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TECHNICAL INFORMATION

TECHNICAL INFORMATION

CONTENTS

Carbon steel and alloy steel for structural use

Type		Korea KS	ISO ISO	Japan JIS	U.S.A AISI SAE	Great Britain BS BS/EN	Germany DIN DIN/EN	France NF NF/EN	Russia GOCT
Carbon steel		SM10C	C10	S10C	1010	040A10 045A10 045M10	C10E C10R	XC10	-
		SM15C	C15E4 C15M2	S15C	1015	055M15	C15E C15R	-	-
		SM20C	-	S20C	1020	070M20 C22, C22E C22R	C22 C22E C22R	C22 C22E C22R	-
		SM25C	C25 C25E4 C25M2	S25C	1025	C25 C25E C25R	C25 C25E C25R	C25 C25E C25R	-
		SM30C	C30 C30E4 C30M2	S30C	1030	080A30 080M30 CC30 C30E C30R	C30 C30E C30R	C30 C30E C30R	30Г
		SM35C	C35 C35E4 C35M2	S35C	1035	C35 C35E C35R	C35 C35E C35R	C35 C35E C35R	35Г
		SM40C	C40 C40E4 C40M2	S40C	1039 1040	080M40 C40 C40E C40R	C40 C40E C40R	C40 C40E C40R	40Г
		SM43C	-	S43C	1042 1043	080A42	-	-	40Г
		SM45C	C45 C45E4 C45M2	S45C	1045 1046	C45 C45E C45R	C45 C45E C45R	C45 C45E C45R	45Г
		SM48C	-	S48C	-	080A47	-	-	45Г
		SM50C	C50 C50E4 C50M2	S50C	1049	080M50 C50 C50E C50R	C50 C50E C50R	C50 C50E C50R	50Г
		SM53C	-	S53C	1050 1053	-	-	-	50Г
		SM55C	C55 C55E4 C55M2	S55C	1055	070M55 C55 C55E C55R	C55 C55E C55R	C55 C55E C55R	-
		SM58C	C60 C60E4 C60M2	S58C	1059 1060	C60 C60E C60R	C60 C60E C60R	C60 C60E C60R	60Г
Alloy steel	Nickel chromium steel	SNC236	-	SNC236	-	-	-	-	40XH
		SNC415(H)	-	SNC415(H)	-	-	-	-	-
		SNC631(H)	-	SNC631(H)	-	-	-	-	30XH3A
		SNC815(H)	15NiCr13	SNC815(H)	-	655M13(655H13)	15NiCr13	-	-
		SNC836	-	SNC836	-	-	-	-	-
	Nickel chromium molybdenum steel	SNCM220	20NiCrMo2 20NiCrMoS2	SNCM220	8615 8617(H) 8620(H) 8622(H)	805A20 805M20 805A22 805M22	20NiCrMo2 20NiCrMoS2	20NCD2	-
		SNCM240	41CrNiMo2 41CrNiMoS2	SNCM240	8637 8640	-	-	-	-
		SNCM415	-	SNCM415	-	-	-	-	-
		SNCM420(H)	-	SNCM420(H)	4320(H)	-	-	-	20XH2M(20XHM)
		SNCM431	-	SNCM431	-	-	-	-	-
		SNCM439	-	SNCM439	4340	-	-	-	-
		SNCM447	-	SNCM447	-	-	-	-	-
		SNCM616	-	SNCM616	-	-	-	-	-
		SNCM625	-	SNCM625	-	-	-	-	-
		SNCM630	-	SNCM630	-	-	-	-	-
		SNCM815	-	SNCM815	-	-	-	-	-
	Chromium steel	SCr415(H)	-	SCr415(H)	-	-	17Cr3 17CrS3	-	15X 15XA
		SCr420(H)	20Cr4(H) 20CrS4	SCr420(H)	5120(H)	-	-	-	20X
		SCr430(H)	34Cr4 34CrS4	SCr430(H)	5130(H) 5132(H)	34Cr4 34CrS4	34Cr4 34CrS4	34Cr4 34CrS4	30X
		SCr435(H)	34Cr4 34CrS4 37Cr4 37CrS4	SCr435(H)	5135(H)	37Cr4 37CrS4	37Cr4 37CrS4	37Cr4 37CrS4	35X
		SCr440(H)	37Cr4 37CrS4 41Cr4 41CrS4	SCr440(H)	5140(H)	530M40 41Cr4 41CrS4	41Cr4 41CrS4	41Cr4 41CrS4	40X
		SCr445(H)		SCr445(H)					45X

• The above Alloy steel can supplied by domestic manufacturing

Type		Korea	ISO	Japan	U.S.A	Great Britain	Germany	France	Russia
		KS	ISO	JIS	AISI SAE	BS BS/EN	DIN DIN/EN	NF NF/EN	GOCT
Alloy steel	Chromium molybdenum steel	SCM415(H)	-	SCM415(H)	-	-	-	-	-
		SCM418(H)	18CrMo4 18CrMoS4	SCM418(H)	-	-	18CrMo4 18CrMoS4	-	20XM
		SCM420(H)	-	SCM420(H)	-	708M20(708H20)	-	-	20XM
		SCM430	-	SCM430	4130	-	-	-	30XM 30XMA
		SCM432	-	SCM432	-	-	-	-	-
		SCM435(H)	34CrMo4 34CrMoS4	SCM435(H)	(4135H) 4137(H)	34CrMo4 34CrMoS4	34CrMo4 34CrMoS4	34CrMo4 34CrMoS4	35XM
		SCM440(H)	42CrMo4 42CrMoS4	SCM440(H)	4140(H) 4142(H)	708M70 709M40 42CrMo4 42CrMoS4	42CrMo4 42CrMoS4	42CrMo4 42CrMoS4	-
		SCM445(H)	-	SCM445(H)	4145(H) 4147(H)	-	-	-	-
	Manganese steel and Manganese chromium steel	SMn420(H)	22Mn6(H)	SMn420(H)	1522(H)	150M19	-	-	-
		SMn433(H)	-	SMn433(H)	1534	150M36	-	-	30Γ2 35Γ2
		SMn438(H)	36Mn6(H)	SMn438(H)	1541(H)	150M36			35Γ2 40Γ2
		SMn443(H)	42Mn6(H)	SMn443(H)	1541(H)	-	-	-	40Γ2 45Γ2
		SMnC420(H)	-	SMnC420(H)	-	-	-	-	-
		SMnC443(H)	-	SMnC443(H)	-	-	-	-	-
	Aluminum chromium molybdenum steel	SACM645	41CrAlMo74	SACM645	-	-	-	-	-

• The above Alloy steel can supplied by domestic manufacturing

Tool steel

Type	Korea	ISO	Japan	U.S.A	Great Britain	Germany	France	Russia
	KS	ISO	JIS	AISI SAE	BS BS/EN	DIN DIN/EN	NF NF/EN	GOCT
High speed steel	SKH2	HS18-0-1	SKH2	T1				
	SKH3	-	SKH3	T4				
	SKH4	-	SKH4	T5				
	SKH10	-	SKH10	T15	BM 2	S6/5/2	Z 85 WDCV	
	SKH51	HS6-5-2	SKH51	M2				
	SKH52	HS6-6-2	SKH52	M3-1				
	SKH53	HS6-5-3	SKH53	M3-2				
	SKH54	HS6-5-4	SKH54	M4	BM 35	S6/5/2/5	6-5-2-5	
	SKH55	HS6-5-2-5	SKH55	M 35				
	SKH56	-	SKH56	M36				
	SKH57	HS10-4-3-10	SKH57	-		S2/9/2		
	SKH58	HS2-9-2	SKH58	M7				
	SKH59	HS2-9-1-8	SKH59	M42				
Alloy tool steel	STS11	-	SKS11	F2				
	STS2	-	SKS2	-				
	STS21	-	SKS21	-				
	STS5	-	SKS5	-				
	STS51	-	SKS51	L6				
	STS7	-	SKS7	-				
	STS8	-	SKS8	-				
	STS4	-	SKS4	-				
	STS41	-	SKS41	-				
	STS43	105V	SKS43	W2-9 1/				
	STS44	-	SKS44	W2-8 1-2				
	STS3	-	SKS3	-		105WCr6	105WC13	
	STS31	105WCr1	SKS31	-				
	STS93	-	SKS93	-				
	STS94	-	SKS94	-				
	STS95	-	SKS95	-	BD3	X210Cr12	Z200C12	
	STD1	210Cr12	SKD1	D3				
	STD11	-	SKD11	D2	BA2	X100CrMoV5 1	Z100CDV5	
	STD12	100CrMoV5	SKD12	A2				
	STD4	-	SKD4	-	BH21	X30WCrV9 3	Z30WCV9	
	STD5	X30WCrV9-3	SKD5	H21				
	STD6	X37CrMoV5-1	SKD6	H11	BH13	X40CrMoV5 1	Z40CDV5	
	STD61	X40CrMoV5-1	SKD61	H13				
	STD62	X35CrWMoV5	SKD62	H12				
	STD7	32CrMoV12-28	SKD7	H10				
	STD8	-	SKD8	H19				
	STF3	-	SKT3	-		55NiCrMoV6	55NCDV7	
	STF4	55NiCrMoV7	SKT4	L6				

• The above High speed steel can supplied by domestic manufacturing

Type	Korea KS	ISO ISO	Japan JIS	U.S.A AISI SAE	Great Britain BS BS/EN	Germany DIN DIN/EN	France NF NF/EN	Russia GOCT
Free cutting carbon steel	SUM11	-	SUM11	1110				
	SUM12	-	SUM12	1109				
	SUM21	9S20	SUM21	1212				
	SUM22	11SMn28	SUM22	1213	230M07	9SMn28	S250	
	SUM22L	11SMnPb28	SUM22L	12L13		9SMnPb28	S250Pb	
	SUM23	-	SUM23	1215	240M07	9SMn36	S 300	
	SUM23L	-	SUM23L	-				
	SUM24L	11SMnPb28	SUM24L	12L14		9SMnPb36	S300Pb	
	SUM25	12SMn35	SUM25	-				
	SUM31	-	SUM31	1117				
	SUM31L	-	SUM31L	-				
	SUM32	-	SUM32	-				
	SUM41	-	SUM41	1137				
	SUM42	-	SUM42	1141				
	SUM43	44SMn28	SUM43	1144				
High carbon chromium	STB1	-	SUJ1	-				
	STB2	B1	SUJ2	52100	534A99	100Cr6	100Cr6	
	STB3	B2	SUJ3	ASTM A 485 Grade 1				
	STB4	-	SUJ4	-				
	STB5	-	SUJ5	-				

• The above Special speed steel can supplied by domestic manufacturing

Stainless steel

Type		Korea KS	ISO ISO	Japan JIS	U.S.A UNS	 AISI SAE	Great Britain BS BS/EN	Germany DIN DIN/EN	France NF NF/EN	Russia GOCT
Stainless steel	Austenitic	STS201	X12CrMnNiN17-7-5	SUS201	S20100	201	284S16	X12CrNi17-7	Z12CMN17-07Az	12X17•9AH4
		STS202	X12CrMnNiN18-9-5	SUS202	S20200	202	301S21	X2CrNiN18-7		07X16H6
		STS301	X10CrNi18-8	SUS301	S30100	301		X12CrNi17-7	Z11CN17-08	
		STS301L	X2CrNiN18-7	SUS301L						
		STS301J1		SUS301J1			302S25			12X18H9
		STS302		SUS302	S30200	302		X10CrNiS18-9	Z12CN18-09	
		STS302B	X12CrNiSi18-9-3	SUS302B	S30215	302B	303S21			
		STS303	X10CrNiS18-9	SUS303	S30300	303	303S41		Z8CNF18-09	12X18H10E
		STS303Se		SUS303Se	S30323	303Se		X5CrNi18-10		
		STS303Cu		SUS303Cu			304S31			08X18H10
		STS304	X5CrNi18-9 X2CrNi18-9	SUS304	S30400	304	304S11	X2CrNi19-11	Z7CN18-09	03X18H11
		STS304L	X2CrNi19-11	SUS304L	S30403	304L		X2CrNiN18-10	Z3CN19-11	
		STS304N1	X5CrNiN18-8	SUS304N1	S30451	304N			Z6CN19-09Az	
		STS304LN	X2CrNiN18-8	SUS304LN	S30453	304LN		X5CrNi18-12	Z3CN18-10Az	
		STS304J1		SUS304J1			305S19			06X18H11
		STS305	X6CrNi18-12	SUS305	S30500	305			Z8CN18-12	
		STS309S		SUS309S	S30908	309S	310S31	X5CrNiMo27-12-2	Z10CN24-13	10X23H18
		STS310S	X6CrNi25-20	SUS310S	S31008	310S	316S31	X5CrNiMo27-13-3	Z8CN25-20	
		STS316	X5CrNiMo17-12-2 X3CrNiMo17-12-3	SUS316	S31600	316	316S11	X2CrNiMo17-13-2 X2CrNiMo17-14-3	Z7CND17-12-02 Z6CND18-12-03	03X17H14M3
		STS316L	X2CrNiMo17-12-2 X2CrNiMo17-12-3 X2CrNiMo18-14-3	SUS316L	S31603	316L			Z3CND17-12-02 Z3CND17-12-03	
		STS316N		SUS316N	S31651	316N	317S16	X6CrNiTi18-10		
		STS317		SUS317	S31700	317	321S31	X6CrNiNb18-10		08X18H10T
		STS321	X6CrNiTi18-10	SUS321	S32100	321	347S31		Z6CNT18-10	08X18H12
		STS347	X6CrNiNb18-10	SUS347	S34700	347		X6CrAl13	Z6CNNb18-10	
		STS384	X3NiCr18-16	SUS384	S38400	384	405S17		Z6CN18-16	
	Ferritic	STS405	X6CrAl13	SUS405	S40500	405			Z8CA12	
		STS410L		SUS410L				X6Cr17	Z3C14	
		STS429		SUS429	S42900	429	430S17	X7CrS18		12X17
		STS430	X6Cr17	SUS430	S43000	430		X6CrMo17-1	Z8C17	
		STS430F	X7CrS17	SUS430F	S43020	430F	434S17		Z8CF17	
		STS434	X6CrMo17-1	SUS434	S43400	434			Z8CD17-01	
		STS444	X2CrMoTi18-2	SUS444	S44400	444			Z3CDT18-02	
		STSXM27		SUSXM27	S44627			X10Cr13	Z1CD26-01	
	Martensitic	STS403		SUS403	S40300	403	410S21			
		STS410	X12Cr13	SUS410	S41000	410	416S21	X20Cr13	Z13C13	
		STS416	X12CrS13	SUS416	S41600	416	420S29	X20CrNi17-2	Z11CF13	20X13
		STS420J1	X20Cr13	SUS420J1	S42000	420	431S29		Z20C13	20X17H2
		STS431	X19CrNi16-2	SUS431	S43100	431			Z15CN16-02	
		STS440A	X70CrMo15	SUS440A	S44002	440A		X7CrNiAl17-7	Z70C15	
	Precipitation hardening type	STS630	X5CrNiCuNb16-4	SUS630	S17400	S17400			Z6CNU17-04	09X17H7IO
		STS631	X7CrNiAl17-7	SUS631	S17700	S17700			Z9CNA17-07	
		STS631J1		SUS631J1						

