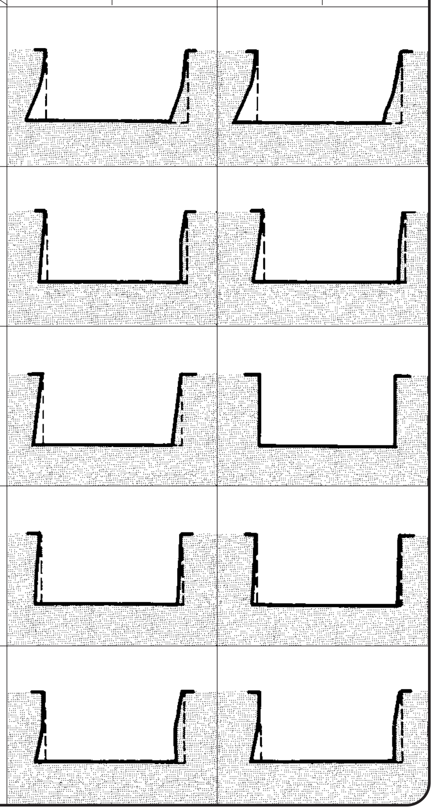


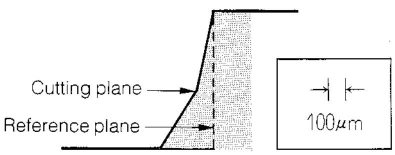
Grooving

Work: Pre-Hardened steel
Condition: V = 25 m/min
Ad = 8 mm
Rd = 8 mm



Feed / Direction / Cat. No.	0.05 mm/rev		0.03 mm/rev	
	Up Cut	Down Cut	Up Cut	Down Cut
SSM2080				
SSM4080				
KSM2080				
SFM2080				
HSM3080				





Endmilling

■ Performance Characteristics

● Number of Teeth

Performance Condition	Performance Parameters		No. of teeth 2	No. of teeth 4
Tool Strength	Twist Rigidity		○	●
	Bending Rigidity		○	●
Surface Roughness	Roughness		○	●
	Undulation		○	●
	Bending of Machined Surface		○	●
Tool Life S50C (HB200) ~ SKD11 (HB320)	Fixed Feed (mm/tooth)	Breakage Resistance	○	●
		Wear Resistance	○	●
	Fixed Efficiency	Breakage Resistance	○	●
		Wear Resistance	○	●
Cutting Range	Finishing		○	●
	Light Cutting		○	●
	Heavy Cutting		○	●

●: Excellent ○: Good

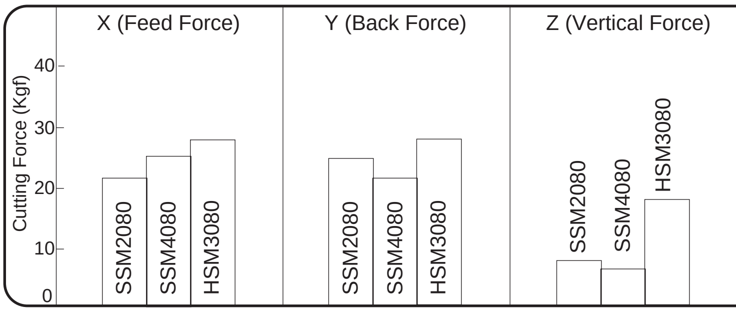
Performance Condition	Performance Parameters	No. of teeth 2	No. of teeth 4
Chip Control	Chip Packing	●	○
	Chip Removal	●	○
Boring	Counter Boring	●	○
	Surface Roughness	●	○
	Hole Expansion	●	○
Grooving	Chip Removal	●	○
	Groove Expansion	●	○
	Key Way Grooving	●	○
Cornering	Surface Roughness	○	●
	Chattering	●	○
Work Material	Alloy Steels	○	●
	Cast Irons	○	●
	Non-ferrous alloys	●	○
	Hard-To-Cut Materials	○	○

● Helix Angles

Helix Angle	Cutting Resistance: Torque	Cutting Resistance: Bending Resistance	Cutting Resistance: Vertical Force	Surface Roughness: Roughness	Surface Roughness: Undulation	Surface Roughness: Bending of Machined Surface	Tool Life: Flank Wear	Tool Life: Peripheral Wear	Tool Life: Breakage	Catalogue No.
30º	●	●	○	●	○	○	●	○	●	SSM 2000 / SSM 4000
60º	●	●	△	●	△	○	○	●	△	HSM 3000

●: Excellent ○: Good △: Fair

● Helix Angle and Cutting Force

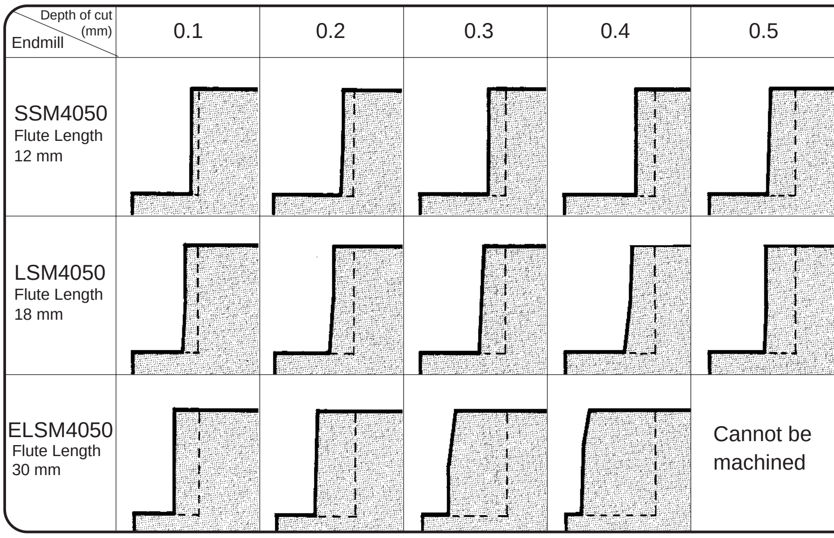


Work: Pre-hardened steel

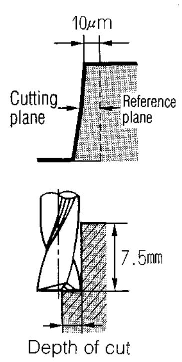
Tool : SSM2080 (30º)
SSM4080 (30º)
HSM3080 (60º)

Condition: V = 25 m/min
f = 0.08 mm/teeth
Dry cut

● Flute Length



Work: S50C (HB230)
Condition:
V = 30 m/min
f = 0.02 mm/rev
Down cut



■ Cutting Fluid

● Features

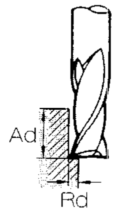
		Lubricity	Adhesion Resistance	Infiltration	Cooling Effect	Rust Prevention	Smoking	Odour
Water Soluble Cutting Fluid	Emulsion type	○	△	○	●	△	●	○
	Soluble type	△	△	○	●	△	●	●
	Solution type	×	△	△	●	△	●	●
Non-water Soluble Cutting Fluid	Chlorinated oil	●	●	●	○	○	△	●
	Sulfo-chlorinated oil	●	●	●	○	○	△	△

● Cutting Fluid and Tool Life

Test Example:

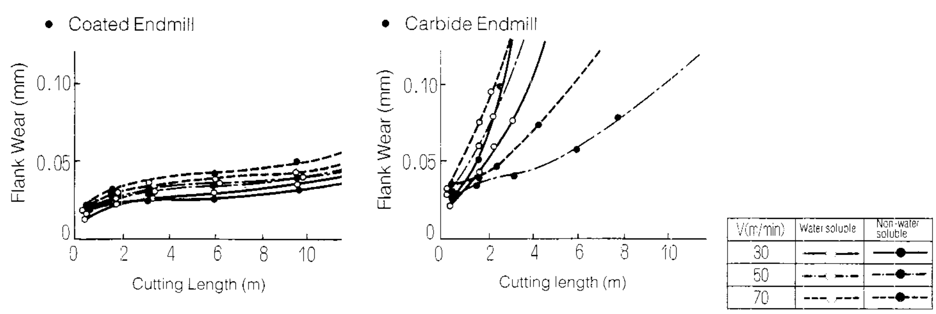
Machine : Mazak V15
Work material : 1) Stainless Steel
2) Alloyed Steel
Tooling : SSM2050 (dia: 5 mm, 2 teeth, Helix angle: 30º)

Cutting Conditions: Cutting Speed: 30, 50, 70 m/min
Feedrate : 0.03 mm/rev
Depth of cut : Ad = 7.0 mm
Rd = 1.0 mm
Cutting Direction : Down cut
Cutting Fluid : Non-water soluble cutting fluid



Results

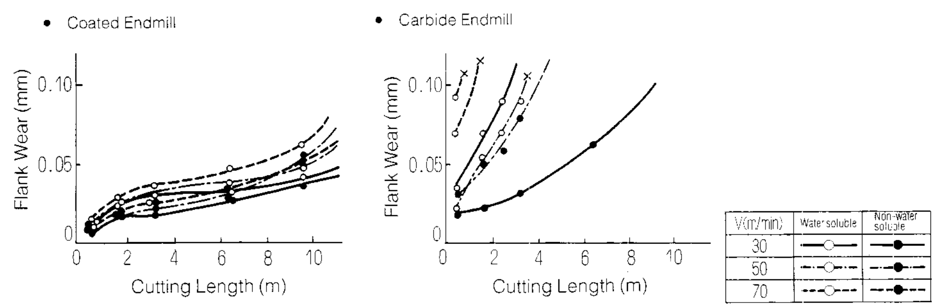
1) Stainless Steel (HB 180)



Findings: - Cutting fluid does not influence cutting performance of coated endmills. Performance is stable under any cutting speed.

- Non-coated endmills are not practical to use at V = 30 m/min because of chipping.
  Better performance with non-water soluble fluid as cutting speed increases.
  A more practical cutting speed is 50 m/min but it has a rather limited application range.