• The above Stainless steel can supplied by domestic manufacturing

Casting or forging steel

Type		Korea KS	ISO ISO	Japan JIS	U.S.A AISI SAE	Great Britain BS BS/EN	Germany DIN DIN/EN	France NF NF/EN	Russia GOCT
Casting Iron	Gray iron casting	GC100 GC150 GC200 GC250 GC300 GC350	100,150, 200, 250, 300, 350	FC100 FC150 FC200 FC250 FC300 FC350	No 20 B No 25 B No 30 B No 35 B No 45 B No 50 B No 55 B	Grade 150 Grade 220 Grade 260 Grade 300 Grade 350 Grade 400	GG 10 GG 15 GG 20 GG 25 GG 30 GG 35 GG 40	Ft 10 D Ft 15 D Ft 20 D Ft 25 D Ft 30 D Ft 35 D Ft 40 D	-
	Spheroidal graphite iron casting	GCD400 GCD500 GCD600 GCD700	700-2, 600-3, 500-7, 450-10, 400-15, 400-18, 350-22	FCD400 FCD500 FCD600 FCD700	60-40-18 80-55-06 100-70-03	SNG 420/12 SNG 370/17 SNG 500/7 SNG 600/3 SNG 700/2	GGG 40 GGG 40.3 GGG 50 GGG 60 GGG 70	FCS 400-12 FGS 370-17 FGS 500-7 FGS 600-3 FGS 700-2	B
	Austempered Spheroidal graphite iron casting	FCAD	-	FCAD	-	EN-GJS-	EN-GJS-	EN-GJS-	-
	Austenitic iron casting	FCA- FCDA-	L-, S-	FCA- FCDA-	Type 1, 2, Type D-2, D-3A Class 1, 2	F1, F2, S2W, S5S	GGL-, GGG-	L-, S-	-

Non-ferrous alloy

Type		Korea KS	ISO ISO	Japan JIS	U.S.A AISI SAE	Great Britain BS BS/EN	Germany DIN DIN/EN	France NF NF/EN	Russia GOCT
Aluminum alloy	Aluminum alloy ingots for casting	AC1B	Al-Cu4MgTi	AC1B	204.0	-	-	A-U5GT	
		AC2A	-	AC2A	-	-	-	-	
		AC2B	-	AC2B	319.0	-	-	-	
		AC3A	-	AC3A	-	LM-6	-	-	
		AC4A	-	AC4A	-	-	G(GK)-AlSi9Cu3	-	
		AC4B	-	AC4B	-	-	-	-	
		AC4C	Al-Si7Mg(Fe)	AC4C	356.0	LM-25	G(GK)-AlSi7MG	A-S7G	
		AC4CH	Al-Si7Mg	AC4CH	A356.0	-	-	-	
		AC4D	Al-Si5Cu1Mg	AC4D	355.0	LM-16	-	-	
		AC5A	Al-Cu4Ni2Mg2	AC5A	242.0	-	G(GK)-AlMg5	A-U4NT	
		AC7A	-	AC7A	514.0	LM-5	-	-	
		AC8A	-	AC8A	-	LM-13	-	A-S12UNG	
		AC8B	-	AC8B	-	LM-26	-	A-S10UG	
		AC8C	-	AC8C	-	-	-	A-S10UG	
		AC9A	-	AC9A	-	LM-29	-	-	
		AC9B	-	AC9B	-	-	GD-AlSi12 (Cu)	A-S18UNG	
	Aluminum alloy die casting	ALDC1	Al-Si12CuFe	ADC1	A413.0	LM20	GD-AlSi10Mg	A-S13	
		ALDC2	-	ADC3	A360.0	-	GD-AlMg9	A-S9G	
		ALDC3	-	ADC5	518.0	-	-	A-G6	
		ALDC4	-	ADC6	-	-	GD-AlSi9Cu3	A-G3T	
		ALDC7	Al-Si8Cu3Fe	ADC10	A380.0	-	GD-AlSi9Cu3	-	
		ALDC7Z	Al-Si8Cu3Fe	ADC10Z	A380.0	LM24	-	-	
		ALDC8	-	ADC12	383.0	LM2	-	-	
		ALDC8Z	-	ADC12Z	383.0	LM2	-	-	
		ALDC9	-	ADC14	B390.0	LM30	EN AW-5052	-	
	Aluminum alloy extruded shapes	A5052S	-	A5052S	5052	EN AW-5052	EN AW-5454	EN AW-5052	
		A5454S	-	A5454S	5454	EN AW-5454	EN AW-5083	EN AW-5454	
		A5083S	AlMg4.5Mn0.7	A5083S	5083	EN AW-5083	EN AW-5086	EN AW-5083	
		A5086S	-	A5086S	5086	EN AW-5086	EN AW-6061	EN AW-5086	
		A6061S	AlMg1SiCu	A6061S	6061	EN AW-6061	EN AW-6063	EN AW-6061	
		A6063S	AlMg0.7Si	A6063S	6063	EN AW-6063	EN AW-7003	EN AW-6063	
		A7003S	-	A7003S	-	EN AW-7003	-	EN AW-7003	
		A7N01S	-	A7N01S	-	-	EN AW-7075	-	
		A7075S	AlZn5.5MgCu	A7075S	7075	EN AW-7075		EN AW-7075	

Heat resistant steel

Type		Korea KS	ISO ISO	Japan JIS	U.S.A UNS	U.S.A AISI SAE	Great Britain BS BS/EN	Germany DIN DIN/EN	France NF NF/EN	Russia ГОСТ
Heat resistant steel	Austenitic	STR31		SUH31			331S42		Z35CNWS14-14	
		STR35		SUH35			349S52	X53CrMnNi21-9	Z52CMN21-09-Az	
		STR36		SUH36			349S54		Z55CMN21-09-Az	
		STR37		SUH37	S63008		381S34			
		STR38		SUH38	S63017					
		STR309		SUH309			309S24	CrNi2520	Z15CN24-13	
		STR310		SUH310	S30900		310S24		Z15CN25-20	
		STR330		SUH330	S31000	309			Z12NCS35-16	
		STR660		SUH660	N08330	310			Z6NCTV25-20	
		STR661		SUH661	S66286	N08330		CrAl1205		
	Ferritic	STR21		SUH21	R30155			X6CrTi12		
		STR409	X6CrTi12	SUH409			409S19		Z6CT12	
		STR409L	X2CrTi12	SUH409L	S40900				Z3CT12	
		STR446		SUH446		409		X45CrSi9-3	Z12C25	
	Martensitic	STR1		SUH1	S44600		401S45		Z45CS9	
		STR3		SUH3	S65007	446			Z40CSD10	
		STR4		SUH4			443S65		Z80CSN20-02	
		STR11		SUH11						
		STR600		SUH600						
		STR616		SUH616	S42200					

• The above Heat resistant steel can supplied by domestic manufacturing

Steel, Non-ferrous metal symbol list

Comparison of workpiece material standards

GROUP		STANDARD TERM	CODE
Structural Steel		Rolled Steel for Welded Suructure	SWS
		Rerolled Steel	SBR
		Rolled Steel for General Structure	SB
		Light Gauge Steel for General Structure	SBC
		Hot- rolled Steel Plate, Sheet/ Strip for Automobile Structural Use	SAPH
Steel Plate		Cold-rolled Steel Sheet/Strip	SBC
		Hot-rolled Soft Steel Sheet/Strip	SHP
Steel Pipe		Carbon Steel Pipe for Ordinary Piping	SPP
		Carbon Steel Pipe for Boiler and Heat Exchanger	STH
		Seamless Steel Pipe for High Pressure Gas Cylinder	STHG
		Carbon Steel Pipe for General Structural Use	SPS
		Carbon Steel Pipe for Machine Structural Use	STST
		Alloy Steel Pipe for Structural Use	STA
		Stainless Steel Pipe for Machine and Structural Use	STS-TK
		Carbon Steel Square Pipe for General Structural Use	SPSR
		Alloy Steel Pipe	SPA
		Carbon Steel Pipe for Pressure Service	SPPS
		Carbon Steel Pipe for High Temperature Service	SPSR
		Carbon Steel Pipe for High Pressure Service	SPPH
		Stainless Steel Pipe	STSxT
Iron and Steel		Carbon Steel for Machine Structural Use	SMxxC, SMxxCK
		Aluminum Chromium Molybdenum Steel	SACM
		Chromium Molybdenum Steel	SCM
		Chromium Steel	SCr
		Nickel Chromium Steel	SNC
		Nickel Chromium Molybdenum Steel	SNCM
		Manganese Steel and manganese Chromium Steel for Machine Structural Use	SMn, SMnC
Special steel	Tool steel	Carbon Tool Steel	STC
		Hollow Drill Steel	SKC
		Alloy Tool Steel	STS, STD, STF
		High Speed Tool Steel	SKH
	Stainless steel	Stainless Steel Bar	STS
	Heat resisting steel	Heat Resisting Steel	STR
		Heat Resisting Steel Bar	STR
		Heat Resisting Steel Sheet	STR
		Free cutting carbon steel	SUM
		Special steel	STB
		Spring steel	SPS

GROUP	STANDARD TERM	CODE
Forged steel	Carbon Steel Forging	SF
	Chromium Molybdenum Steel Forging	SFCM
	Nickel Chromium Molybdenum Steel Forging	SFNCM
Cast iron	Gray Cast iron	GC
	Spheroidal Graphite Cast iron	GCD
	Blackheart Malleable Cast iron	BMC
	Whiteheat Malleable Cast iron	WMC
	Pearlitic Malleable Cast iron	PMC
Cast steel	Carbon Cast Steel	SC
	High Tensile Strength Carbon Cast Steel&Low Alloy Cast Steel	HSC
	Stainless Cast Steel	SSC
	Heat Resisting Cast Steel	HRSC
	High Manganese Cast Steel	HMnSC
	Cast Steel for High Temperature and High Pressure Service	SCPH
Casting	Brass Casting	BsC
	High Strength Brass Casting	HBsC
	Bronze Casting	BrC
	Phosphoric Bronze Casting	PCB
	Aluminum Bronze Casting	AIBC
	Aluminum Alloy Casting	ACxA
	Magnesium Alloy Casting	MgC
	Zinc Alloy Die Casting	ZnDC
	Aluminum Alloy Die Casting	ADC
	Magnesium Alloy Die Casting	MgDC
	White Metal	WM
	Aluminum Alloy Casting for Bearing	AM
	Brass Alloy Casting for Bearing	KM

SI unit conversion table

Major SI unit conversion table

Force

N	kgf	dyn
1	1.01972×10^{-1}	1×10^{5}
9.80665	1	9.80665×10^{5}
1×10^{-5}	1.01972×10^{-6}	1

Stress

Pa or N/m^2	MPa or N/mm^2	kgf/mm^2	kgf/cm^2	kgf/m^2
1	1×10^{-6}	1.01972×10^{-7}	1.01972×10^{-5}	1.01972×10^{-1}
1×10^{6}	1	1.01972×10^{-1}	1.01972×10	1.01972×10^{5}
9.80665×10^{6}	9.80665	1	1×10^{2}	1×10^{6}
9.80665×10^{4}	9.80665×10^{-2}	1×10^{-2}	1	1×10^{4}
9.80665	9.80665×10^{-6}	1×10^{-6}	1×10^{-4}	1

Pressure

Pa	kPa	MPa	bar	kgf/cm^2
1	1×10^{-3}	1×10^{-6}	1×10^{-5}	1.01972×10^{-5}
1×10^{3}	1	1×10^{-3}	1×10^{-2}	1.01972×10^{-2}
1×10^{6}	1×10^{3}	1	1×10	1.01972×10
1×10^{5}	1×10^{2}	1×10^{-1}	1	1.01972
9.80665×10^{4}	9.80665×10	9.80665×10^{-2}	9.80665×10^{-1}	1

Work, Energy, Calorie

J	kW·h	kgf·m	kcal
1	2.77778×10^{-7}	1.01972×10^{-1}	2.38889×10^{-4}
3.60000×10^{6}	1	3.67098×10^{5}	8.60000×10^{2}
9.80665	2.72407×10^{-6}	1	2.34270×10^{-3}
4.18605×10^{3}	1.16279×10^{-3}	4.26858×10^{2}	1

Power

W	kW	kgf·m/s	PS	kcal/h
1	1×10^{-3}	1.01972×10^{-1}	1.35962×10^{-3}	0.860
1×10^{3}	1	1.01972×10^{2}	1.359 62	8.60000×10^{2}
9.81 65	9.80665×10^{-3}	1	1.33333×10^{-2}	8.433 71
7.355×10^{2}	7.355×10^{-1}	7.5×10	1	6.32529×10^{2}
1.162 79	1.16279×10^{-3}	1.18572×10^{-1}	1.58095×10^{-3}	1