2) Die-mould Steel (HRC 48)

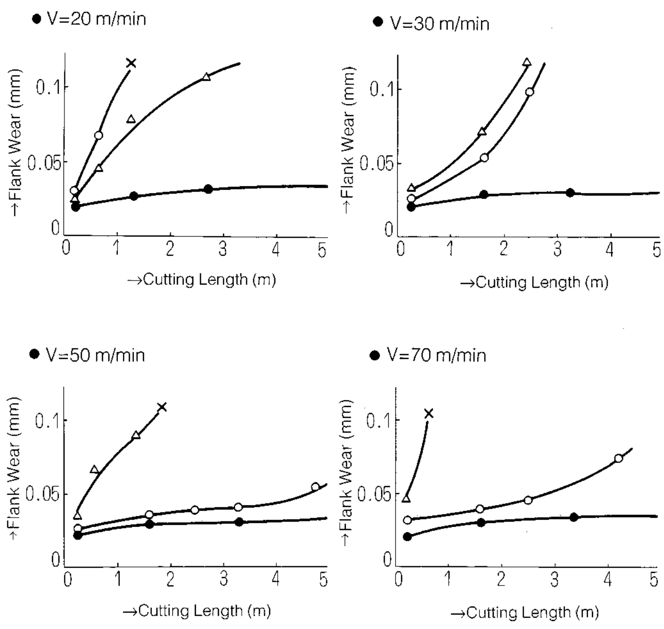


Findings: - Non-water soluble fluid is slightly better for coated endmills. Performance is basically stable under any cutting speed.

- Apparently non-water soluble fluid is more stable for uncoated endmills.
  At lower cutting speeds, performance is better.
  Non-water soluble fluids are more practical for uncoated endmills at cutting speeds below 30m/min

■ Features and Performance of PVD Coated Carbide Endmills

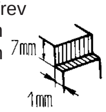
● Wide Range of Cutting Speeds



Work: SUS304 (HB 180)
Endmill size: Dia 5 mm, 2 flutes

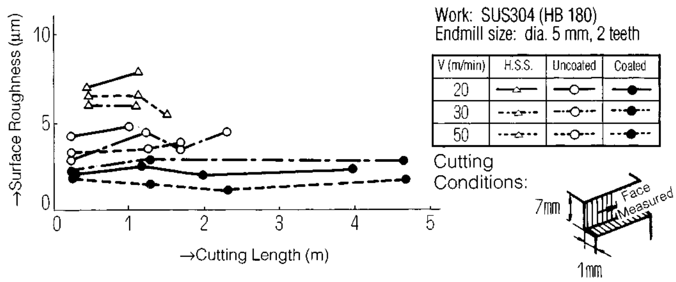
H.S.S	Uncoated	Coated
—△—	—○—	—●—

Cutting Conditions:
Feedrate : 0.03 mm/rev
Depth of cut : Ad= 7mm
Rd= 1mm



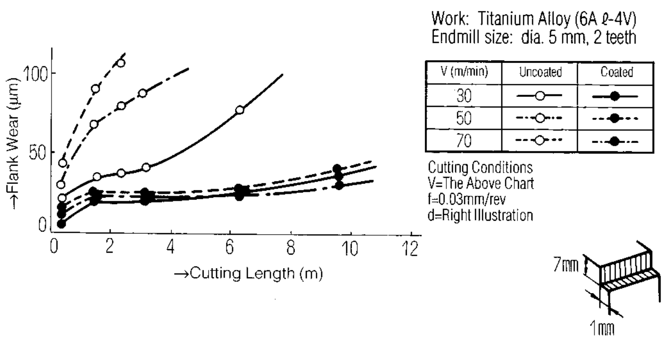
Results:
- Coated endmills show the least flank wear without welding and are stable at any speeds.
- Uncoated endmills were out performed by H.S.S at low cutting speeds (V= 20m/min) and show flank wear at high cutting speeds. Their performance was best at around V = 50m/min.
- H.S.S endmills work at speeds of less than V = 20m/min but early fracture occurs at over V = 50m/min.

● Excellent Surface Roughness



Results:
- Coated endmills produce an excellent surface roughness of about 2~3 μm. This is due to the wear resistance of the coated layer.

● Optimum Machining for Hard-to-cut Materials



Results:
- Coated endmills show the least flank wear and could perform over 3 times better than uncoated endmills.
- Uncoated endmills can work only at around V = 30 m/min

High Speed Endmilling

Performance Comparison by grade

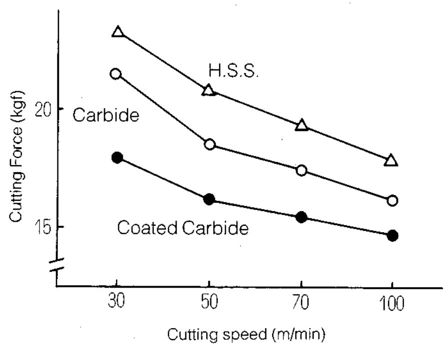
A high speed cutting performance comparison between carbide, coated carbide and H.S.S endmills were conducted.
(Note: At cutting speeds of over 70 m/min, an endmill with edge treatment is most efficient.)

Cutting Conditions

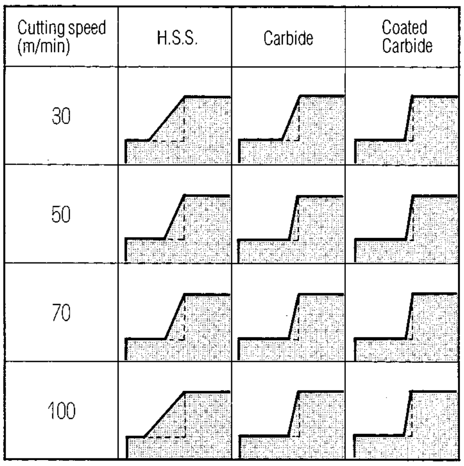
Work : SCM440 (HRC30)
Tool : SSM2080, SSM2080ZX, H.S.S Tool (8 mm, 2 teeth)

Cutting speed (V)= 30, 50, 70, 100 m/min
Feedrate (f)= 0.04 mm/teeth
Depth of cut (d): Ad = 12 mm
Rd = 0.8 mm
Up cut, Water soluble fluid

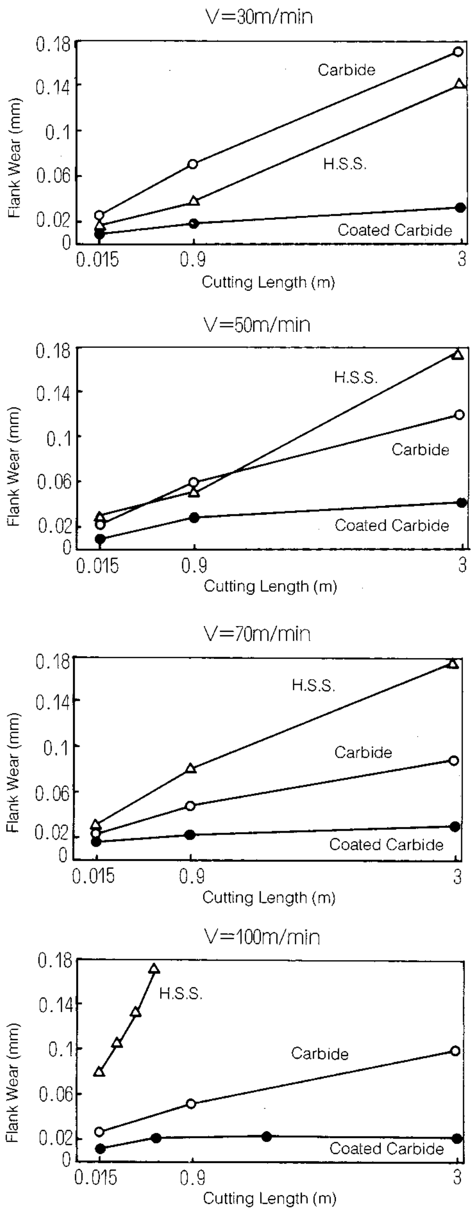
- **Cutting Force**



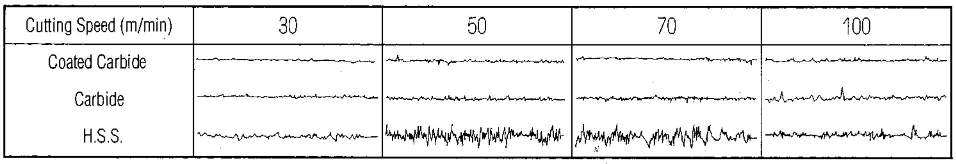
- **Bending of machined surface on work**



- **Tool Life**



- **Surface roughness**



■ Trouble Shooting Guide for Endmilling

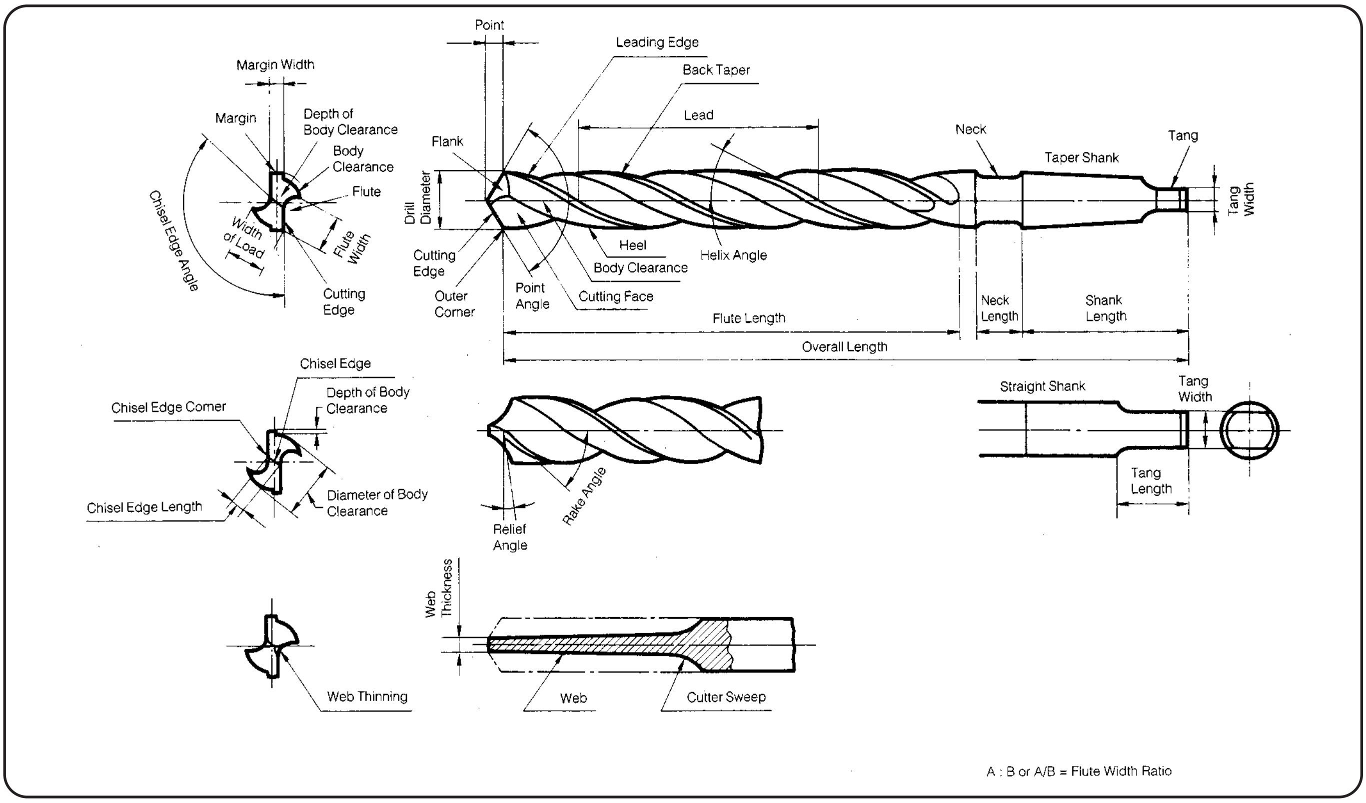
● Standard Steps for Common Problems

Trouble		Basic Remedies		Details
Edge Failure	Excessive wear on periphery and end cutting edges	Tool material	- Use higher wear-resistant grades	- For solid endmills - change from uncoated to coated endmills eg. SSM-ZX type
		Cutting conditions	- Decrease speed and increase feed - Examine cutting fluids	- Cutting fluids - change from water soluble type to non-water soluble type.
	Chipping of the cutting edges	Cutting conditions	- Reduce feedrate - Use down-cut milling - Reduce the depth-of-cut	
		Machine and others	- Remove backlash on the machine - Stronger clamping of the workpiece - Reduce the amount of overhang	
	Tool breakage while cutting	Cutting conditions Tool	- Increase speed - Decrease feedrate - Decrease depth-of-cut - Shorten the length of cut - Reduce the amount of overhang	- If the spindle speed is not fast enough, use an arbor speed inducer
Unsatisfactory surface finish	Poor surface finish: - Surface roughness - Surface waviness - Surface squareness	Tool material	- Use materials that have a high Young's Modulus	
		Tool	- Enlarge the helix angle - Increase the number of flutes - Shorten the length of cut	- Use High-Helix Spiral Endmills (HSM type) - Change the endmill from 2 teeth to 4 teeth (ex. SSM2000 type change to SSM4000 type)
		Cutting conditions	- Reduce feedrate - Reduce the depth-of-cut - Use up-cut milling	
		Others	- Prevent build-up on the cutting edge	
	Chattering marks	Cutting conditions	- Decrease speed - Use down-cut milling - Use cutting fluid	
		Others	- Ensure that both the workpiece and tool are properly secured	- Check the clearances between the chuck, collet and endmill
Others	Packing of chips	Tool	- Reduce the number of flutes	- Change the endmill from 4 teeth to 2 teeth (ex. SSM4000 type change to SSM2000 type)
		Cutting conditions	- Reduce feedrate - Reduce the depth of cut	

Drilling Guidance

D1 ~ D11

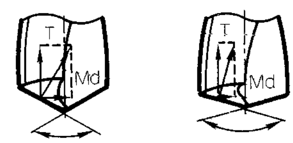
■ Twist Drill Nomenclature



■ Comparison Table of Each Multidrill Type

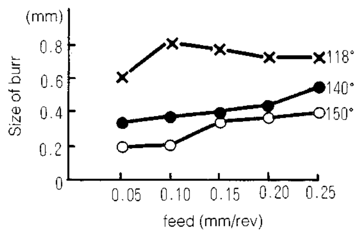
		Characteristics & Consequences	MultiDrill K Type	MultiDrill P Type	MultiDrill HK Type	MultiDrill G Type	MultiDrill A Type	MultiDrill BA Type
1. Point Angle	Point Angle	150° / 140° / 118° / 70° — Small ↑ Torque ↓ Large; Large ↑ Thrust ↓ Small; Small ↑ Burr ↓ Large	●	●	●	●	●	●
2. Helix Angle	Helix Angle	40° / 30° / 25° / 10° — Good ↑ Cutting ↓ Bad; Bad ↑ Chip Flow ↓ Good; Small ↑ Twist Rigidity ↓ Large	●	●	●	●	●	●
3. Back Taper	Back Taper	Big / Small — Small ↑ Cutting Resistance ↓ Big; Few ↑ Number of Regrinds ↓ Many	●	●	●	●	●	●

Point Angle and Cutting Resistance



Point Angle (small) Point Angle (large)

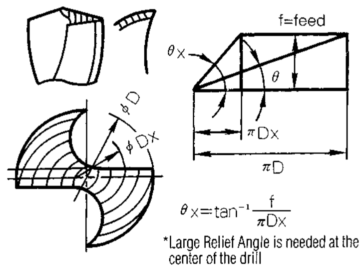
Point Angle & Burr



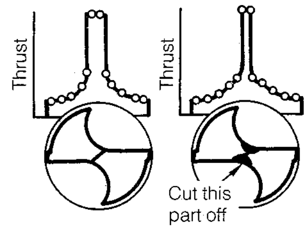
Work: SS41
Speed: V=50m/min

Item		Characteristics & Consequences			MultiDrill K Type	MultiDrill P Type	MultiDrill HK Type	MultiDrill G Type	MultiDrill A Type	MultiDrill BA Type
4. Relief Angle (Relief Angle)	15° / 12° / 10° / 7°	Small ↑ Cutting Edge ↓ Large	Small ↑ Tool Wear ↓ Large	Large ↑ Run Out ↓ Stable	12° ~ 8°					
5. Web Thickness (Web Thickness)	30% / 25% / 20% / 18% / 10%	Large ↑ Thrust ↓ Small	Large ↑ Twist Rigidity ↓ Small	Strong ↑ Bending Resistance ↓ Weak	●	●	●	●	●	●
6. Chisel Width (Chisel Width)	Wide / Narrow (Zero)	Large ↑ Thrust ↓ Small	Difficult ↑ Centripe-tance ↓ Easy	Weak ↑ Rigidity ↓ Strong	●	●	●	●	●	●
7. Flute Width Ratio (Flute Width Ratio)	2.0 / 0.5	Small ↑ Twist Rigidity ↓ Large	Weak ↑ Bending Resistance ↓ Strong	Good ↑ Chip Removal ↓ Bad	●	●	●	●	●	●
8. Edge Treatment Width (Edge Treatment Width)	Wide / Zero	Large ↑ Cutting Resistance ↓ Small	Strong ↑ Strength of the edge ↓ Weak		●	●	●	●	●	●
9. Edge Treatment Angle (Edge Treatment Angle)	Big / Zero	Large ↑ Cutting Resistance ↓ Small	Strong ↑ Edge Strength ↓ Weak		●	●	●	●	●	●

Minimum Relief Angle

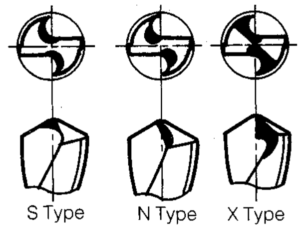


Web Thickness and Thrust (Effect of the Thinning)



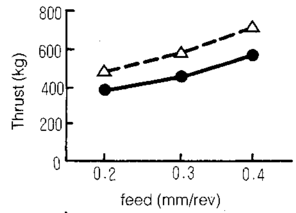
The thinning makes concentrating thrust small. This means easy cutting, good chip removal and longer tool life.

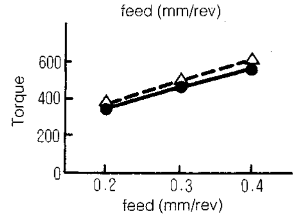
Small Chisel Width by the Thinning (Thinning Example)



S Type: Standard web thinning
N Type: Mainly on thinner webs
X Type: For hard-to-cut material and deep holes

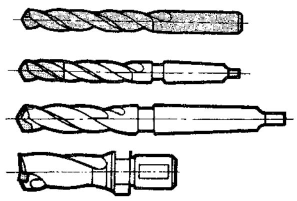
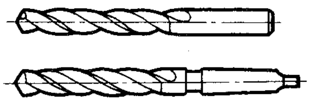
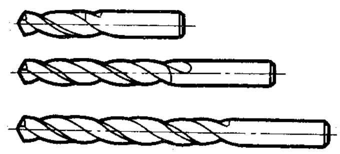
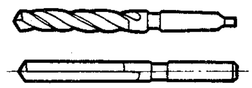
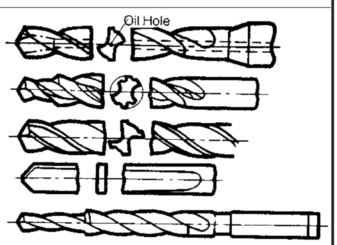
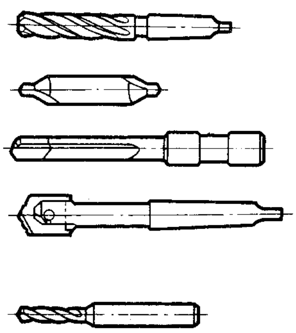
Edge Treatment Width & Cutting Resistance





Drill: MultiDrill KDS215MA
Edge Treatment Width: ●:0.15 mm △:0.23 mm
Work: S50C (HB230)
Cutting Conditions: V = 50 m/min
Water Soluble Oil