Specific heat

J/(kgK)	kcal/(kg°C) cal/(g°C)
1	2.38889×10^{-4}
4.18605×10^{3}	1

Thermal conductivity

W/(mk)	kcal/(hm°C)
1	8.6000×10^{-1}
1.16279	1

Revolution per minute

min^{-1}	s^{-1}	r.p.m.
1	0.0167	1
60	1	60

Hardness calculating table

Work piece hardness calculating table

Vickers 50kgf HV	Brinell, 3000kgf HB: Standard ball 10mm	Brinell, 3000kgf HB: Cemented carbide ball 10mm	Rockwell: A scale 60kgf Diamond particle HRA	Rockwell: B scale 100kgf 1/16in ball HRB	Rockwell: C scale 150kgf Diamond particle HRC	Rockwell: D scale 100kgf Diamond particle HRD	Shore HS	Tensile strength (approximate value) MPa(1)
940	-	-	85.6	-	68.0	76.9	97	
920	-	-	85.3	-	67.5	76.5	96	
900	-	-	85.0	-	67.0	76.1	95	
880	-	(767)	84.7	-	66.4	75.7	93	
860	-	(757)	84.4	-	65.9	75.3	92	
840	-	(745)	84.1	-	65.3	74.8	91	
820	-	(733)	83.8	-	64.7	74.3	90	
800	-	(722)	83.4	-	64.0	74.8	88	
780	-	(710)	83.0	-	63.3	73.3	87	
760	-	(698)	82.6	-	62.5	72.6	86	
740	-	(684)	82.2	-	61.8	72.1	84	
720	-	(670)	81.8	-	61.0	71.5	83	
700	-	(656)	81.3	-	60.1	70.8	81	
690	-	(647)	81.1	-	59.7	70.5	-	
680	-	(638)	80.8	-	59.2	70.1	80	
670	-	630	80.6	-	58.8	69.8	-	
660	-	620	80.3	-	58.3	69.4	79	
650	-	611	80.0	-	57.8	69.0	-	
640	-	601	79.8	-	57.3	68.7	77	
630	-	591	79.5	-	56.8	68.3	-	
620	-	582	79.2	-	56.3	67.9	75	
610	-	573	78.9	-	55.7	67.5	-	
600	-	564	78.6	-	55.2	67.0	74	
590	-	554	78.4	-	54.7	66.7	-	2055
580	-	545	78.0	-	54.1	66.2	72	2020
570	-	535	77.8	-	53.6	65.8	-	1985
560	-	525	77.4	-	53.0	65.4	71	1950
550	(505)	517	77.0	-	52.3	64.8	-	1905
540	(496)	507	76.7	-	51.7	64.4	69	1860
530	(488)	497	76.4	-	51.1	63.9	-	1825
520	(480)	488	76.1	-	50.5	63.5	67	1795
510	(473)	479	75.7	-	49.8	62.9	-	1750
500	(465)	471	75.3	-	49.1	62.2	66	1705
490	(456)	460	74.9	-	48.4	61.6	-	1660
480	488	452	74.5	-	47.7	61.3	64	1620
470	441	442	74.1	-	46.9	60.7	-	1570
460	433	433	73.6	-	46.1	60.1	62	1530
450	425	425	73.3	-	45.3	59.4	-	1495
440	415	415	72.8	-	44.5	58.8	59	1460
430	405	405	72.3	-	43.6	58.2	-	1410
420	397	397	71.8	-	42.7	57.5	57	1370
410	388	388	71.4	-	41.8	56.8	-	1330
100	379	379	70.8	-	40.8	56.0	55	1290
390	369	369	70.3	-	39.8	55.2	-	1240
380	360	360	69.8	(100.0)	38.8	54.4	52	1205
370	350	350	69.2	-	39.9	53.6	-	1170
360	341	341	68.7	(109.0)	36.6	52.8	50	1130
350	331	331	68.1	-	35.5	51.9	-	1095
340	322	322	67.6	(108.0)	34.4	51.1	47	1070
330	313	313	67.0	-	33.3	50.2	-	1035
320	303	303	66.4	(107.0)	32.2	49.4	45	1005
310	294	294	65.8	-	31.0	48.4	-	980
300	284	284	65.2	(105.5)	29.8	47.5	42	950
295	280	280	64.8	-	29.2	47.1	-	935
290	275	275	64.5	(104.5)	28.5	46.5	41	915
285	270	270	64.2	-	27.8	46.0	-	905
280	265	265	63.8	(103.5)	27.1	45.3	40	890
275	261	261	63.5	-	26.4	44.9	-	875
270	256	256	63.1	(102.0)	25.6	44.3	38	855
265	252	252	62.7	-	24.8	43.7	-	840
260	247	247	62.4	(101.0)	24.0	43.1	37	825
255	243	243	62.0	-	23.1	42.2	-	805
250	238	238	61.6	99.5	22.2	41.7	36	795
245	233	233	61.2	-	21.3	41.1	-	780
240	228	228	60.7	98.1	20.3	40.3	34	765
230	219	219	-	96.7	(18.0)	-	33	730
220	209	209	-	95.0	(15.7)	-	32	695
210	200	200	-	93.4	(13.4)	-	30	670
200	190	190	-	91.5	(11.0)	-	29	635
190	181	181	-	89.5	(8.5)	-	28	605
180	171	171	-	87.1	(6.0)	-	26	580
170	162	162	-	85.0	(3.0)	-	25	545
160	152	152	-	81.7	(0.0)	-	24	515
150	143	143	-	78.7	-	-	22	490
140	133	133	-	75.0	-	-	21	455
130	124	124	-	71.2	-	-	20	425
120	114	114	-	66.7	-	-	-	390
110	105	105	-	62.3	-	-	-	-
100	95	95	-	56.2	-	-	-	-
95	90	90	-	52.0	-	-	-	-
90	86	86	-	48.0	-	-	-	-
85	81	81	-	41.0	-	-	-	-

Note1.) Gothic number is ASTM E 1 in the list 140

Note2.) 1. 1MPa=1N/㎟

2. The number In the blank is not generally used ranges.

Properties of Korloy grades

Physical properties of Korloy grades

Application		ISO Classification symbol	Korloy grades	Specific gravity (g/cm³)	Hardness (HRA)	TRS (kgf/mm²)	Compressive strength (kg/mm²)	Young's modulus (103kgf/mm²)	Thermal expansion coefficient (10^{-6}/°C)	Thermal conductivity (cal/cm·sec·°C)
Grades for cutting tools	P	P01	ST05E	10.6	92.7	140	440	-	-	-
		P10	ST10P	10.0	92.1	175	460	48	6.2	25
		P20	ST20E	11.8	91.9	200	480	56	5.2	42
		P30	A30	12.2	91.3	230	500	53	5.2	-
	M	M10	U10E	12.9	92.4	170	500	47	-	-
		M20	U2	13.1	91.1	210	500	-	-	88
		M30	A30	12.2	91.3	230	500	53	5.2	-
		M40	A40	13.3	89.2	270	440	-	-	-
	K	K01	H2	14.8	93.2	185	-	61	4.4	105
		K10	H01	13.0	92.9	210	570	66	4.7	109
		K20	G10E	14.7	90.9	250	500	63	-	105
Ultra fine grain alloy	Z	Z10	FA1	14.1	91.4	290	-	58	5.7	-
		Z20	FCC	12.5	91.3	235	-	-	-	-
Grade for tungsten carbide wear parts	V	V1	D1	15.0	92.3	205	520	-	-	-
		V2	D2	14.8	90.9	250	150	-	-	-
		V3	D3	14.6	89.7	310	410	-	-	-
		V4	G5	14.3	89.0	320	380	-	-	-
		V5	G6	14.0	87.7	350	330	-	-	-
Grade for mining and civil engineering tools	E	E1	GR10	14.8	90.9	220	-	-	-	-
		E2	GR20	14.8	90.3	240	-	-	-	-
		E3	GR30	14.8	89.0	270	-	-	-	-
		E4	GR35	14.8	88.2	270	-	-	-	-
		E5	GR50	14.5	87.0	300	-	-	-	-

The physical properties of element

Element	Specific gravity (g/cm³)	Hardness (Hv)	Young's modulus (×103kgf/mm²)	Thermal conductivity (cal/cm·sec·°C)	Thermal expansion coefficient (×10^{-6}/°C)	Melting point (°C)
WC	15.6	2,150	70	0.3	5.1	2,900
TiC	4.94	3,200	45	0.04	7.6	3,200
TaC	14.5	1,800	29	0.05	6.6	3,800
NbC	8.2	2,050	35	0.04	6.8	3,500
TiN	5.43	2,000	26	0.07	9.2	2,950
Al_2O_3	3.98	3,000	42	0.07	8.5	2,050
cBN	3.48	4,500	71	3.1	4.7	-
Diamond	3.52	9,000	99	5.0	3.1	-
Co	8.9	-	10~18	0.165	12.3	1,495
Ni	8.9	-	20	0.22	13.3	1,455

Technical information for Stainless steel

Guide of stainless-steel machining

▶ Stainless steels are well known for their excellent anti-corrosive property.
▶ Excellent anti-corrosive property is due to the Chromium added to these alloys. In general, stainless steels have 4%~10% Chromium content .

● Classifications & Features of Stainless steel.

1) Austenite series : One of the most general kinds of stainless steels, it has some of the best corrosion-resistance properties due to a high Cr & Ni content. A high Nickel content also makes machining more difficult. Austenite series stainless steels are usually used for can processing, chemical products and construction purposes. (AISI 303,304,316)
2) Ferrite series : It has Chromium content similar to Austenite series, but none of the Ni content which results in freer machining. (AISI 410,430,434)
3) Martensite series : The only stainless steel with the ability to be heat treated. It has a high carbon content but poor corrosion resistance, so it is used for parts that need higher hardness. (AISI410, 420,432)
4) Precipitate hardened series : A Chromium-Nickel alloy, it has improved hardness through low temperature heat-treatment and has superior corrosion resistance and toughness at the same time. (AISI 17, 15)
5) Austenite-Ferrite series : Though it has similar properties with Austenite and Ferrite, it has much more superior heat-resistance (approx. 2 times better). Usually used where thermal-corrosion stability is needed, such as condensers (AISI S2304, 2507).

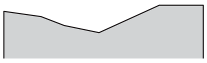
● Difficult-to-Cut Factors of Stainless steel.

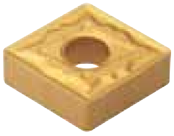
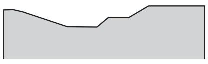
1) Work-hardening property - Causes premature wear of tool and poor control chip.
2) Low thermal conductivity - Causes plastic deformation of cutting edge and fast wear of tools.
3) Built-up-edge - More susceptible to micro-chipping on cutting edges and causes bad surface-finish.
4) Chemical affinity between tool and workpiece caused by work-hardening and low thermal-conductivity of workpiece, this might generate abnormal-wear, chipping and/or abnormal fracture.

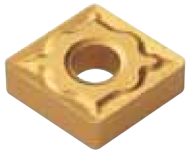
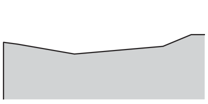
● Tips for Machining of Stainless steel.

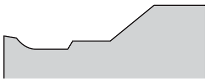
1) Use a tool that has higher thermal-conductivity
   Low thermal-conductivity of stainless steels accelerates tool wear resulting from a decline in hardness of the cutting edge of an insert, this is due to heat piling up. It is better to use a tool that has higher thermal conductivity and with enough coolant.
2) Sharper cutting edge-line
   It is necessary to utilize larger rake-angles and wider chip-breaker lands to reduce cutting-load pressure and prevent build-up-edge. This will help provide better chip control.
3) Optimal cutting condition
   Inappropriate machining conditions like extremely low or high-speeds or low feed rates can cause poor tool life due to work-hardening of work piece.
4) Choose an appropriate tool
   Tools for stainless steels should have good toughness attributes, enough strength on their edge-line (cutting edge) & a higher film adhesion.

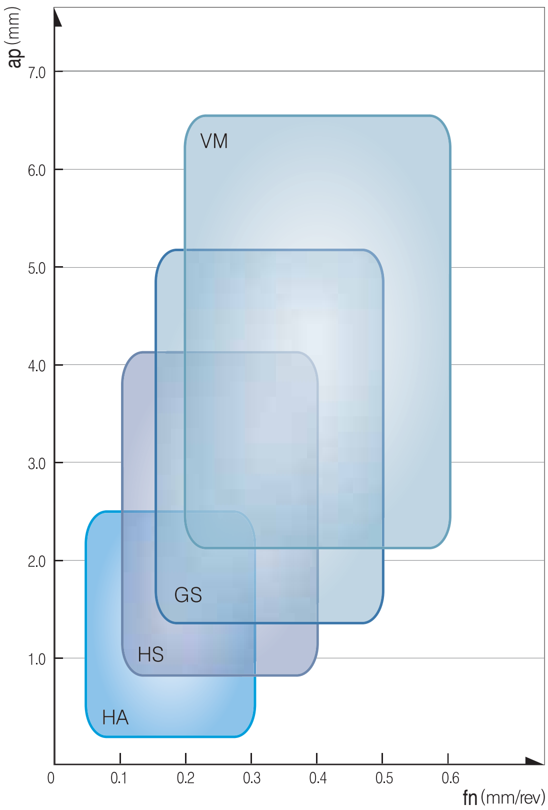
Chip Breakers for Stainless steel

HA / Finishing		
		• Sharp edge for shallow depth cutting • Increase tool life through reduced chip control friction at high speed cutting • Good surface finish of work piece

HS / Medium cutting		
		• Enhanced cutting efficiency and increase tool life due to enhanced chip flow. • Reinforced wear resistance through adopting a high land rake angle. • Special land design to prevent notching and enhance toughness

GS / Medium to Rough cutting		
		• Superior tool life at light intermittent cutting • Better chip flow through wide chip pocket • Prevent build-up-edge by low cutting force design

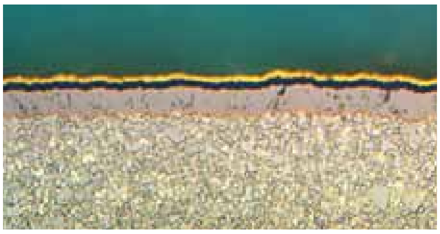
VM / Roughing		
		• Chip breaker for intermittent cutting • Unique chip breaker design provide smooth chip control. • Strong edge line permit superior toughness



Korloy's New Grades for Stainless steel machining.

▶ KORLOY New Grades for Stainless steel machinig

NC9020, For high speed turning of Stainless steel.



▶ Specially designed substrate & film suitable for high-speed machining of stainless steels.
▶ Superior cutting performance under conditions in moderate-speed applications for cutting low-carbon steels and low-carbon alloy steel
▶ Longer tool-life can be achieved thanks to a superior chipping-resistance design in the grade.
▶ Obtain better cutting performance. Korloy offers a variety of combinations of chip breakers to machine easily even in deeper depth of cut.