■ Varieties of Classification for Drills

	No.	Type	Descriptions	Illustrations
1. Classification According to Type	1	Solid Drill	A drill which is wholly composed of the same material eg. hard alloys.	 (1)
	2	Solid Carbide-End	A drill which has a carbide portion of a defined length brazed to its tip.	(2)
	3	Tipped Drill	A drill that has brazed carbide tips.	(3)
	4	Throw-Away Tipped Drill	A drill which uses throw-away inserts which are mechanically clamped on its tip.	(4)
2. Classification According to Shank Configurations	5	Straight Shank Drill	A drill with a cylindrical formed shank. (There are also straight shank drills with tennon or threaded drivers.)	 (5)
	6	Taper Shank Drill	A drill with a Morse taper shank. (There are also threaded morse taper shank drills.)	(6)
3. Classification According to The Length	7	Stub Drill	A drill with a much shorter overall length as compared to a normal drill of the same diameter.	 (7)
	8	Regular Length Drill	A drill with a standard market length.	(8)
	9	Long Drill	A drill with a longer overall length as compared to a normal drill of the same diameter.	(9)
4. Classification According to The Helix Angle	10	Twist Drill	A drill with left or right handed flutes twisting along the length of its body.	 (10)
	11	Straight Fluted Drill	A drill with no twists in its flutes.	(11)
5. Classification According to Profiles	12	Oil Hole Drill	A drill with through-tool coolant holes.	 (12)
	13	Sub-land Step Drill	A drill with two diameter sizes with an individual flute for each diameter size.	(13)
	14	Double Margin Drill	A drill with two fluted lands.	(14)
	15	Flat Drill	A straight fluted drill with a plate-like cutting portion.	(15)
	16	Step Drill	A drill designed to perform step drilling or to produce a countersunk hole.	(16)
6. Classification According to Functions and Applications	17	Core Drill	A drill which has no center point cutting but is used for finishing or reaming of pre-drilled holes.	 (17)
	18	Center Drill	A drill is used for making pilot holes.	(18)
	19	Gun Drill	A long drill used on a special machine for drilling of very long holes.	(19)
	20	Spade Drill	A straight fluted drill having a plate-liked formed cutting portion, usually mechanically held infixed to the body.	(20)
	21	Pivot Drill	A drill with its diameter size different from its shank diameter.	(21)
	22	Micro Drill	A small sized drill used to drill circuit boards for electronic equipment.	(22)
7. Classification According to Materials of The Cutting Portion	●	High Speed Steel Drill	A drill made wholly out of H.S.S. material.	eg. SKH9, SKH55, M7, M33, etc
	●	Carbide Drill	A drill made wholly out of Carbide material.	eg. Carbides - K10 & K20, ultra-corpuscle alloys etc.
	●	Coated Drill	The above-mentioned drills with coating	eg. Corresponding to our Multidrills
	●	Others	A drill with either a sintered CBN or PCD drill tip.	eg. Corresponding to our SumiDia drills.

■ Machine Rigidity

● Machine Capacity

Carbide Drills are used for high efficiency cutting. In order to realize their capabilities fully, use rigid and powerful machines.

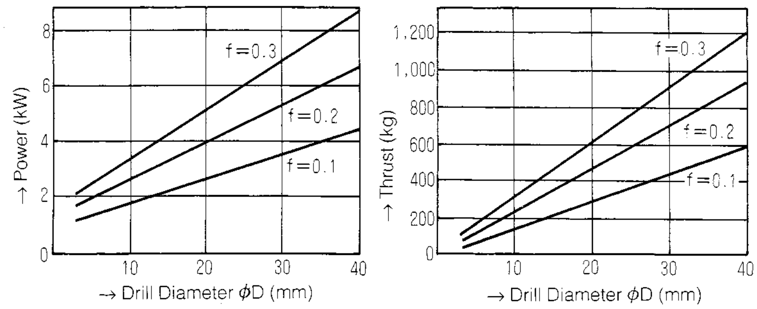
1. Power Consumption & Thrust Formula for Multi Drills

Power Consumption = $(H_B \times D^{0.68} \times V^{1.27} \times f^{0.59}) / 36000$

Thrust = $0.24 \times H_B \times D^{0.68} \times f^{0.61}$

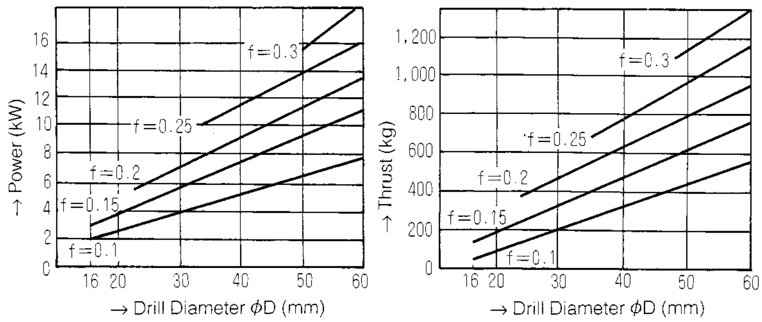
Power Consumption (kW) Thrust (kg.f)
H_B: Brinell Hardness
D : Drill Diameter
V: Velocity (m/min)
f : Feedrate (mm/rev)

On the designing the machine, please multiply 1.6 on Power Consumption and 1.4 on Thrust.



Work: S48C (H_B220)
Speed: 50m/min

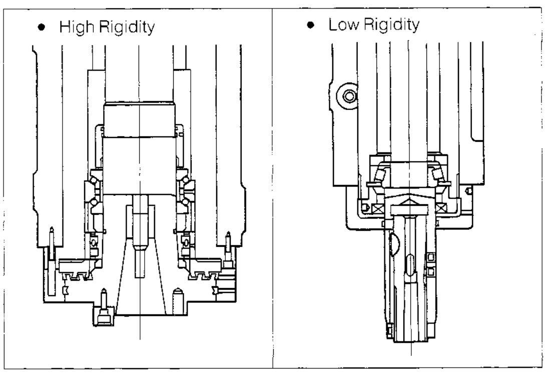
2. Power Consumption &Thrust Formula for WDS-Drill



Work: SCM440 (H_B220)
Speed: 100m/min

● Spindle

When using above chart, please consider the motor power and machine rigidity especially during high efficiency drilling (high thrust) where it requires high rigidity of the spindle. Although it is important to consider the horsepower requirements, the structure and of the main spindle axle is also an important factor for considerations. In general machining centres, rigidity of the machine's configuration are as specified:
1) BT50 > BT45 > BT40
2) single axle>plural axle



● Clamping

As high efficiency drilling enhances a large horizontal cutting force in addition to large thrust and torque forces, it is therefore essential to have a rigid and stable clamping.

■ Clamping Selection

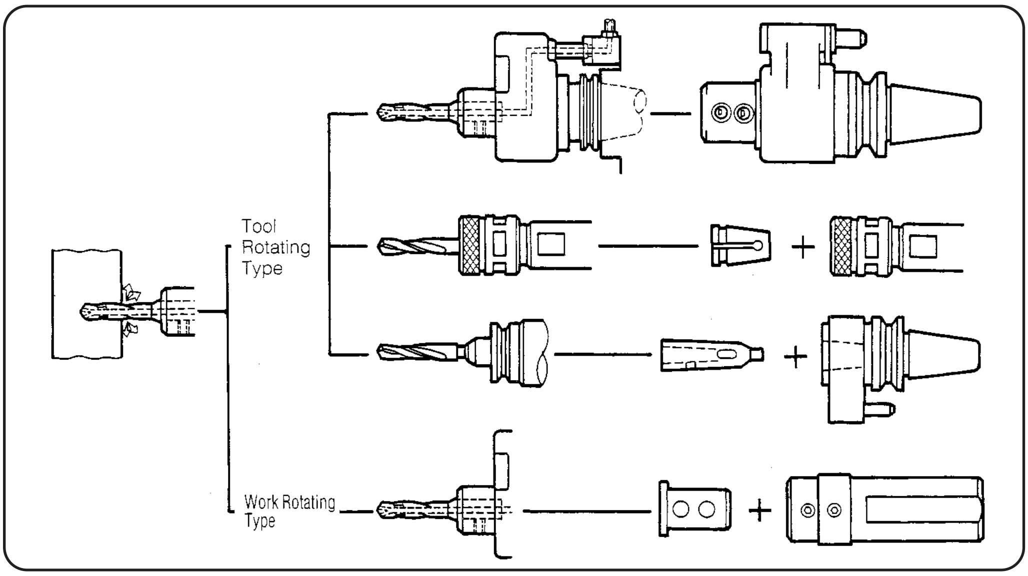
1) Deflection Accuracy
2) Rigid Clamping
Both are very important factors for carbide drilling, it is therefore important to select a suitable clamping system as recommended below.

1) External Coolant

Spindle Head									
Drill Shank		Tapered		Straight			Straight with Tang		Straight with Flat face
Chucking		Tapered Holder	Taper Holder Sleeve	Milling Chuck	Collet Holder	Drill Chuck	QC Type stub holder	Taper Holder Sleeve	Side Lock Holder
Drill	Brazed Carbide-Tipped Drill	●	○	●	●	×	●	○	●
Drill	MultiDrill (Type K,P,G)	×	×	●	●	×	●	×	●
Drill	MultiDrill (Type A,FA)	○	×	●	●	×	○	×	●
Drill	Economical Solid Carbide Drill	×	×	●	●	○	○	×	×

○:Excellent ●:Good × :Poor

2) Internal Coolant



3) Correct Operation

Oil Coolant

1. Selection Of Oil

To maximise the hole accuracy and tool life, the most suitable cutting fluid for **MULTI DRILLS** is non-water soluble (neat) cutting oil but one must be careful about the development of smoke and fire. Please supply in adequate volume. Neat oil is not suitable at high speeds. (V>40 m/min).

At high speeds, the most suitable cutting fluid is water-emulsifiable, high density oil. (7-10 times dilution.)

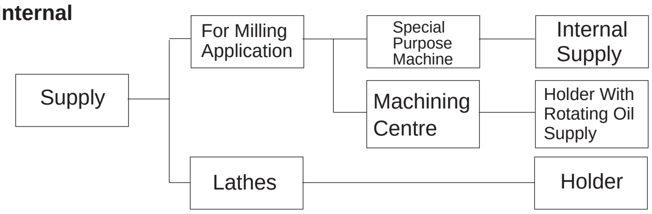
Soluble oil and Chemical fluids are not recommended.

2. Features

		Lubricity	Adhesion Resistance	Permeability	Cooling Capability	Rust Resistance	Smoke Retardant	Odor
Water Soluble Oil	Emulsifiable Oil	○	△	○	●	△	●	○
	Soluble Oil	△	△	○	●	△	●	●
	Solution Oil	×	△	△	●	△	●	●
Non Water Soluble Oil	Chlorinated Oil	●	●	●	○	○	△	●
	Sulfo-Chlorinated Oil	●	●	●	○	○	△	△

3. Oil Supply

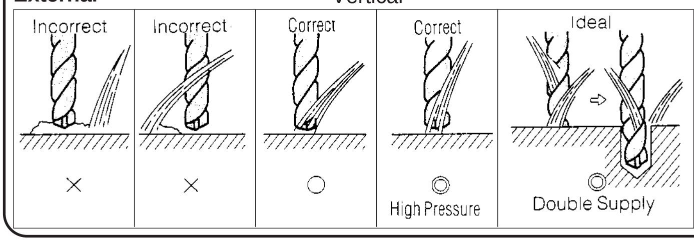
Internal



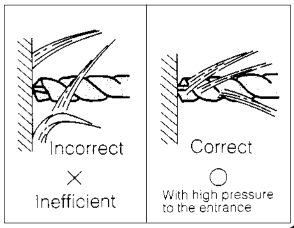
Higher oil pressure and large amounts of oil are desirable. Min. pressure is 3~5 kg/cm^2. Min. volume is 2~5 l/min.

External

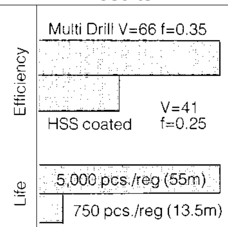
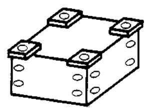
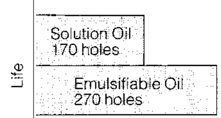
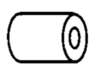
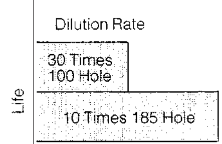
Vertical



Horizontal



4. Examples

Work	Drill	Machine Conditions	Results	Remarks
Brake Hose Part Low Carbon Steel (HB150~160) 	MDS110SK Dia. 11mm	NC Lathe V=66m/min f=0.35mm/rev		-Productivity was 2.2 times higher -Tool life was 6.7 times higher - Good hole accuracy which can omit reaming process
Construction Machine Part Low Carbon Steel (HB150) 	KDS240LA Dia. 24mm	Machining Centre V=65m/min f=0.35mm/rev		-1.6 times tool life by using emulsifiable oil
Machine Part Alloy Steel (HB280) 	KDS194LA Dia. 19.4mm	NC Lathe V=60m/min f=0.25mm/rev		-10 times dilution is good. -5 times may be too dense

■ Hole Accuracy

1) Selection of the Drill Diameter

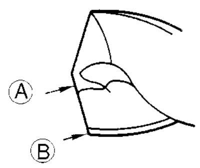
The chart below shows the actual expansion of the hole diameter for various types of materials, please consider these expansion when selecting a drill.

Drill	Soft Steel	General Steel Alloy Steel	Ductile Cast Iron	Cast Iron	Aluminium
MDS Type	+20 ~ +50	0 ~ +30	0 ~ +40	0 ~ +40	-10 ~ +40
KDS Type	+20 ~ +70	+30 ~ +80	+10 ~ +50	+10 ~ +50	0 ~ +40

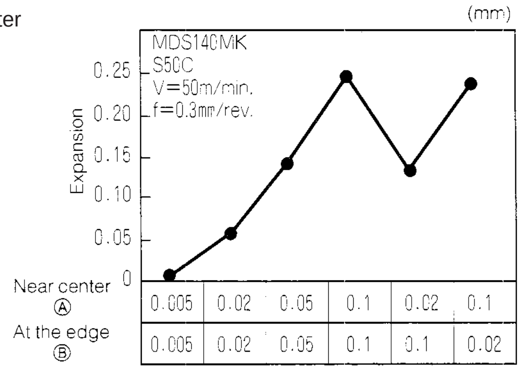
Example : If you want to drill a hole of diameter 13.1 ~ 13.15 on soft steel, the drill diameter to be selected should be ϕ13.10 (MDS131MP)

2) Run-Out of the Drill

Run-out of the drill at the edge and near the center are important.



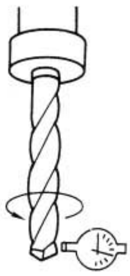
A: Difference after thinning
B: Lip Height Difference

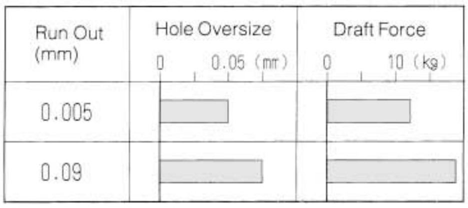


3) Deflection Accuracy (Tool rotating)

The run-out of the drill after chucking should be within 0.03mm.

The big run-out will cause over-sized holes and when used on a machine with low rigidity, it may cause drill breakage.

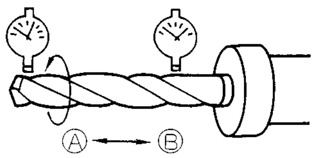




MDS120MK Carbon Steel (HB230)
V=50m/min, f=0.3mm/rev, depth=38mm

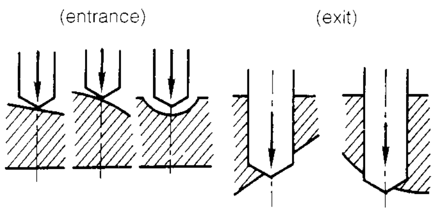
4) Deflection Accuracy (Work rotating)

On a lathe, the run-out at both positions Ⓐ and Ⓑ should be within 0.03mm.



5) Uneven Work Surfaces

If the surface of the workpiece is not flat at the entrance and exit points, the feedrate should be reduced to about 0.1~0.5 mm/rev.

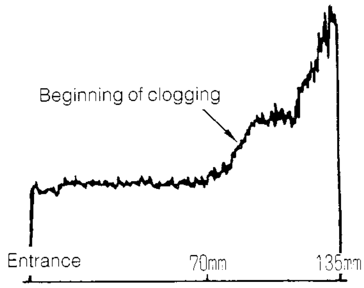
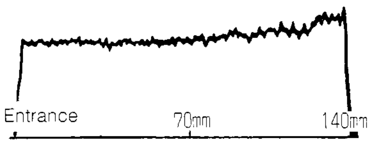
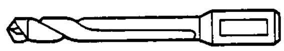


■ Relationship Between Hole Depth & Cutting Resistance

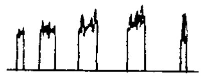
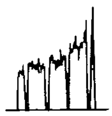
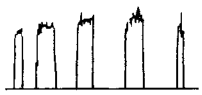
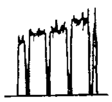
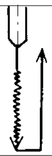
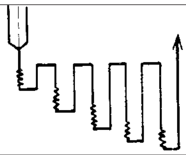
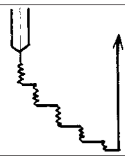
● Control the Cutting Resistance

Chip removal is very difficult in one-pass deep hole drilling. Clogged chips in the flute makes cutting forces higher and it may lead to drill breakage.

Solution by Flute Design

	Conventional Design	Deep Hole Application	
Horse Power (KW)			Drill size:ϕ20mm Material : High Carbon Steel Conditions: V = 60m/min f = 0.25mm/rev d = 140mm
Design			

Solution by Step-Feed

		Normal Drilling	Step Feed [Type 1]	Step Feed [Type 2]	
Cutting Resistance	Torque				Drill : MDS080MK Material : High Carbon Steel Conditions: V = 50m/min f = 0.25mm/rev d = 38mm
	Thrust				
Drill path					

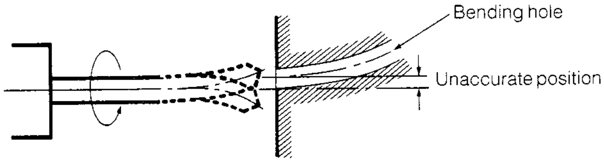
Step-feeding has two objectives: 1) Chip formation and 2) chip removal.
Low speed drilling by HSS, solid carbide or twist drills requires step-feeding [Type 2] to ease chip removal.
Conversely, high speed drilling with MultiDrills requires step-feeding [Type 1] to assist in chip formation.

Drilling

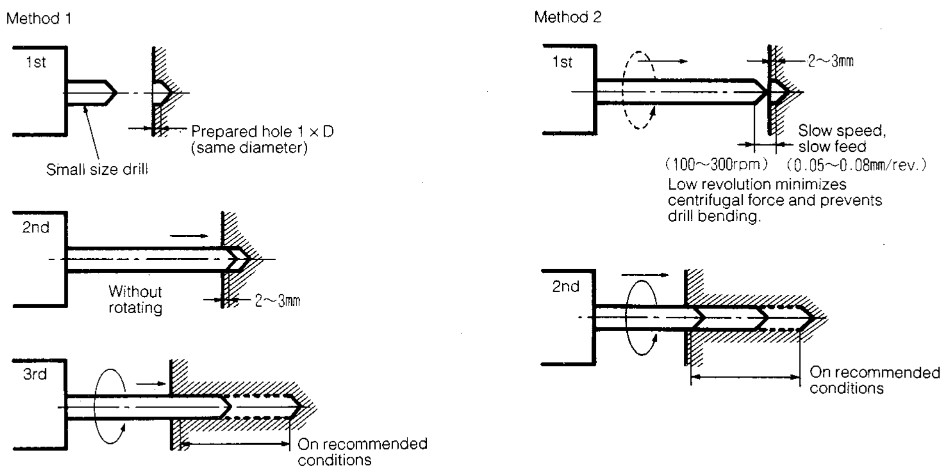
■ Remarks on Using Longer Drills (KDS-DA, KDS-FA)

● Problem

High speed cutting with longer sized drills leads to the deflection of the drill, bending of drilled hole and drill breakage.