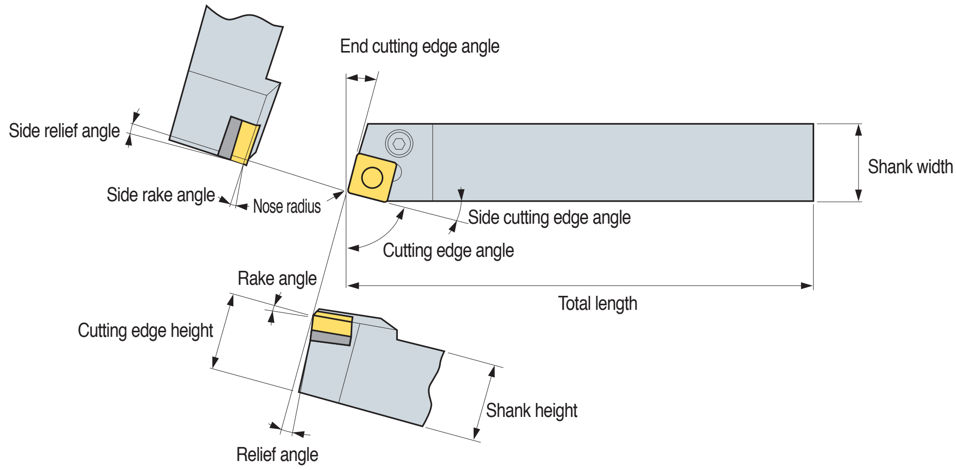
PC9030, for medium to low speed turning of Stainless steel.

▶ By using an ultra fine carbide substrate, the PC9030 has a tougher substrate for moderate speed machining and intermittent cutting of Stainless steel
▶ A PVD coating is applied to this grade to enhance chipping-resistance and adhesion-resistance during machining of difficult-to-cut material
▶ Exclusive grade for stainless steel, using tougher carbide as a substrate and a PVD coated, this gives the insert superior lubrication properties.
▶ Enhance your surface finish and reduce burrs by utilizing our chip-breakers, exclusively made for Stainless steels.

PC9530, for medium to low speed milling of Stainless steel.

▶ Tough ultra-fine carbide substrate primarily used for roughing and/or intermittent milling applications in stainless steel
▶ A PVD coating is applied to achieve better tool life in stainless steel and Ni-Cr steel applications.
▶ To reduce chipping in the cutting edge Korloy uses a tough carbide substrate and PVD coating to help prevent material build up around the cutting edges.

Insert shape and terminology

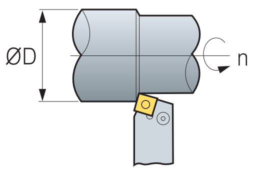


Relating angles between tool and workpiece

Cutting edge inclination	Terminology	Function	Effect
Rake angle	Side rake angle Rake angle	• Cutting force, Cutting heat, The effects of chip control on tool life	• (+) : Excellent machine-ability (reducing cutting force, weakening cutting edge strength) • (+) : When machining excellent machine-ability or thin workpiece. • (-) : When strong cutting edge is needed at interrupted condition or mill scale.
Relief angle	Relief angle Side relief angle	• Only cutting edge contact with cutting face	• (-) : Cutting edge is strong but has short tool life to make bad influence on flank wear.
Cutting edge angle	Cutting edge angle	• Affects chip control and cutting force direction	• (+) : Improved chip control because chip thickness is big.
	Side cutting edge angle	• Affects chip control and cutting force direction	• (+) : Strong cutting edge due to distributed cutting force but chip control is bad by thin chip thickness • (-) : Improved chip performance.
	End cutting edge angle	• Prevent friction between cutting edge and cutting face	• (-) : Cutting edge is strong but has short tool life to make bad influence on flank wear.

Calculation formulas for machining

Cutting speed



$$vc = \frac{\pi \times D \times n}{1000} \text{ (m/min)}$$

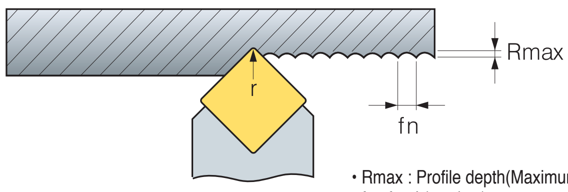
• vc : Cutting speed (m/min)
• D : Diameter (mm)
• n : Revolution per minute (min^{-1})
• π : Circular constant(3.14)

Feed

$$fn = \frac{vf}{n} \text{ (mm/rev)}$$

• fn : Feed per revolution(mm/rev)
• vf : Table feed (mm/min)
• n : Revolution per minute (min^{-1})

Surface finish



• Rmax : Profile depth(Maximum height roughness) (μ)
• fn : feed (mm/rev)
• r : nose radius

• Theoretical surface roughness

$$Rmax = \frac{fn^2}{8r} 1000 (\mu m)$$

• Practical surface roughness

Steel : Rmax × (1.5~3)
Cast iron : Rmax × (3~5)

Power requirement

$$P_{kw} = \frac{Q \times kc}{60 \times 102 \times \eta} \qquad P_{HP} = \frac{P_{KW}}{0.75} \qquad Q = \frac{vc \times fn \times ap}{1000}$$

• PKW : Power requirement [kW]
• PHP : Power requirement (horse power) [HP]
• vc : Cutting speed [m/min]
• ap : Depth of cut [mm]
• fn : Feed per revolution [mm/rev]
• kc : Specific cutting resistance [kg/mm²]
• η : Machine efficiency rate (0.7~0.8)

Rough Kc	
Mild steel	190
Medium carbon steel	210
High carbon steel	240
Low alloy steel	190
High alloy steel	245
Cast iron	93
Malleable cast iron	120
Bronze, Brass	70

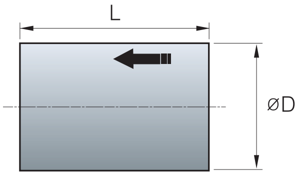
Material removal rate

$$Q = \frac{vc \times fn \times ap}{1000}$$

• Q : Material removal rate [㎤/min]
• ap : Depth of cut [mm]
• vc : Cutting speed [m/min]
• fn : Feed per revolution [mm/rev]

Machining time

External face machining 1



Constant Revolution per minute

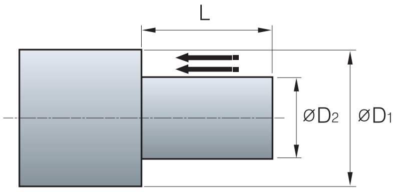
$$T = \frac{60 \times L}{fn \times n}$$

Constant cutting speed

$$T = \frac{60 \times \pi \times L \times D}{1000 \times fn \times vc}$$

- T : Machining time [sec]
- L : Cutting length [mm]
- fn : Feed per revolution [mm/rev]
- n : Revolution per minute [min]
- D : Diameter of workpiece [mm]
- vc : Cutting speed [m/min]

External face machining 2



Constant Revolution per minute

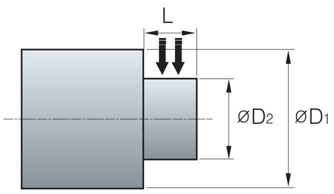
$$T = \frac{60 \times L}{fn \times n} \times N$$

Constant cutting speed

$$T = \frac{60 \times \pi \times L \times (D_1 + D_2)}{2 \times 1000 \times fn \times vc} \times N$$

- T : Machining time [sec]
- L : Cutting length [mm]
- fn : Feed per revolution [mm/rev]
- n : Revolution per minute [min]
- D1 : Maximum diameter of workpiece [mm]
- D2 : Minimum diameter of workpiece [mm]
- vc : Cutting speed [m/min]
- N : The number of pass = (D1-D2)/d/2

Facing



Constant Revolution per minute

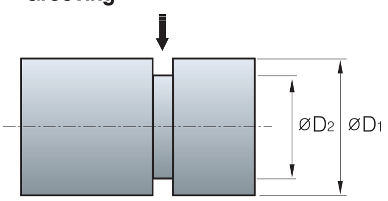
$$T = \frac{60 \times (D_1 - D_2)}{2 \times fn \times n} \times N$$

Constant cutting speed

$$T_1 = \frac{60 \times \pi \times (D_1 + D_2) \times (D_1 - D_2)}{4000 \times fn \times vc} \times N$$

- T : Machining time [sec]
- T1 : Machining time before the maximum rpm[sec]
- L : Width of machining [mm]
- fn : Feed per revolution [mm/rev]
- n : Revolution per minute [min-1]
- D1 : Maximum diameter of workpiece [mm]
- D2 : Minimum diameter of workpiece [mm]
- vc : Cutting speed [m/min]
- N : The number of pass = (D1-D2)/d/2

Grooving



Constant Revolution per minute

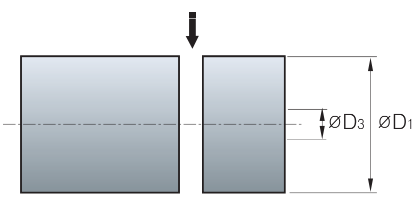
$$T = \frac{60 \times (D_1 - D_2)}{2 \times fn \times n}$$

Constant cutting speed

$$T_1 = \frac{60 \times \pi \times (D_1 + D_2) \times (D_1 - D_2)}{4000 \times fn \times vc}$$

- T : Machining time [sec]
- T1 : Machining time before the maximum rpm[sec]
- L : Width of machining [mm]
- fn : Feed per revolution [mm/rev]
- n : Revolution per minute [min-1]
- D1 : Maximum diameter of workpiece [mm]
- D2 : Minimum diameter of workpiece [mm]
- vc : Cutting speed [m/min]

Parting



Constant Revolution per minute

$$T = \frac{60 \times D_1}{2 \times fn \times n}$$

Constant cutting speed

$$T_1 = \frac{60 \times \pi \times (D_1 + D_3)\ (D_1 - D_3)}{4000 \times fn \times vc}$$

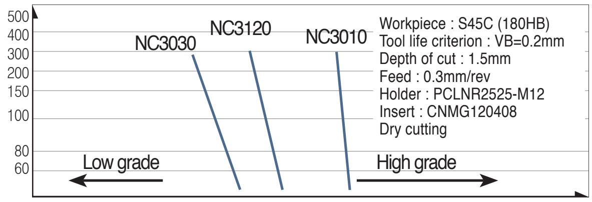
$$T_3 = T_1 + \frac{60 \times D_3}{2 \times fn \times n_{max}}$$

- T : Machining time [sec]
- T1 : Machining time before the maximum rpm[sec]
- T3 : Machining time till maximum RPM[sec]
- fn : Feed per revolution [mm/rev]
- n : Revolution per minute [min-1]
- nmax : Maximum revolution per minute [min-1]
- D1 : Maximum diameter of workpiece [mm]
- D3 : Maximum diameter at maximum RPM [mm]
- vc : Cutting speed [m/min]

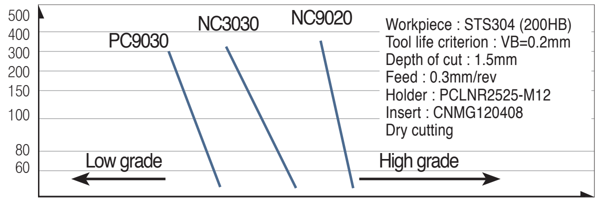
The affects of cutting condition

▶ The most desirable machining means short machining time, long tool life and good precision. This is the reason that proper cutting condition for each tools should be selected according to material's properties, hardness, shapes, the efficiency of machine.

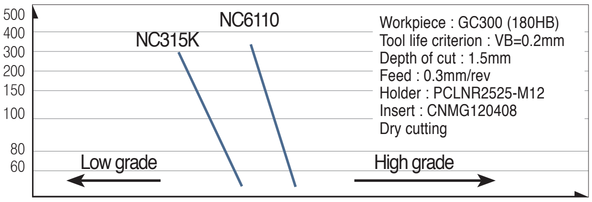
Cutting speed



The tool life feature of P grade



The tool life feature of M grade



The tool life feature of K grade

Cutting Speed's effects

▶ When the cutting speed increases up to 20% in an application, the tool life respectively decreases down 50%. Although inversely, if the cutting speed increases up to 50% the tool life decreases 20%. On the other hand if cutting speed is too low (20-40m/min) Tool life shortens due to vibration.

Feed

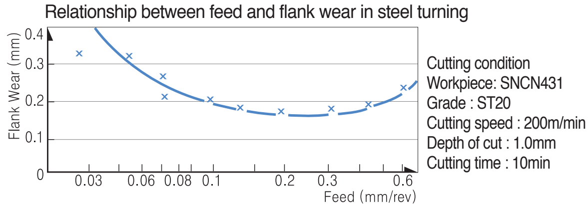
▶ The feed rate in turning means the progressed interval of a distance in a work piece within 1 revolution. The feed rate in a milling application means the table feed divided by number of teeth of cutter (feed rate per tooth).

The effects of feed

▶ When the feed rate decreases the flank wear is increased. When the feed rate is too low, the tool life shortens radically.

▶ When the feed rate increases, the flank wear increases due to high temperatures, however the feed rates effects tool life less than the cutting speed. And higher feed rates improve machining efficiency.

Relationship between feed and flank wear in steel turning



Depth of cut

▶ Determined by the required allowances in machining a material and the capacity the machine can tolerate. There are cutting limits according to the different shapes and sizes of the insert.

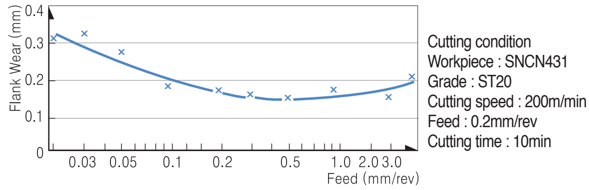
The effect of a depth of cut

▶ The depth of cut does not have a big influence on tool life.

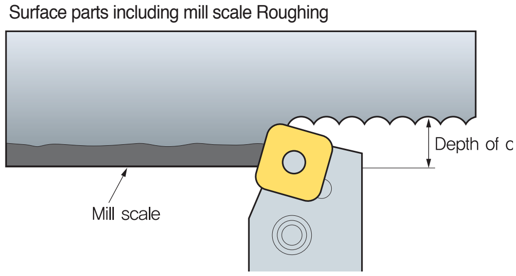
▶ When the depth of cut is small the work piece is not cut but rather rubbed. In these cases, machine off the work hardened parts that decrease tool life.

▶ When machining a cast skin or milling scale smaller depth of cuts usually cause chipping and abnormal wear because of hard impurities in the surface of the work piece.