● Two Solutions



■ Trouble Shooting Guide & Remedies for Twist Drills

● Standard Step for Common Problems

	Trouble	Basic Remedies		Proven Remedies
Drill Failures	Excessive Wear of the Cutting Edge	Tool Conditions Cutting Fluid	- Enlarge the clearance angle. - Use higher wear-resisting tool material. - Set the correct cutting speeds. - Use more efficient cutting fluids with high lubricity.	- Clearance angle of 10°~12° for steels - Change to PVD-coated MultiDrills - Change to emlusifiable type coolant, higher viscosity for heavy duty drilling
	Chisel Point Chipping	Tool Conditions Cutting Fluid	- Machine correct the web thinning and honing. - Shorten the overall length of drill and overhang. - Reduce the feedrate (more on entry). - Change to correct cutting fluid.	- Water-soluble fluid for heavy duty drilling (Emulsifiable Type)
	Chipping of Peripheral Cutting Edge	Tool Conditions Cutting Fluid	- Increase edge honing. - Decrease cutting speed. - Reduce feed during entrance or break-through. - Change to correct cutting fluid with a minimum of 5 bars pressure.	- Water-soluble fluid for heavy duty drilling (Emulsifiable Type)
	Deposition, Wear of Margin Part	Tool Cutting Fluid Others	- Slightly enlarge the back taper on diameter. - Narrow the width of margin - Supply cutting fluids sufficiently minimum of 5 bars - Early regrinding - Direction of coolant supply should be correct	- Water-soluble fluid for heavy duty drilling (Emulsifiable Type)
	Fracture of Drill Body	Tool Conditions Cutting Fluid Others	- Use a more rigid drill. - Slightly enlarge the back taper on diameter and narrow the margin width. - Decrease the cutting speed and feedrate. - Increase the coolant flow rate to min 5 bars. - Avoid packing of chips by pecking. - Increase rigidity of the machine. - Increase clamping rigidity of the work.	- Use MultiDrill K Types - Increase the number of pecks per cycle
Unsatisfactory Working Accuracies	Excessive Over-Sized Holes	Tool Conditions Cutting Fluid	- Correctly grind the point configuration. - Decrease the cutting speed and feed. - Reduce the oil pressure and flow rate.	- Eliminate the eccentricity of the chisel edge - Minimise the difference between lip heights (within 0.02 mm)
	Poor Surface Finish	Tool Conditions Cutting Fluid	- Increase rigidity of the machine. - Increase the cutting speed when built-up edge occurs. - Adjust the feedrate proportionally. - Supply sufficient cutting fluids.	- Use Multi Drill K Type - Use sulfurised oil as the cutting fluid
	Drill Wondering	Tool	- Eliminate the eccentricity of right and left cutting lips. - Correct deflection and run-out of the drill	- Minimise the difference between lip heights (within 0.02 mm) - Use the guide bush (not suitable for MultiDrills)
Unsatisfactory Chip Control	Packing of Chips	Conditions Cutting Fluid	- Introduce peck-drilling. - Decrease speed and increase feedrate. - If through-tool coolant system is used, increase the coolant pressure and flow rate.	
	Stringy Swarf	Conditions	- Decrease the cutting speed. - Increase feedrate.	
Others	Chattering During Drilling	Tool	- Reduce the clearance angle. - Use a more rigid drill.	- Change to MultiDrill K Type

Exotic Materials Guidance

X1 ~ X8

■ Insert Grades & Cutting Conditions for Exotic Materials

● Turning

[▬ Cutting Speed (V) : m/min, —— Feed rate (f) : mm/rev]

Work Materials: Type	Work Materials: Examples	General Machining and Roughing: Recommended Insert Grades		General Machining and Roughing: Conditions	Finishing: Recommended Insert Grades		Finishing: Conditions
Stainless Steels	SUS410	AC3000 AC304 EH10Z (Coated)	V f	100–180 0.2–0.6	T110A (Cermet)	V f	120–250 0.1–0.2
Stainless Steels	SUS304	AC3000 AC304 EH10Z (Coated)	V f	80–160 0.2–0.6	EH20Z (Coated)	V f	100–200 0.1–0.2
Nickel Alloys	Inconel 718	EH20Z (Coated)	V f	30–50 0.05–0.25	BN600 (CBN)	V f	50–200 0.05–0.15
Nickel Alloys	Inconel 718	EH10Z (Coated)	V f	20–40 0.1–0.3	BN600 (CBN)	V f	50–200 0.05–0.15
Nickel Alloys	Hastelloy B	EH10Z (Coated)	V f	30–50 0.1–0.3	BN600 (CBN)	V f	50–150 0.05–0.15
Nickel Alloys	Nimonic 80A	EH10Z (Coated)	V f	30–50 0.1–0.3	BN600 (CBN)	V f	50–150 0.05–0.15
Cobalt Alloys		EH10Z (Coated)	V f	20–60 0.1–0.2	BN600 (CBN)	V f	100–200 0.05–0.15
Ferrite Alloys		AC2000 (Coated)	V f	30–60 0.1–0.3	BN600 (CBN)	V f	100–200 0.05–0.15
Pure Titanium		EH10Z (Coated)	V f	30–60 0.1–0.3	BN600 (CBN)	V f	100–200 0.1–0.2
Titanium Alloys	Ti-6Al-4V	EH10Z (Coated)	V f	20–50 0.1–0.3	BN600 (CBN)	V f	100–200 0.05–0.15
Stellite		EH10Z (Coated)	V f	20–60 0.1–0.2	BN600 (CBN)	V f	70–150 0.05–0.15
Shape Memory Alloy		EH10Z (Coated)	V f	20–50 0.05–0.15	BN600 (CBN)	V f	50–100 0.05–0.15
Heat Resistant Sintered Alloys (Valve Seat Ring)		EH10Z (Coated)	V f	30–70 0.05–0.15	BNX4 (CBN)	V f	50–150 0.05–0.15
Quench Hardened Steels	Hardened Blister Steels (Over HRC55)	EH10Z (Coated)	V f	50–150 0.05–0.1	BNX20 BN250 BN300 (CBN)	V f	50–150 0.05–0.2
High Manganese Steels	SCMnH3	NB90S (Ceramics)	V f	50–150 0.1–0.3	BNX20 BN250 BN300 (CBN)	V f	100–300 0.02–0.2
Carbide	85WC-15Co	EH10Z (Coated)	V f	10–30 0.05–0.2	DA90 (PCD)	V f	10–30 0.05–0.2
FRP	CFRP Carbon Fiber Reinforced Plastic	EH10Z (Coated)	V f	–	DA150 (PCD)	V f	150–300 0.05–0.2

● Milling

[▬ Cutting Speed (V) : m/min, —— Feed rate (f) : mm/t]

Work Materials		Recommended Tools		Recommended Cutting Conditions	
Type	Example	Cutter Type	Grades	V f	20 50 100 200 400 0.02 0.05 0.1 0.2 0.4
Stainless Steels	Hot Rolled Stainless Steel Strips (AISI)	UFO-Type	T130Z (Coated Cermet) AC325 (Coated Carbide)	V f	160 – 220 0.15 – 0.4
Nickel Base Heat Resistant & Corrosion Resistant Materials	Inconel 718	GRC-Type	EH20(Z) (K10 Coated Carbide)	V f	20 – 50 0.1 – 0.2
Titanium Alloys	Ti6Al-4V	GRC-Type	EH20(Z) (K10 Coated Carbide)	V f	20 – 50 0.1 – 0.2
Quench Hardened Steels	SKD61	Sumiboron Facemill BNM-Type	BN250 (CBN)	V f	100 – 200 0.05 – 0.15
High Manganese Steels	SCMnH3	UFO-Type	A30N (P30 Carbide)	V f	40 – 80 0.15 – 0.3

● EndMilling

[▬ Cutting Speed (V) : m/min, —— Feed rate (f) : mm/rev]

Work Materials		Recommended Tools		Recommended Cutting Conditions	
Type	Example	Endmill Type	Grades	V f	20 50 100 200 400 0.02 0.05 0.1 0.2 0.4
Stainless Steels	Hot Rolled Stainless Steel Strips (AISI)	Coated Solid Spiral Endmill SSM-ZX Type	Coated Carbide	V f	30 – 70 0.015 – 0.05
Nickel Base Heat Resistant & Corrision Resistant Materials	Inconel 718	High Lead Coated Endmill HSM-ZX Type	Coated Carbide	V f	20 – 40 0.015 – 0.05
Titanium Alloys	Ti6Al-4V	Coated Spiral Endmill SSM-ZX Type	Coated Carbide	V f	30 – 70 0.015 – 0.05
Quench Hardened Steels	Alloy Tool Steels (AISI)	Sumiboron Endmill BNES-Type BNBS-Type	BNX3 (CBN)	V f	30 – 150 0.015 – 0.05

● Drilling

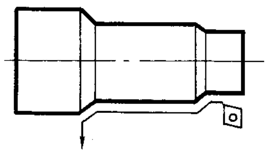
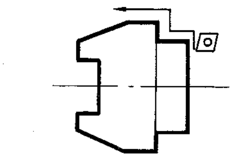
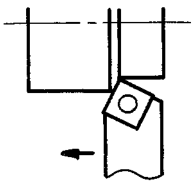
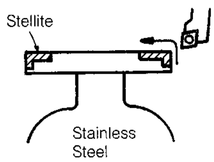
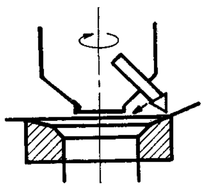
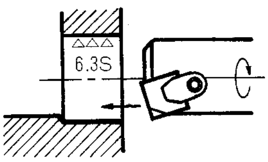
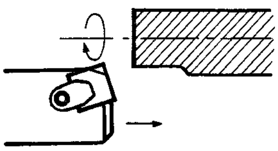
[▬ Cutting Speed (V) : m/min, —— Feed rate (f) : mm/rev]

Work Materials		Recommended Tools		Recommended Cutting Conditions	
Type	Example	Drill Type	Grades	V f	20 50 100 200 400 0.02 0.05 0.1 0.2 0.4
Stainless Steels	Stainless Steel Wires (AISI)	MultiDrill HK-Type MultiDrill K-Type MultiDrill A-Type	ZX Coated ZX Coated Coated	V f	20 – 70; 0.1 – 0.3 15 – 30; 0.1 – 0.3

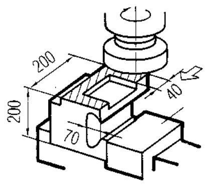
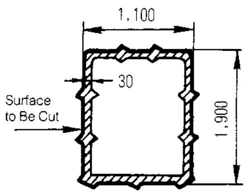
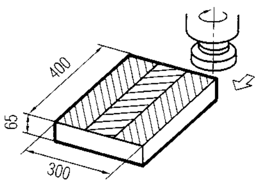
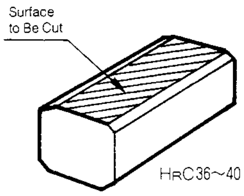
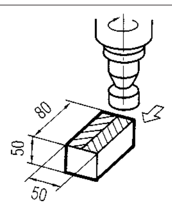
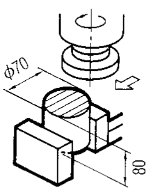
Exotic Mat.