Relationship between depth of cut and flank wear in steel turning



Surface parts including mill scale Roughing



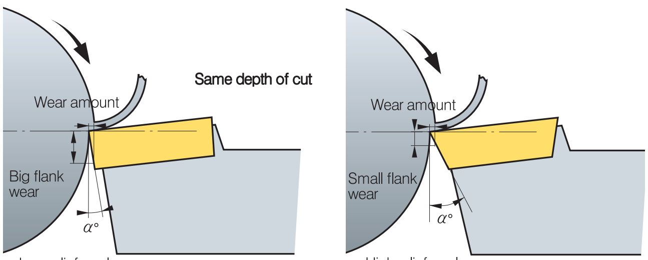
General Information

L

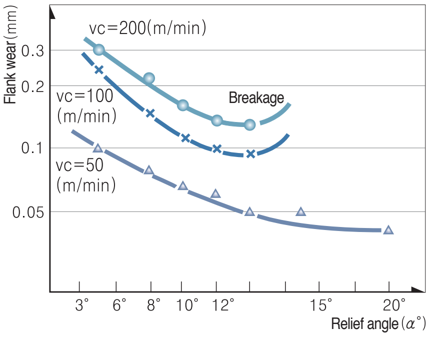
Relief angle

Relief angle avoids the friction between workpiece and relief face and makes cutting edge move along workpiece easily.

Relationship between various relief angle and flank wear



Low relief angle High relief angle



- Workpiece : SNCM431(HB200)
- Grade : P20
- ap : 1mm
- fn : 0.32mm/rev
- T : 20min

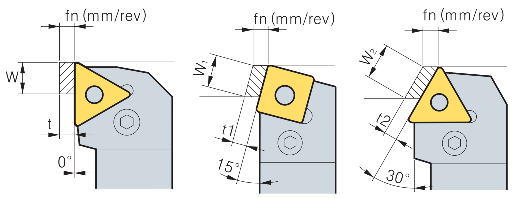
- Affects
  1. If relief angle is big Flank wear decreases.
  2. If relief angle is big Cutting edge strength weakens.
  3. If relief angle is small Chattering occurs .

- Selection system
  1. Hard workpiece / When strong cutting edge is needed - Low relief angle
  2. Soft workpiece / Workpiece turning to work hardening easily - High relief angle

Side cutting edge angle

Side cutting edge angle has big influence on chip flow and cutting force therefore proper Side cutting edge angle is very important.

Side cutting edge angle and Chip thickness

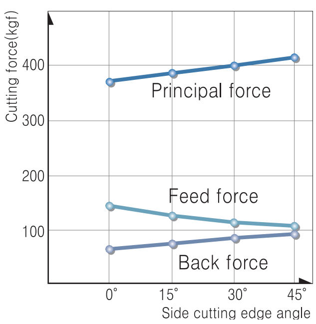


① Approach angle 0˚ ② Approach angle 15˚ ③ Approach angle 30˚

As side cutting edge angle is getting bigger chips are getting thinner and wider(refer to left picture).
At the same feed and depth of cut with approach angle 0˚
Chip thickness is the same as feed(t=fn) and chip width is equal to depth of cut (W=ap).

t1 = 0.97t, W1 = 1.04W
t2 = 0.87t, W2 = 1.15W

Side cutting edge angle and 3 cutting forces

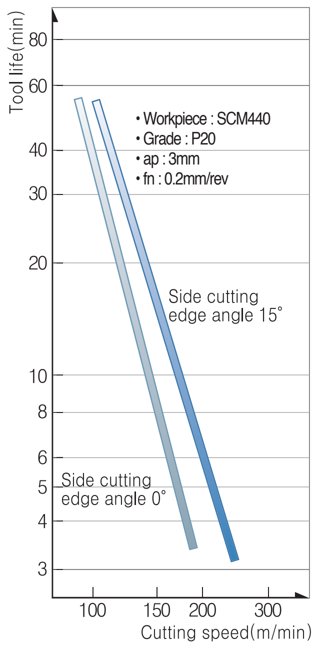


- Workpiece : SCM440(HB250)
- Grade : TNGA220412
- vc= 100m/min
- ap= 4mm
- fn= 0.45mm/rev

- Affects
  1. Big side cutting edge angle with the same feed makes chip attaching length longer and chip thickness thinner. So that cutting forces scatter to long cutting edge therefore tool life gets longer.
  2. Big side cutting edge angle for machining long bars can cause bending.

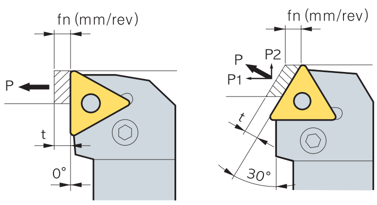
- Selection system
  1. Deep depth of cut finishing / Long thin workpiece / Low machine rigidity - Side cutting edge angle
  2. Hard and high calorific power workpiece / Roughing big workpiece / High machine rigidity - Side cutting edge angle

Side cutting edge angle and Tool life



- Workpiece : SCM440
- Grade : P20
- ap : 3mm
- fn : 0.2mm/rev

Side cutting edge angle and Cutting load



① "Force P is loaded." ② "Force P is scattered to P1, P2."

As approach angle gets bigger Back force gets bigger and feed force gets smaller.

Side cutting edge angle and Cutting performance

Specification	Low ← Approach angle → High	
Wear rate	High	Low
Workpiece	Easy to cut material	Difficult to cut material
Machining power	Small	Big
Chatter	Hard to occur	Easy to occur
How to machine	Finishing	Roughing
Workpiece rigidity	Long thin workpiece	Thick workpiece
Machine rigidity	In case of low rigidity	In case of high rigidity

End cutting edge angle

It affects machined surface to prevent interference between surface of workpiece and insert.

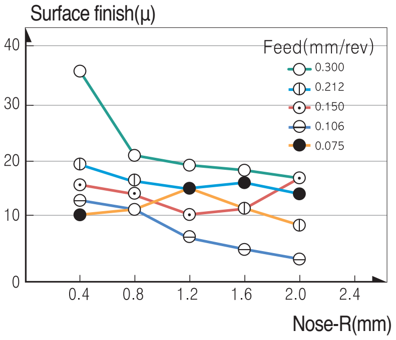
Affects

1. If end cutting edge angle reduces cutting edge get stronger but cutting heat generated by machining increases.
2. Small end cutting edge angle can cause chattering due to the increases cutting force.

Nose-R

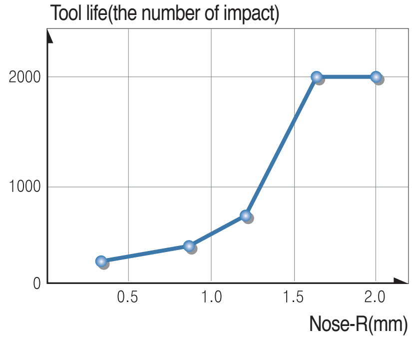
1. Nose-R affects not only surface roughness but strength of cutting edge.
2. In general, It's desirable that Nose-R is 2~3 times bigger than feed.

Nose R and surface finish



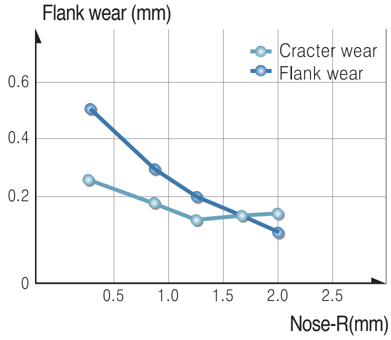
- Workpiece : SNCM439, HB200
- Grade : P20
- vc = 120m/min, ap = 0.5mm

Nose R and tool life



- Workpiece : SCM440, HB280
- Grade : P10
- vc = 100m/min, ap = 0.5mm
- fn = 0.3mm/rev

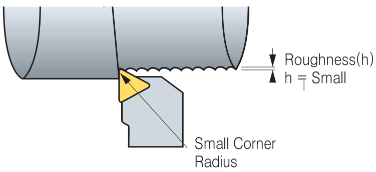
Nose R and wear of tool



- Workpiece : SNCM439, HB200
- Grade : P10
- vc = 140m/min, ap = 2mm
- fn = 0.2mm/rev, T = 10min

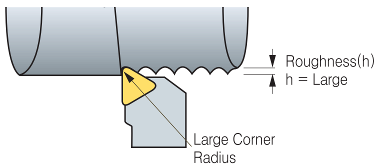
Affects of Nose-R

1. Big Nose-R improves surface finish.
2. Big Nose-R improves cutting edge strength.
3. Big Nose-R reduces flank wear and crater wear.
4. Too big Nose-R causes chattering due to increased cutting force.

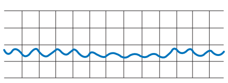
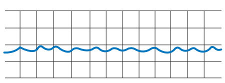
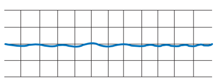
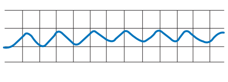
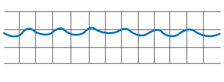
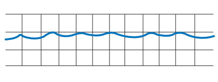
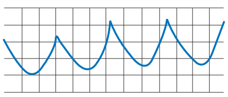
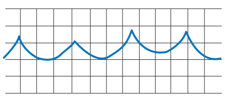
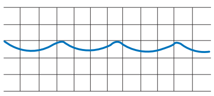


Selection system

1. For finishing with small depth of cut / long and thin workpiece / When machine power is low - Small Nose-R
2. For applications that need strong cutting edge such as intermittent and machining mill scale / For roughing of big workpiece / When the machine power is strong eough - Big Nose-R



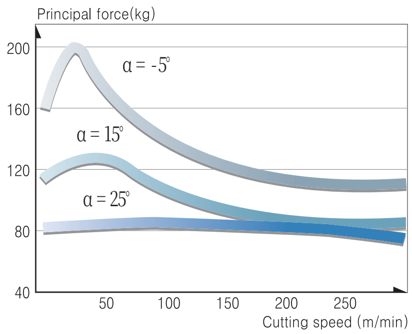
Relationship between nose radius, feed and various surface roughness.

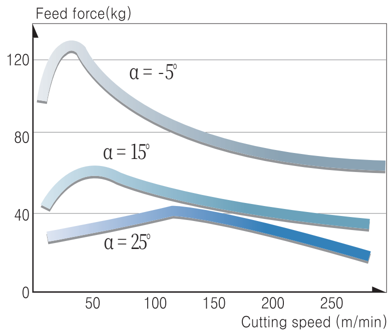
Nose "R" / Feed(mm/rev)	0.4	0.8	1.2
0.15			
0.26			
0.46			

Cutting edge shape and the affects

Rake angle

Rake angle has big influence on cutting force, chip flow and tool life.





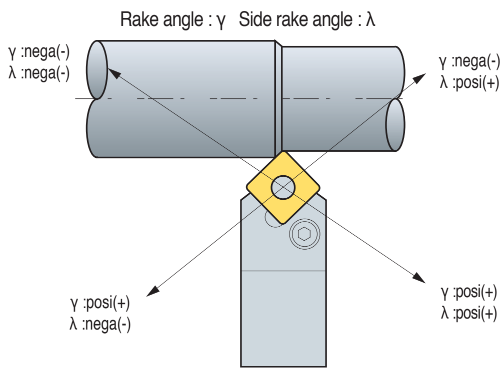
· Affects

1. High rake angle results in good suface finish.
2. As the rake angle increases by 1° Machining power decreases by 1%.
3. High rake angle weakens cutting edge.

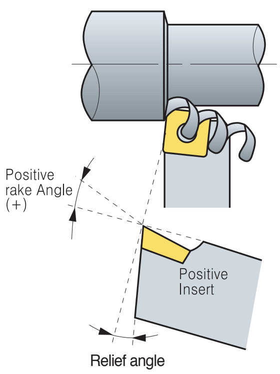
· Selection system

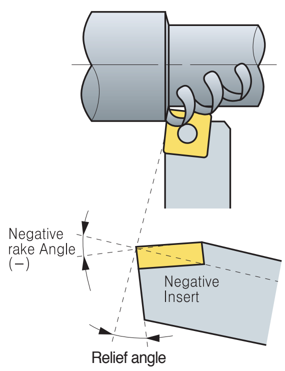
1. For hard workpiece / For applications that need strong cutting edge such as interrupted and machining mill scale
   - Low rake angle
2. For soft workpiece / Easy to cut material / When the rigidity of machine power and workpiece is low - High rake angle

Rake angle and the direction of chip flow



In order to prevent machined surface from damages Avoid nega, posi combination. γ :nega(-) λ :posi(+)





Selecting proper tools

Nowadays, It's very difficult to select the best tools in complicating tooling system and various cutting conditions.
However, It can be simplified by classifying basic factors below.

Selection of inserts and tool holder

Listed below is the basic factors and choose B according to A.

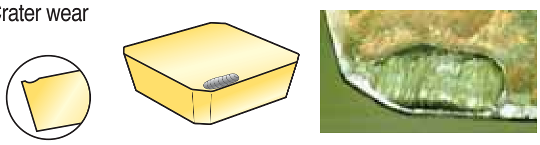
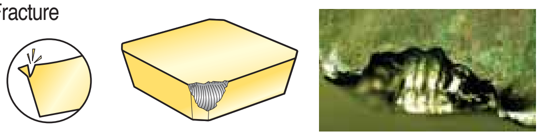
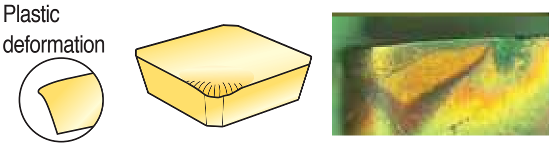
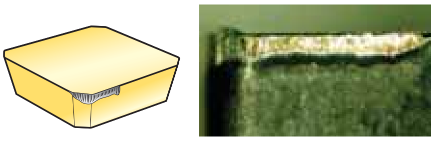
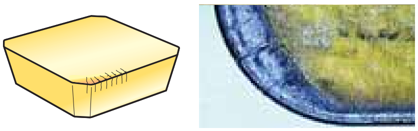
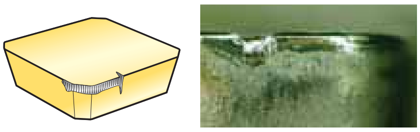
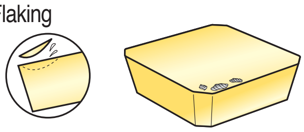
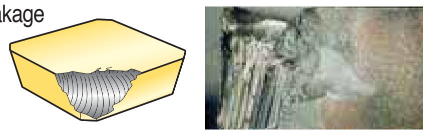
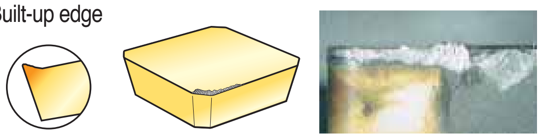
A : Basic factors

· Workpiece material
· Workpiece shape
· Workpiece size
· Hardness of workpiece
· Surface roughness of workpiece (before machining)
· Surface finish required
· Type of lathe machine
· Condition of lathe machine (rigidity, power etc)
· Horse power of machine
· Clamping method of workpiece

B : Selection system

① Select as big approach angle as possible.
② Select as big shank as possible.
③ Select as strong cutting edge of insert as possible
④ Select as big nose radius as possible
⑤ In finishing, Select the insert using many corners
⑥ Select as small insert as possible
⑦ Cutting speed should be determined carefully according to cutting conditions
⑧ Select as deep depth of cut as possible
⑨ Select as fast feed as possible
⑩ Cutting condition should be determined within chip breaker application ranges.

Trouble shooting

Tool Failure	Cause	Solution
Crater wear 	• Improper grade • Excessive cutting condition	• Choose harder grade • Decrease cutting condition
Fracture 	• Improper grade • Excessive feed • Shorten cutting edge strength • Insufficient rigidity of holder	• Choose tougher grade • Decrease feed • Apply to large honed or chamfered edge • Choose bigger size holder
Plastic deformation 	• Improper grade • Excessive cutting condition • High cutting temperature	• Choose harder grade • Decrease cutting condition • Choose grade wich heat conductivity are big
Wear on nose radius (Flank wear) 	• When the hardness of workpiece is too high compare with tool • When machinig surface hardened workpiece • Improper grade • Excessive cutting speed • Too small relief angle • Too low feed	• Choose harder grade • Decrease cutting speed • Choose lager relief angle • Increase feed
Thermal crack 	• Expansion and shrinking by cutting temperature • Improper grade (*Specially milling operation)	• Apply to dry cutting (In case of wet cutting, use enough coolant) • Choose tougher grade
Chipping 	• Improper grade • Excessive feed • Shorten cutting edge strength • Insufficient rigidity of holder	• Choose tougher grade • Decrease feed • Apply to large honing or chamfer edge • Choose bigger size holder
Notch wear 	• Surface hardened workpiece • Friction due to bad chip geometry (Generate vibration)	• Choose harder grade • Improve chip control form large rake angle
Flaking 	• Deposition on cutting edge • Bad chip control	• Improve cutting performance fromd large rake angle • Apply to chip pocket with big size
Complete breakage 	• Unusable condition due to wear off the most parts of cutting edge by progress of wear	• Reduce the feed rate. • Reduce the depth of cut. • Select a tougher grade. • Select a stronger chipbreaker. • Select a thicker insert.
Built-up edge 	• Slow cutting speed • Sticky materials	• Increase cutting speed. • Use more positive rake geometry. • Use tougher grade

Types of tool failure and trouble shooting

Troubles	Causes	Solution																	
		Cutting conditions				Selecting insert grade				Tool shape							Machine clamping		
		Cutting speed	Feed	Depth of cut	Coolant	Select harder grade	Select tougher grade	Select better heat-impact resistance grade	Select better adhesion resistance grade	Chip breaker valuation	Rake angle	Nose radius	Side cutting edge angle	Cutting edge strength Honing	Improving insert precision M class → G class	Improving holder rigidity	Clamping workpiece	Holder overhang	Machine vibration
Poor precision Unstable machining size	Insert precision is variable														●				
	Workpiece, Separation of tool									●	↑	↓				●	●	●	●
Cutting edge back thrust is big It's necessary to adjust because machining precision changes during operation.	Flank wear increase					●						↑							
	Cutting condition is improper	↓	↑																
Poor surface roughness for finishing Criterion of tool life.	Weakened cutting force by increasing wear of tool	↓			Wet cutting	●			●	●	↑	↑		↓	●				
	Cutting edge chipping		↓	↓			●			●		↑		↑			●	●	●
	Adhesion, built-up edge	↑	↑		Wet cutting				●	●	↑			↓	●				
	Improper cutting conditions	↑	↓	↓	Wet cutting														
	Improper tool and shape of cutting edge									●		↑		↓	●				
	Vibration, chattering	↓	↓	↓	Wet cutting		●			●	↑	↓		↓		●	●	●	●
Cutting heat generation Poor machining precision and short tool life by cutting heat	Improper cutting conditions	↓	↓	↓															
	Improper tool and shape of cutting edge					●				●	↑			↓					
burr, chipping, nap steel, aluminum (burr)	Improper cutting conditions	↓	↑		Wet cutting														
	Wear on the tool, improper shape of cutting edge					●			◉	●	↑	↓		↓					
Cast iron (Weak chipping)	Improper cutting conditions		↓	↓															
	Wear on the tool, improper shape of cutting edge					●				●	↑	↑		↓		●	●	●	●
Soft steel (nap)	Improper cutting conditions	↑	↕		Wet cutting														
	Wear on the tool, improper shape of cutting edge					●			◉	●	↑			↓					

↑ : Increase ↓ : Decrease ● : use ◉ : Correct use

Tool life criterion

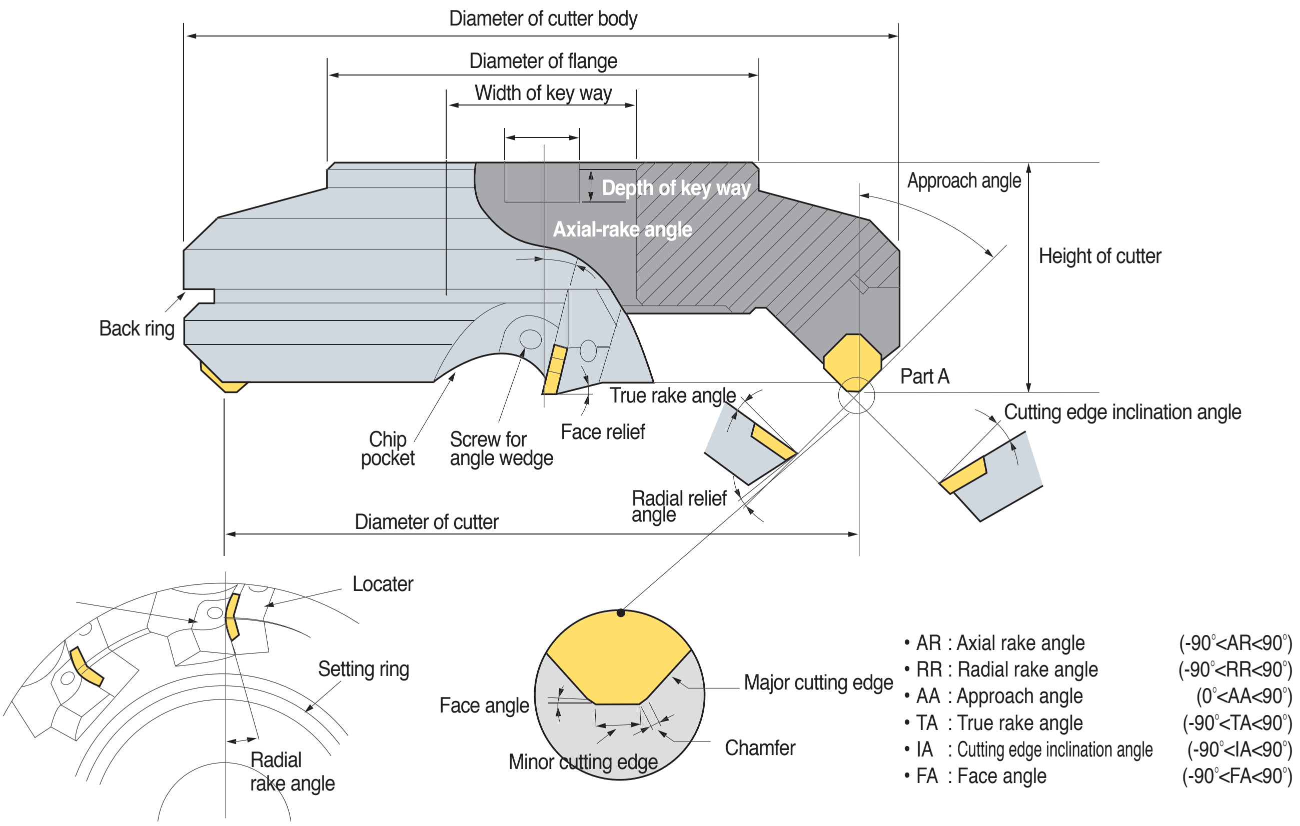
● KS B0813

Flank wear width	0.2mm	Precision light cutting , Finishing in nonferrous alloy
	0.4mm	Machining special steel
	0.7mm	General cutting in cast iron, steel etc
	1~1.25mm	General cutting in cast iron, steel etc
Depth of crater wear	In general 0.05~0.1 mm	

● ISO(B8688)

Tool life criterion	Application
Complete breakage	Machining special steel
Flank wear width VB = 0.3mm	Even flank wear of cemented carbides, Ceramic tool
VBmax = 0.5mm	Uneven flank wear
Crater wear width KT = 0.06+0.3fmm (f:mm/rev)	Cemented carbides tool
Criterion by surface roughness 1, 1.6, 2.5, 4, 6.3, 10㎛Ra	When surface roughness is important

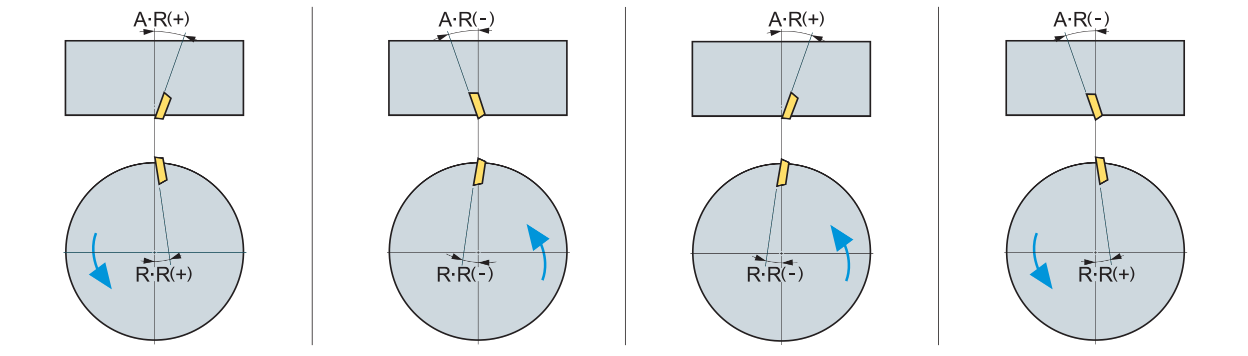
Milling cutter shape and designation



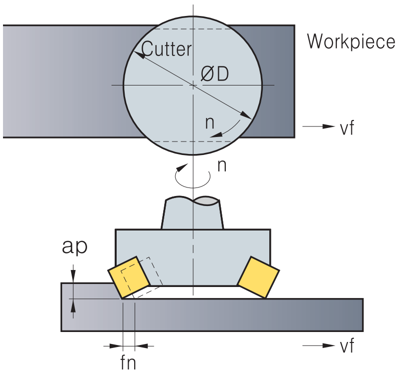
The terminology and functions of cutting edge angle

	Tool failure	Symbol	Function	Effects
1	Axial rake angle	A.R	Chip flow direction, Adhesion	-
2	Radial rake angle	R.R	Affecting on thrust	-
3	Approach angle	A.A	Chip thickness, Determines flow direction	(+) : Chip thickness become thinner, cutting force could be reduced.
4	True rake angle	T.A	Effective rake angle	(+) : Better cutting. Preventing adhesion, Weakening cutting edge strength. (-) : Cutting edge strength increases, easy to adhere
5	Cutting edge inclination angle	I.A	Determines chip flow direction	(+) : Good chip flow, cutting force decreases, Corner edge strength weakens
6	Face angle	F.A	Controlling surface roughness for finishing	(-) : Surface roughness improves
7	Relief angle	R.A	Controlling cutting edge strength, tool life and chattering	-

Features by combination of rake angle

	Double positive angle	Double negative angle	Posi - Negative angle	Nega - Positive angle
				
Use	• General machining of steel, cast iron, stainless steel • Machining soft steel that brings about built-up edge easily • Machining material having tendency to poor surface roughness	• Under interrupted cutting condition • Roughing of cast iron and steel	• Machining difficult to cut material • Roughing with deep depth of cut and wide width of cut in steel and cast iron	• Chip flows to center of cutter body
Advantages	• As for tough workpiece material It prevents built-up edge to improve surface roughness. • Low cutting load and better machinability	• Strong cutting edge. • Roughing of workpiece that has bad surface condition containing sand, mill scale • Double sided inserts can be applied(Economical). • Good chip control.	• Good chip flow and machinability. • Suitable for machining of difficult-to-cut material • Un-even partition clamping prevents chattering	-
Disadvantages	• Weak cutting edge strength. • Only single sided inserts are available (No economical). • Machine and cutter need enough power and rigidity.	• Machine and cutter need enough power and rigidity.	• Only single sided inserts are available (No economical)	• Since the chips flows toward the center of cutter. Chips scratch on machined surface. • Bad chip flow. • No economical

Major cutting formulas



● Cutting speed

$$vc = \frac{\pi \cdot D \cdot n}{1000} \text{ (m/min)}$$

- •vc : Cutting speed (m/min)
- •D : Diameter of tool (mm)
- •n : Revolution per minute (min^{-1})
- •π : Circular constant (3.14)

● Feed

$$fz = \frac{vf}{z \cdot n} \text{ (mm/t)}$$

- •fz : Feed per tooth (mm/t)
- •vf : Feed per minute (mm/min)
- •n : Revolution per minute (min^{-1})
- •z : Number of tooth

● Chip removal amount

$$Q = \frac{L \times vf \times ap}{1000} \text{ (cm}^3\text{/min)}$$

- •Q : Chip removal amount (cm^3/min)
- •L : Width of cut (mm)
- •vf : Table feed (mm/min)
- •ap : Depth of cut (mm)

● Power requirement

$$P_{kw} = \frac{Q \times kc}{60 \times 102 \times \eta} \qquad P_{hp} = \frac{P_{kw}}{0.75}$$