■ Application Examples

● Turning

	Application	Work 1) Part Name 2) Materials	Tool 3) Tool Name 4) Grade	Cutting Conditions V = Speed f = Feed d = Depth of Cut	Results
Stainless Steels		1) Valve Parts 2) SUS304	3) CNMG120408N-UP 4) AC3000, AC304	V = 90~110 f = 0.25 d = 2.5~3.5	Smoother cut and superior chip-control than conventional chip breakers
Stainless Steels		1) Seat Ring 2) SUS304	3) CNMG120408N-UP 4) AC3000, AC304	V = 100 f = 0.25 d = 4~5	Superior anti-notch wear and better chip control than conventional chip breakers
Hastelloy	1) Aerospace Parts 2) Nimonic 75 (Ni60%, Cr20%, Co, C, etc) Exotic Materials (Co20%, Cr20%, Ni47%)		3) CNMG120408N-UP 4) EH20Z	V = 45 f = 0.15 d = 0.25	Wear resistance and chip control is superior as compared to the competitor's
Titanium Alloys		2) Titanium Alloy (Ti-6Al-4V)	3) SNMG120408N-UP 4) EH10Z EH20Z (K10 Coated Carbide)	V = 30 m/min f = 0.15 mm/rev d = 1.0 mm Wet (Water Soluble)	
Stellite	 	1) Valve 2) Combination of Hot Rolled Stainless Steel Strips (AISI) and stellite	3) CNMG120408N-UG 4) EH10Z	V = 20~40 m/min f = 0.1 mm/rev d = 1~2 mm Dry	EH10Z: 5 pcs/corner Competitor's K10 Carbide: 2 pcs/corner (EH10Z grade gives a smoother cut and good surface finish on both stellite and stainless parts)
P/M Sintered Alloys		1) Valve Seat 2) P/M Sintered Alloy	3) Special Holder (Carbide Shank) 4) BNX4 (CBN)	V = 56 m/min f = 0.1 mm/rev d = 0.3 mm Wet	Tool Life of BNX4 is twice that of competitor's CBN grade
Quench Hardened Steels	 	1) Crank Web Pin Hole 2) JIS S48C (HRC55~62)	3) SumiBoron Insert SPGN090312 4) BN250	V = 90 m/min f = 0.07 mm/rev d = 0.15 mm Wet	Tool Life: 400 pcs Surface Finish: 3~4 µm (Rmax) Diameter Compensation: 100 pcs each
Inconel 718		1) Aircraft Part 2) Inconel 718	3) CNMG190612N-MU 4) EH10Z	V = 40 m/min f = 0.15 mm/rev d = 1.5 mm	
Carbide		1) Round bar 2) Carbide G6	3) SumiDia Insert SNGN120408 4) DA90 (PCD)	V = 10 m/min f = 0.065 mm/rev d = 0.05 mm Dry	Machining time per regrind is approx 20 minutes

● Milling

	Tool Selection and Work Application (mm)	Work Materials 1) Part Name 2) Materials	Tools 3) Cutter Cat. No. 4) Insert Cat. No. (Grade)	Cutting Conditions V = Cutting Speed f = feed/tooth d = Depth of Cut	Results
Stainless Steels		1)Machine Tool Parts 2)Casted Stainless Steel	3) UFO4160R 4) SFEN12T3AZTN (AC325)	V = 176 m/min N = 350 rpm F = 550 mm/min f = 0.2 mm/tooth d = 2 mm	Efficiency is 220% higher when compared to conventional cutters with 25º posi-inserts Very stable machining without chattering and chipping of the cutting edges.
Inconel		1)Thin Structural Work 2) Inconel 625	3) GRC6160R 4) RGEN2004SN (EH20) Competitor's Cutter: ø160 mm (Coated Inserts)	V = 40~50 m/min f = 0.2~0.3 mm/tooth d = 3~5 mm Competitor's Cutter V = 20 m/min f = 0.25 mm/tooth d = 5 mm	Our cutter performed for over 35 minutes Initially there were sparks and after 20 minutes, the competitor's inserts were totally broken.
—		1) Plate 2) MONEL 400	3) UFO4100R 4) SFEN12T3AZTN (AC325)	V = 250 m/min N = 796 rpm F = 498 mm/min f = 0.125 mm/tooth d = 5 mm Wet	Using a cutter with 15º posi round-insert is difficult because the chips adhere to the cutting edge. As the rake angle of UFO is much higher and performance of chip exhaust is superior, they get 370% higher efficiency.
Titanium Alloys		1) Block 2) Titanium-Alloy (Ti-6Al-4V)	3) GRC6160R 4) RGEN2004SN (EH20)	V = 30 m/min f = 0.2 mm/tooth d = 3~4 mm	Performed for over 40 minutes.
Titanium Alloys	—	1) ---- 2) Ti-6Al-4V (HRC32~34)	3) UFO4160R 4) SFEN12T3AZTN (EH20Z)	V = 54 m/min N = 113 rpm F = 181 mm/min f = 0.2 mm/tooth d = 2.5 mm	As compared with G10E grade inserts, the Z-coated inserts provided 170% higher efficiency and 200% longer tool life.
Die Steels		1) Block 2) SKD11	3) UFO4063ER 4) SFKN12T3AZTN (AC325)	V = 200 m/min N = 1010 rpm F = 1000 mm/min f = 0.2 mm/tooth d = 0.8 mm 2 pass/area	Even when machining the forged surface, the UFO cutter cuts smoothly and provides a good surface finish.
		1) Forging Die Part 2) HAP72 (HRC40)	3) UFO4100R 4) SFEN12T3AZTN (A30N)	V = 182 m/min N = 580 rpm F = 305 mm/min f = 0.11 mm/tooth d = 3 mm	Machining was impossible using 15º or 20º posi-insert cutters but with UFO cutter, there wass no problem under these conditions.

■ Machinability of Hard to Cut Materials

< Machinability >

● **Machinability Denotes ....**

Machinability and Machining of hard-to-cut Materials:
1) Less cutting tool failures and longer tool life
2) Smaller cutting resistance and power consumption
3) Satisfactory finishing of products
4) Satisfactory chip control

● **Machinability Index**

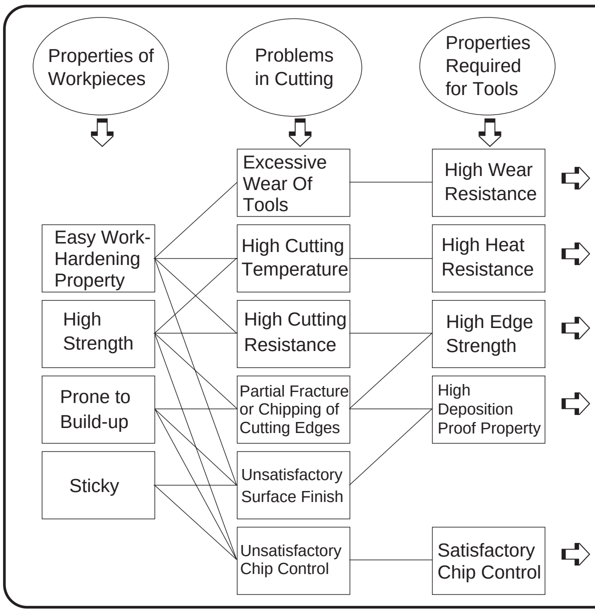
- An index designed in the U.S.A. in which machinability is expressed by taking notice of the tool life only.
- Machinability is numerically shown and therefore it is used as the standard to determine suitability of cutting.
- The material becomes difficult to cut as the numeric value decreases. 45 and below is designated as hard-to cut-work material.

● **Machinability Index Of Typical Materials**

Workpiece		Machinability Index	Workpiece		Machinability Index	Workpiece			Machinability Index
Copper Alloy		100 ~ 70	Stainless Steel	Ferritic	65 ~ 50	Heat and Corrosion Resisting Alloys	Fe Base	A-286 Inconel 901	30 ~ 10
Steel	Mild	85 ~ 70		Martensitic	55 ~ 40		Ni Base	Nimonic 80A Inconel 901	16 ~ 6
	Medium	65 ~ 50		Austenitic	50 ~ 35		Cr Base	L-605 Stellite 21	15 ~ 6
	Hard	60 ~ 50	Alloy Tool Steel		30 ~ 25				
Low Alloy Steel		65 ~ 50	High Maganese Steel		40 ~ 30				
Cast Iron		70 ~ 50	Titanium Alloy		30 ~ 20				

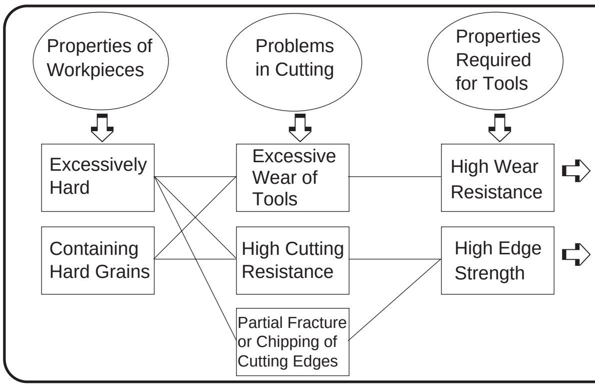
< Problems Of Hard To Cut Materials & Remedies >

● **For Heat and Corrosion Resistant Alloys**



Properties Required for Tools	Remedy in Tool Design: Rake Angle	Clearance Angle	Side Cutting Edge Angle	Nose Radius	Others	Selection of Tool Material: Sintered Diamond	Sintered CBN	Ceramic	Cermet	Coated	Carbide
High Wear Resistance			Enlarge	Enlarge			●			●	
High Heat Resistance			Enlarge	Enlarge			●	●		●	● K Class
High Edge Strength	Reduce	Reduce	Enlarge	Enlarge						●	● K Class
High Deposition Proof Property	Enlarge	Enlarge		Enlarge					●	●	
Satisfactory Chip Control					Chip Breaker						

● **For Hardened Materials (Quench-Hardened Steels, Carbides, etc)**



Properties Required for Tools	Remedy in Tool Design: Rake Angle	Clearance Angle	Side Cutting Edge Angle	Nose Radius	Others	Selection of Tool Material: Sintered Diamond	Sintered CBN	Ceramic	Cermet	Coated	Carbide
High Wear Resistance		Enlarge	Enlarge			●	●	●			
High Edge Strength	Reduce	Reduce	Enlarge	Enlarge			●				● K Class

● **Common Considerations For Cutting Hard-to-Cut Work Materials**

- Machines : All backlash should be eliminated with exceptional axial rigidity.
- Tools : Use a larger shank size and minimise the overhang to increase rigidity.
- Workpiece : Assure fittings and protection from run-out and chatter.