- •Pc : Power requirement (kW)
- •H : Horse power requirement (hp) (mm/min)
- •Q : Chip removal amount (cm^3/min)
- •kc : Specific cutting resistance (kgf/mm^2)
- •η : Machine efficiency rate (0.7~0.8)

● Machining time

$$T = \frac{60 \times Lt}{vf} \text{ (sec)}$$

- •T : Machining time (sec)
- •Lt : Total length of table feed (mm)(=Lw+D+2R)
- •Lw : The length of workpiece (mm)
- •D : The diameter of cutter body (mm)
- •vf : Table feed (mm/min)
- •R : Relief length (mm)

● True rake angle / Cutting edge inclination angle

True rake angle $\tan(T) = \tan(R) \times \cos(AA) + \tan(A) \times \sin(C)$

Cutting edge inclination angle $\tan(I) = \tan(A) \times \cos(AA) - \tan(R) \times \sin(C)$

Values of specific cutting resistance

Workpiece	Tensile strength (kg/㎟) and hardness	Specific cutting resistance according to various feed kc(MPa) 0.1 (mm/t)	0.2 (mm/t)	0.3 (mm/t)	0.4 (mm/t)	0.6 (mm/t)
Soft steel	52	220	195	182	170	158
Medium carbon steel	62	198	180	173	160	157
High carbon steel	72	252	220	204	185	174
Tool steel	67	198	180	173	170	160
Tool steel	77	203	180	175	170	158
Chrome manganese steel	77	230	200	188	175	166
Chrome manganese steel	63	275	230	206	180	178
Chrome molybdenum steel	73	254	225	214	200	180
Chrome molybdenum steel	60	218	200	186	180	167
Nickel Chrome molybdenum steel	94	200	180	168	160	150
Nickel Chrome molybdenum steel	HB352	210	190	176	170	153
Cast steel	52	280	250	232	220	204
Hardened cast iron	HRC46	300	270	250	240	220
Meehanite cast iron	36	218	200	175	160	147
Gray cast iron	HB200	175	140	124	105	97
Brass	50	115	95	80	70	63
Light alloy(Al - Mg)	16	58	48	40	35	32
Light alloy(Al - Si)	20	70	60	52	45	39

Chip removal amount(cm3/min) per rated horse power

Workpiece	Rated horse power	5Hp	10Hp	20Hp	30Hp	40Hp	50Hp
Steel	Soft	32	75	163	295	425	570
	Medium	26	55	127	212	310	425
	hard	18	41	93	163	228	310
Cast iron	Soft	52	116	260	455	670	880
	Medium	32	75	163	295	425	570
	hard	26	55	127	212	310	425
Bronze Brass	Soft	77	163	390	670	980	1,280
	Medium	54	118	275	490	700	910
	hard	26	55	127	245	325	425
Aluminum		90	195	440	780	1,110	1,500

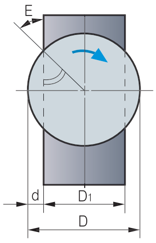
Selection of MILL-MAX diameter(D)

● Selection by machine rigidity

Machine horse power(PS)	10~15	15~20	Over 20
Proper cutter body specification(mm)	ø80~ø100	ø125~ø160	ø160~ø200

● Selection by machine rigidity

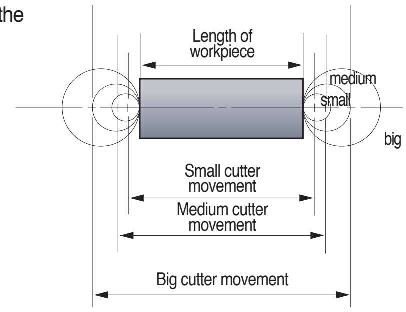
Workpiece	E	δ
Steel	+20°~-10°	3 : 2
Cast iron	Under +50°	5 : 4
Light alloy	Under +40°	5 : 3



D : External diameter of cutter body
D1 : Width of workpiece
d : Projected part of cutter body
E : Engage angle
δ : Ratio of cutter body and width of workpiece(D:D1)

● Selection by machining time

The bigger size cutter the longer machining time.

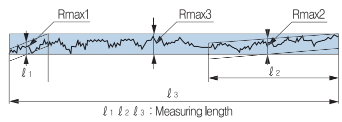
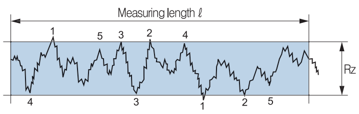
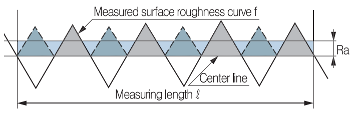
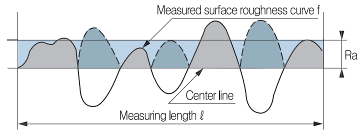


● Selection by number of tooth

Workpiece	Steel	Cast iron	Light alloy
Number of tooth	D×(1~1.5)	D×(1~4)	D×1+α

ex) D=ø100 ⇒4″×(1~1.5)=4~6　　D is the size of cutter body converted into inch size.

Classification of surface roughness

Type	Symbol	How to calculate	Measured value
Maximum height	Rmax	• The distance between the top of profile peak line and the bottom of profile valley line on this sampled portion is measured in the longitudinal magnification direction of roughness curve (Expressed by unit: µ). • Exclude extraordinary values(too small or big) that look like grooves or mountains.	
+10 point mean roughness	Rz	• Sampled from the roughness curve in the direction of its mean line, the sum of the average value of absolute value of the highest profile peaks and the depths of five deepest profile valleys measured in the vertical magnification direction is expressed by micro meter(µ).	
Arithmetic mean roughness	Ra	• Sampling only the reference length from the roughness curve in the direction of mean line , taking X-axis in the direction of mean line and Y-axis in the direction of longitudinal magnification of this sampled part and is expressed by micro meter(µ). • Generally, Read measured value by Ra measurer.	

Finish mark		▽▽▽▽	▽▽▽	▽▽	▽	~
Surface roughness	Rmax	0.8s	6.3s	25s	100s	Unspecified
	Rz	0.8z	6.3z	25z	100z	
	Ra	0.2a	1.6a	6.3a	25a	

General Information

Trouble shooting for milling

Trouble	Causes	Solutions										
		Cutting conditions				Tool shape					Insert grade	
		Cutting speed	Depth of cut	Feed	Coolant	Rake angle	Relief angle	Approach angle	Chattering at cutting edge	Nose radius	Toughness	Hardness
Flank wear	• Improper insert grade • Improper cutting conditions • Chattering	↓		↑			↑	↓		↑		↑
Crater wear	• Improper cutting conditions • Improper insert grade	↓	↓	↓	●	↑				↓		↑
Chipping	• Lack of insert toughness • Excessive feed • Excessive cutting load			↓		↓	↓	↓		↑	↑	
Built-up edge	• Improper cutting conditions • Improper cutting edge shape • Improper insert grade	↑	↓	↑		↑				↓		
Chattering	• Improper cutting conditions • Lack of number of cutting teeth • Improper cutting edge shape • Bad chip flow • Unstable workpiece clamping		↓	↓	●	↑		↑	↓	↓		
Poor surface finish	• Built-up edge • Improper cutting conditions • Chattering • Bad chip flow	↑	↓	↓	●	↑			↓	↑		
Thermal crack	• Improper cutting conditions • Improper insert grade	↓	↓	↓	◉	↑				↑	↑	
Fracture	• Improper insert grade • Excessive cutting load • Bad chip flow • Chattering • Excessive overhang		↓	↓	●						↑	

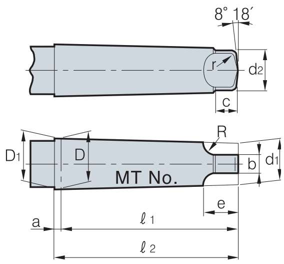
↑ : Increase ↓ : Decrease ● : use ◉ : Correct use

General formulas for milling

● Machine efficiency rate (η)

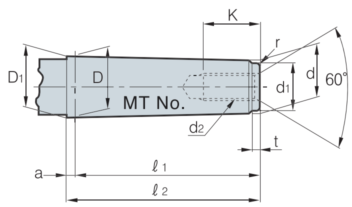
Power transmission mode	Efficiency rate (E)	Reference
Principal axis direct connection driving	0.90	
Belt driving	0.85	Double connection : 0.85 × 0.85 ≒ 0.70
Starting driving	0.75	
Oil pressure driving	0.60~0.90	

Morse taper (Tang type)



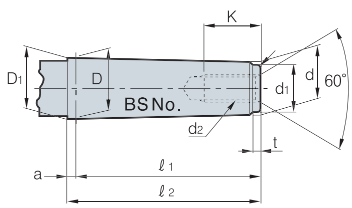
MT No.	Taper	Taper angle(α)	D	a	D_1	d_1	ℓ_1	ℓ_2	d_2	b	c	e	R	r
0	$\frac{1}{19.212}$	1°29′27″	9.045	3	9.201	6.104	56.5	59.5	6.0	3.9	6.5	10.5	4	1
1	$\frac{1}{20.047}$	1°25′43″	12.065	3.5	12.240	8.972	62.0	65.5	8.7	5.2	8.5	13.5	5.	1.2
2	$\frac{1}{20.020}$	1°25′50″	17.780	5	18.030	14.034	75.0	80.0	13.5	6.3	10	16	6	1.6
3	$\frac{1}{19.922}$	1°26′16″	23.825	5	24.076	19.107	94.0	99.0	18.5	7.9	13	20	7	2
4	$\frac{1}{19.254}$	1°29′15″	31.267	6.5	31.605	25.164	117.5	124.0	24.5	11.9	16	24	8	2.5
5	$\frac{1}{19.002}$	1°30′26″	44.399	6.5	4.741	36.531	149.5	156.0	35.7	15.9	19	29	10	3
6	$\frac{1}{19.180}$	1°29′36″	63.348	8	63.765	52.399	210.0	218.0	51.0	19.0	27	40	13	4
7	$\frac{1}{19.231}$	1°29′22″	83.058	10	83.578	68.186	286.0	296.0	66.8	28.6	35	54	19	5

Morse taper (Screw type)



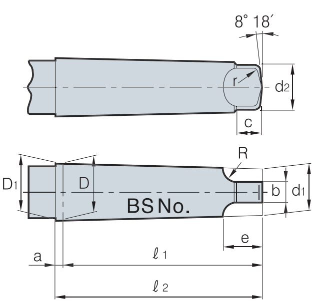
MT No.	Taper	Taper angle(α)	D	a	D_1	d	ℓ_1	ℓ_2	d_1	d_2	k	t	r
0	$\frac{1}{19.212}$	1°29′27″	9.045	3	9.201	6.442	50	53	6	-		4	0.2
1	$\frac{1}{20.047}$	1°25′43″	12.065	3.5	12.230	9.396	53.5	57	9	M6	16	5	0.2
2	$\frac{1}{20.020}$	1°25′50″	17.780	5	18.030	14.583	64	69	14	M10	24	5	0.2
3	$\frac{1}{19.922}$	1°26′16″	23.825	5	24.076	19.759	81	86	19	M12	28	7	0.6
4	$\frac{1}{19.254}$	1°29′15″	31.267	6.5	31.605	25.943	02.5	109	25	M16	32	9	1
5	$\frac{1}{19.002}$	1°30′26″	44.399	6.5	4.741	37.584	129.5	136	35.7	M20	40	9	2.5
6	$\frac{1}{19.180}$	1°29′36″	63.348	8	63.765	53.859	182	190	51	M24	50	12	4
7	$\frac{1}{19.231}$	1°29′22″	83.058	10	83.578	70.058	250	260	65	M33	80	18.5	5

Brown sharp taper (Screw type)



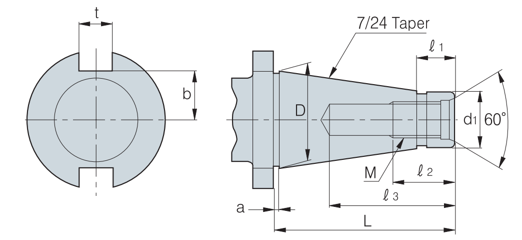
B&S No.	D	a	D_1	d	d_1	ℓ_1	ℓ_2	t	r	d_2	K
4	10.221	2.4	10.321	8.890	8.0	31.0	34.2	2	0.2	-	-
5	13.286	2.4	13.386	11.430	10.0	44.4	46.8	3	0.2	-	-
6	15.229	2.4	15.330	12.700	11.0	60.0	62.7	3	0.2	M 8(1/4)	20
7	18.424	2.4	18.524	15.240	14.0	76.2	78.6	4	0.2	M10(3/8)	24
8	22.828	3.2	22.962	19.090	17.0	90.5	93.7	4	0.6	M12(1/2)	28
9	27.104	3.2	27.238	22.863	21.0	101.6	104.8	4	0.6	M12(1/2)	28
10	32.749	3.2	32.887	26.534	24.0	144.5	147.7	5	1.0	M16(5/8)	32
11	38.905	3.2	39.039	31.749	29.0	171.4	174.6	5	1.0	M16(5/8)	32
12	45.641	3.2	45.774	38.103	35.0	181.0	184.2	6	2.5	M20(3/4)	40
13	52.654	3.2	52.787	44.451	41.0	196.8	200.0	6	3.0	M20(3/4)	40
14	59.533	3.2	59.666	50.800	47.0	209.6	212.8	7	4.0	M24(1)	40
15	66.408	3.2	66.541	57.150	53.0	222.2	225.4	7	4.0	M24(1)	50
16	73.292	3.2	73.425	63.500	59.0	35.0	238.2	8	5.0	M30(11/8)	60

Brown sharp taper (Tang type)