■ Machining of Stainless Steel

● Classification & Properties

Classification	Alias	Material (JIS)	Machinability	Machinability Index	Quench Hardened	Magnetism	Typical Applications
Martensitic	13 Chrome	SUS410, etc	Rather Bad	55~40	Yes	Yes	Tableware, Cutlery, Gauges
Ferritic	18 Chrome	SUS430, etc	Fairly Good	65~50	No	Yes	Valves, Parts for Pumps
Austenitic	18-8 Stainless	SUS304, etc	Bad	50~35	No	No	Industrial Parts, Kitchen Appliances
Precipitation Hardening		SUS631, etc	Rather bad				

● Reasons For Cutting Difficulty & Influence

Cause	Influence on Tools
Excessive Work-Hardening	Chipping of the flank and increased nose wear.
Low Heat Conductivity	Poor heat dissipation and plastic deformation of edges.
Excessive Deposition with Tools	Deposition of chips causes chipping of cutting edges and tearing of work surface.

● Turning Stainless Steels

1) Tool Design (Rake Angle).

2) Recommended insert materials.

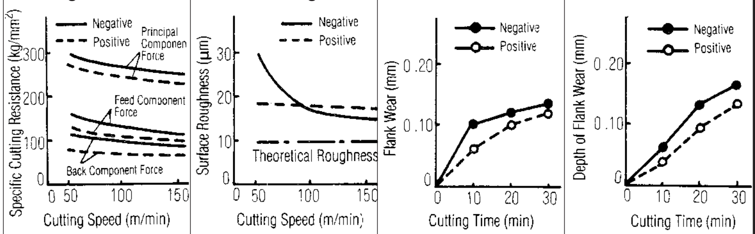
3) Recommended Cutting Conditions.

Recommended Rake Angle : 12° ~18°
Right-hand Fig. shows relation between the rake angle and properties in the case of SUS304

For Finishing:
- T1200A (Cermet)
- EH10Z (PVD Coated)

For General Cutting:
- AC2000 (Coated)
- AC3000 (Coated)

Cutting Resistance | Surface Roughness | Flank Wear | Face Wear



V=Variable, f=0.25mm/rev, d=1.5mm | V=100m/min, f=0.42mm/rev, d=2mm

● Chip Control (Chip Breaker "UP" Type for Turning Stainless Steels)

Features of UP Type Breaker and Configuration

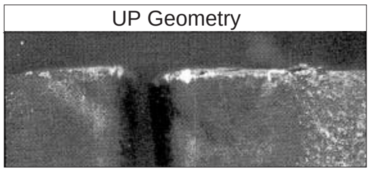
Capable of wide-ranged chip control.

In addition, it shows steady performance due to the strengthened cutting edges.

This is a special breaker developed specially for the machining of stainless steels.

Comparison of Wear Resistance

UP Geometry



Conventional Geometry

Workpiece: SUS304
Tool: PCLNR2525 CNMG120408 (AC3000)
Cutting Conditions:
V = 40~100 (m/min)
f = 0.35 (mm/rev)
d = 2.0 (mm)
T = 10 (min)
Interrupted Cutting

● Milling Stainless Steels

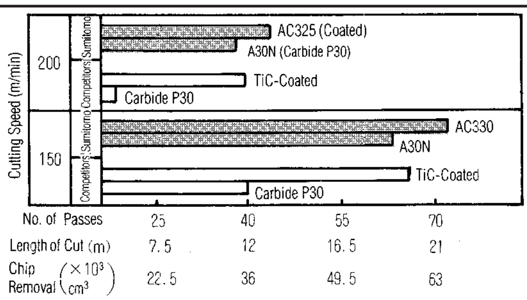
1) Recommended Cutter

2) Recommended insert materials

3) Recommended Cutting Conditions

SEC-ACE Mill UFO Type
Unique design for superior sharpness and excellent chip removal. It has a Negative-Positive geometry with an approach angle of 45°

- A30N (Carbide P30)
- AC325 (Coated)
- AC230 (Coated)



Workpiece: SUS304
Cutter: UFO4160
Insert: SFKN12T3AZTN
Grades: A30N, AC325
Cutting Conditions:
V = 150~200 m/min
f = 0.3 mm/tooth
d = 3 mm, Dry

● End-Milling Stainless Steels

1) Recommended Endmills
2) Recommended Tool Material
3) Recommended Cutting Conditions

SSM-ZX Type - Coated solid spiral endmills
ZX-Coating - TiAlN compounds coated on the carbide base material, having 3~5 times longer life than normal.
Conditions - Cutting speed (V) = 30~70 m/min, Feedrate (f) = 0.015~0.05 mm/tooth.

■ Cutting Quench-Hardened Steels

< Quench-Hardened Steels & CBN >

● **Features Of Quench Hardened Steels**

Quench-hardened steels with martensite content are excessively hard and strong. Therefore, the cutting resistance, especially thrust force, is high.

● **Machining Quench-Hardened Steels (New CBN tools replace; grinding with cutting)**

The conventional finishing process for hardened steels has been dependent upon grinding but due to the development of CBN tools which provide better capabilities, more and more users are converting to CBN for finishing of hardened steels

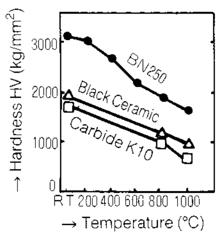
Merits of conversion from grinding to cutting:
- Reducing the cutting time.
- Reducing the cost of equipment.
- Able to perform various operations.

● **Sintered CBN (Sumiboron)**

Sintered CBN is a new material for cutting tools which is composed mainly of cubic boron nitride and sintered at ultrahigh pressure and temperature
SumiBoron is a sintered CBN tool developed by Sumitomo

Material	Hardness (Hv)	Features	Applications (Workpieces)
BN250	3100 ~ 3300	High Wear Resistance & Fracture Resistance	Hardened Steel: Continuous ~ Light Interrupted Cut
BN300	3300 ~ 3500	High Toughness & Chipping Resistance	Hardened Steel: Medium ~ Heavy Interrupted Cut
BNX20	3200 ~ 3400	High Toughness & Hot Hardness	High Efficiency Cutting
BN600	3900 ~ 4200	Good Thermal Cracking Resistance & Toughness	Hardened Steel & High Speed Cast Iron Turning

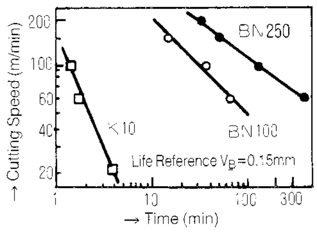
Hardness Of Tool Materials At High Temperature



< Cutting Quench-Hardened Steels By CBN >

● **Cutting of Quench-Hardened Steels and Tool Life**

Tool Life Diagram In Cutting Carburize-Quenched Steel



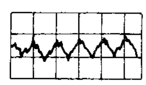
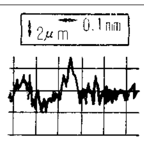
Cutting Conditions:
Depth of Cut, 0.2 mm; feed, 0.12 mm/rev
Wet; Tool Configuration, -5,-6,5,6,15,15,0.8R

Carbide K10 fails within 2 minutes at 60 m/min, while BN250 has a longer life, some 100 minutes at 100 m/min

● **Comparison Between Surfaces Finished By Grinding & Cutting**

Comparison Between Surfaces Finished By Grinding & Cutting With BN250

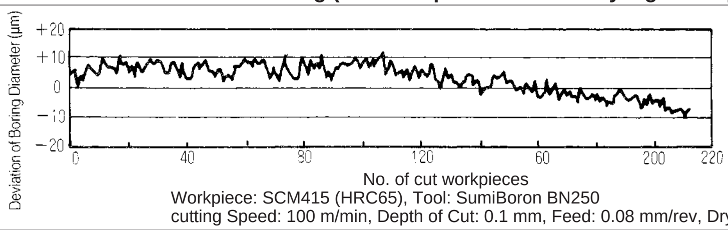
Workpiece: SNCM8 (HrC50) 840 Oil-Quenched, 200 Tempered

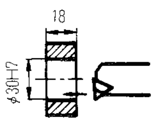
	Surface Roughness	Tool	Conditions
Cutting		Sumiboron BN250 SNGN120408	Cutting Speed:150m/min Depth of Cut: 0.2 mm Feed: 0.1 mm/rev Dry System
Grinding		WA60K	Peripheral Speed of Wheel: 1450 m/min Peripheral Speed of Work: 30 m/min Depth of Cut: 0.015 mm Use of water soluble grinding fluid

BN250 produces an extremely regular and fine surface finish compared to grinding

● **Machining Accuracies**

Dimensional Fluctuation in Boring (The workpiece is rotated by a general purpose lathe)



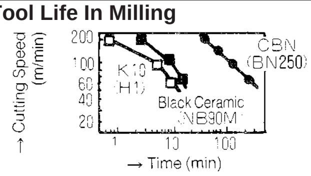


Workpiece: SCM415 (HRC65), Tool: SumiBoron BN250
cutting Speed: 100 m/min, Depth of Cut: 0.1 mm, Feed: 0.08 mm/rev, Dry System

The deviation of hole diameter corresponds to a receded amount of the cutting edges due to tool wear and complies with a tolerance width of Class H7 after cutting 200 pcs.

● **Milling & Tool Life**

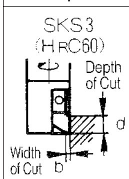
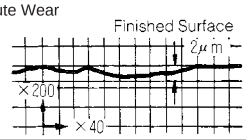
Tool Life In Milling



Workpiece: SKD61 (HRC65)
Tool: Double-Negative
Cutting Conditions: Depth of Cut, 0.2 mm; Feed, 0.08 mm/tooth
Mean Flank Wear: 0.2 mm Reference

● **SumiBoron Endmill Example**

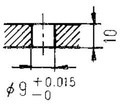
An Example Of The Sumiboron Endmill :

Workpiece	Applied Tool & Conditions	Results
	BNE1025T (25 mm Endmill) N = 1,300 rpm (V = 104 m/min) b = 0.1 mm d = 7 mm F = 100 mm/min f = 0.08 mm/rev Down-cut	Cutting for 30 min Cutting length: 3 m Minute Wear Finished Surface 

● **SumiBoron Jig Boring Tool Example**

An Actual Example of The Sumiboron Jig Boring Tool

Workpiece: Quenched Parts (Precision Boring)
Workpiece: SKS3HRC58~50
Tool: SumiBoron Jig Boring Tool SJB1008 (Dia. 8)



Cutting Conditions:
V=30m/min
d=0.1mm
f=0.05mm/rev
Dry

Results

Machining Time :	0.5 min/pcs
Surface Roughness (Rmax):	1.7 μm
Bore Concentricity :	1/1000 mm
Bore Consistency :	5/1000 (30pcs)