B&S No.	D	a	D_1	d_1	d_2	ℓ_1	ℓ_2	b	c	e	R	r
4	10.221	2.4	10.321	8.458	8.1	42.1	44.5	5.5	8.7	14.4	7.9	1.3
5	13.286	2.4	13.386	10.962	10.7	55.6	58.0	6.3	9.5	16.2	7.9	1.5
6	15.229	2.4	15.330	12.167	11.7	73.0	75.4	7.1	11.1	18.0	7.9	1.5
7	18.424	2.4	18.524	14.675	14.2	89.7	92.1	7.9	11.9	20.3	9.5	1.8
8	22.828	3.2	22.962	18.453.	18.0	104.8	108.0	8.7	12.7	22.0	9.5	2.0
9	28.104	3.2	27.238	22.200	21.8	117.5	120.7	9.5	14.3	25.4	11.1	2.5
10	32.749	3.2	32.887	25.751	25.7	162.7	165.9	11.1	16.7	28.1	11.1	2.8
11	38.905	3.2	39.039	30.985	30.7	189.7	192.9	11.1	16.7	30.0	12.7	3.3
12	45.641	3.2	45.774	37.246	37.1	201.6	204.8	12.7	190	32.5	12.7	3.8
13	52.654	3.2	52.787	43.589	43.4	217.5	220.7	12.7	19.0	35.7	15.9	4.3
14	59.533	3.2	59.666	49.841	49.8	232.6	235.8	14.2	21.4	41.2	19.0	4.8
15	66.408	3.2	66.541	56.186	56.1	245.3	248.5	14.2	21.4	44.4	22.2	5.3
16	73.292	3.2	73.425	62.441	62.2	260.4	263.6	15.8	23.8	50.0	25.4	5.8

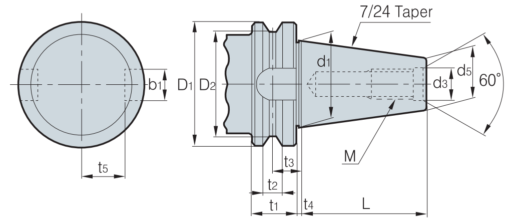
● Standard taper of American milling machine



(mm)

NT No.	Dimensions	D	D_1	L	ℓ1	M	ℓ2	ℓ3	a	t	b
30	$1\frac{1}{4}$	31.750	$17.40^{-0.29}_{-0.36}$	70	20	UNC $\frac{1}{2}$"	24	50	1.6	15.9	6
40	$1\frac{3}{4}$	44.450	$25.32^{-0.30}_{-0.384}$	95	25	UNC $\frac{5}{8}$"	30	60	1.6	15.9	22.5
50	$2\frac{3}{4}$	69.850	$39.60^{-0.31}_{-0.41}$	130	25	UNC 1"	45	90	3.2	25.4	35
60	$4\frac{1}{4}$	107.950	$60.20^{-0.34}_{-0.46}$	210	45	UNC $1\frac{1}{4}$"	56	110	3.2	25.4	60

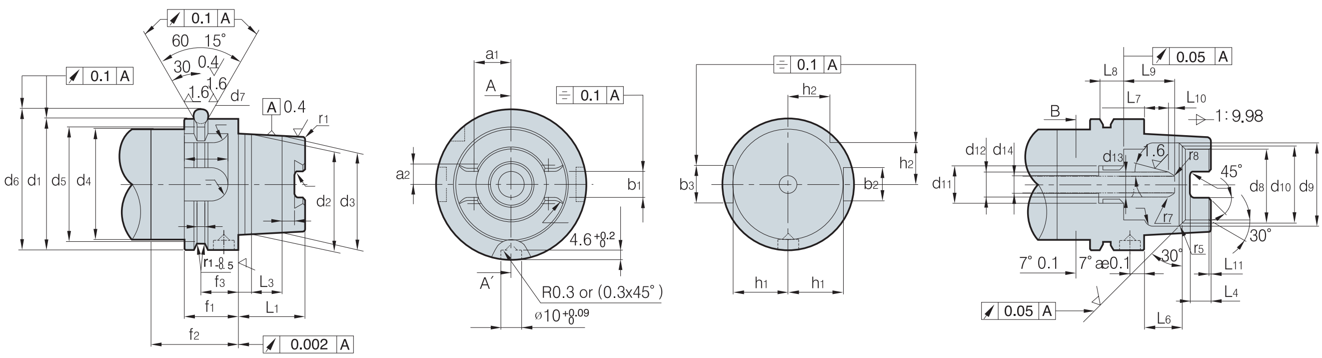
● Bottle grip taper



(mm)

BT No.	D_1	D_2	t_1	t_2	t_3	t_4	d_1	d_3	L	M	b_1	t_5	d_5
35	53	43	22	10	14.6	2	38.1	13	56.5	M12×1.75	16.1	19.6	21.62
40	63	52	25	10	16.6	2	44.45	17	65.4	M16×2	16.1	22.6	25.3
45	85	73	30	12	21.2	3	57.15	21	82.8	M20×25	19.3	29.1	33.1
50	100	85	35	15	23.2	3	69.85	25	101.8	M24×3	25.7	35.4	40.1
60	155	135	45	20	28.2	3	107.95	31	161.8	M30×3.5	25.7	60.1	60.7

● HSK shank (DIN 69893)



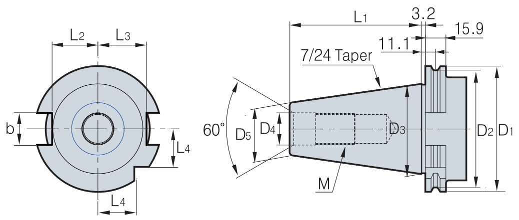
(mm)

HSK No.	b_1	b_2	b_3	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}	d_{12}	d_{13}	d_{14}	a_1	a_2
50	10.54	12	14	50	38	36.90	42	43	59.3	7	26	32	29	M16X1	10	6.8	6.8	13.997	7.648
63	12.5	16	14	63	48	46.53	53	55	72.3	7	34	40	37	M18X1	12	8	8.4	17.862	9.25
100	20	20	14	100	75	72,80	85	92	109.75	7	53	63	58	M24X1.5	16	12	12	27.329	15.00

(mm)

HSK No.	f_1	f_2	f_3	f_4	b_1	b_2	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}	L_{12}	r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8
50	26	42	18	3.75	2	15.5	25	5	11	7.5	4.5	14.13	10	10	23	3	1	19	1	1.5	2.38	6	0.5	1	2	6
63	26	42	18	3.75	28.5	20	32	6.3	14.7	10	6	18.13	10	12	24.5	3	1	21	1.2	1.5	3	8	0.6	1.5	3	8
100	29	45	20	3.75	44	31.5	50	10	24	15	10	28.56	12.5	16	28	3	1.5	24	2	2	3	12	1	1.5	3	10

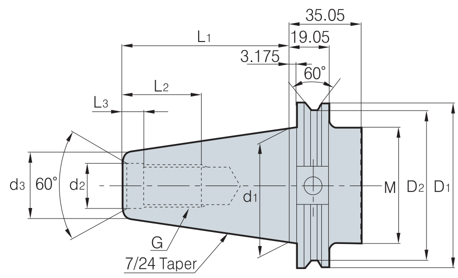
● DIN 69871



(mm)

Shank No	D_1	D_2	D_3	D_4	D_5	L_1	L_2	L_3	L	b	M
30	50.0	44.3	31.75	13	17.8	47.8	16.4	19.0	33.5	16.	M12×1.75
40	63.5	56.2	44.45	17	24.5	68.4	22.8	25.0	42.5	16.1	M16×2
45	82.5	57.2	57.15	21	33.0	82.7	29.1	31.3	52.5	19.3	M20×2.5
50	97.5	91.2	68.85	25	40.1	101.7	35.5	37.7	61.5	25.7	M24×3

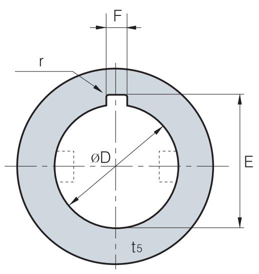
● CAT shank



(mm)

Shank No	D_1	D_2	M	d_1	d_2	d_3	L_1	L_2	L_3	G
CAT40	63.5	56.36	44.45	44.45	16.28	21.84	68.25	28.45	4.78	5/8-11
CAT45	82.55	75.41	57.15	57.15	19.46	27.69	82.55	38.1	4.78	3/4-10
CAT50	98.43	91.29	69.85	69.85	26.19	35.05	101.6	44.45	6.35	1-8

● Standard of milling cutter hole (KSB3203)



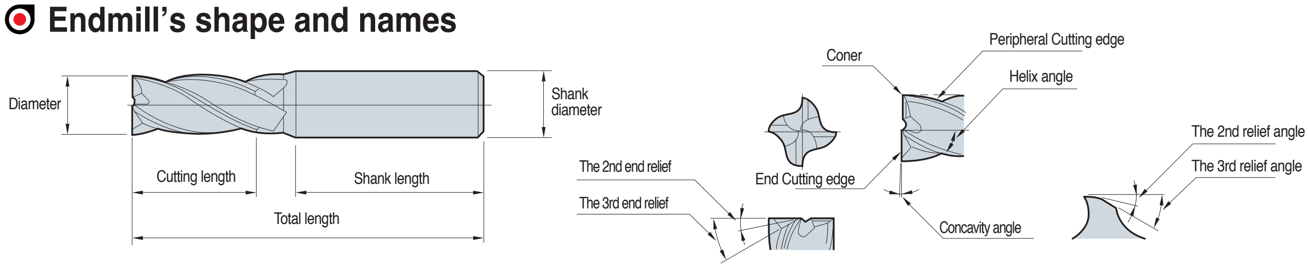
● Type A

Diameter	øDH7	E	F	r
8	$8^{+0.015}_{0}$	$8.9^{+0.25}_{0}$	$2^{+0.16}_{+0.06}$	0.4
10	$10^{+0.015}_{0}$	$11.5^{+0.25}_{0}$	$3^{+0.16}_{+0.06}$	0.4
13	$13^{+0.018}_{0}$	$14.6^{+0.25}_{0}$	$3^{+0.16}_{+0.06}$	0.6
16	$16^{+0.018}_{0}$	$17.7^{+0.25}_{0}$	$4^{+0.19}_{+0.07}$	0.6
19	$19^{+0.021}_{0}$	$21.1^{+0.25}_{0}$	$5^{+0.19}_{+0.07}$	1
22	$22^{+0.021}_{0}$	$24.1^{+0.25}_{0}$	$6^{+0.19}_{+0.07}$	1
27	$27^{+0.021}_{0}$	$29.8^{+0.25}_{0}$	$7^{+0.23}_{+0.08}$	1.2
32	$32^{+0.025}_{0}$	$34.8^{+0.25}_{0}$	$8^{+0.23}_{+0.08}$	1.2
40	$40^{+0.025}_{0}$	$43.5^{+0.3}_{0}$	$10^{+0.23}_{+0.08}$	1.2
50	$50^{+0.025}_{0}$	$53.5^{+0.3}_{0}$	$12^{+0.275}_{+0.095}$	1.6
60	$60^{+0.030}_{0}$	$64.2^{+0.3}_{0}$	$14^{+0.275}_{+0.095}$	1.6
70	$70^{+0.030}_{0}$	$75.0^{+0.3}_{0}$	$16^{+0.275}_{+0.095}$	2
80	$80^{+0.030}_{0}$	$85.5^{+0.3}_{0}$	$18^{+0.275}_{+0.095}$	2
100	$100^{+0.035}_{0}$	$107.0^{+0.3}_{0}$	$24^{+0.32}_{+0.11}$	2.5

● Type B

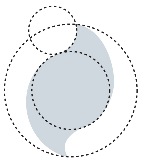
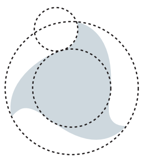
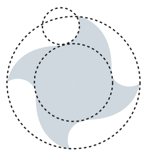
Diameter	øDH7	E	F	r
$\frac{1}{2}$	$12.70^{+0.018}_{0}$	$14.17^{+0.25}_{0}$	$2.38^{+0.31}_{+0.13}$	0.5
$\frac{5}{8}$	$15.875^{+0.018}_{0}$	$17.74^{+0.25}_{0}$	$3.18^{+0.31}_{+0.13}$	0.8
$\frac{3}{4}$	$19.050^{+0.021}_{0}$	$20.89^{+0.25}_{0}$	$3.18^{+0.31}_{+0.13}$	0.8
$\frac{7}{8}$	$22.225^{+0.021}_{0}$	$24.07^{+0.25}_{0}$	$3.18^{+0.31}_{+0.13}$	0.8
1	$25.40^{+0.021}_{0}$	$28.04^{+0.25}_{0}$	$6.35^{+0.31}_{+0.13}$	1.2
$1\frac{1}{4}$	$31.750^{+0.025}_{0}$	$35.18^{+0.25}_{0}$	$7.94^{+0.32}_{+0.14}$	1.6
$1\frac{1}{2}$	$38.10^{+0.025}_{0}$	$42.32^{+0.25}_{0}$	$9.53^{+0.89}_{+0.25}$	1.6
$1\frac{3}{4}$	$44.450^{+0.025}_{0}$	$49.48^{+0.25}_{0}$	$11.11^{+0.89}_{+0.25}$	1.6
2	$50.80^{+0.03}_{0}$	$55.83^{+0.25}_{0}$	$12.7^{+0.89}_{+0.25}$	1.6
$2\frac{1}{2}$	$63.50^{+0.03}_{0}$	$69.42^{+0.25}_{0}$	$15.81^{+0.89}_{+0.25}$	1.6
3	$76.20^{+0.03}_{0}$	$82.93^{+0.25}_{0}$	$19.05^{+0.89}_{+0.25}$	2.4
$3\frac{1}{2}$	$88.90^{+0.035}_{0}$	$98.81^{+0.25}_{0}$	$22.23^{+0.89}_{+0.25}$	2.4
4	$101.60^{+0.035}_{0}$	$111.51^{+0.25}_{0}$	$25.4^{+0.89}_{+0.25}$	2.4
$4\frac{1}{2}$	$114.30^{+0.035}_{0}$	$125.81^{+0.25}_{0}$	$25.58^{+0.89}_{+0.25}$	3.2
5	$127.0^{+0.04}_{0}$	$140.08^{+0.25}_{0}$	$31.75^{+0.89}_{+0.25}$	3.2

Endmill's shape and names



The comparison according to number of flute

Features of number of flute

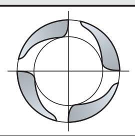
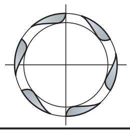
Ø10mm	2 flutes (IFE2100)	3 flutes (IFE3100)	4 flutes (IFE4100)
Shape			
Cross section	44mm²	46mm²	48mm²
Ratio	56%	58%	61%
Advantages	Good chip flow	Good chip flow	High rigidity
Disadvantages	Weak rigidity	Difficult to measure external diameter	Bad chip flow
Usages	Side facing, Grooving	Side facing, Grooving	Side cutting
	Multi-functional	Medium, finishing	Finishing

Affection of number of flute

Specification	Major features	2 flutes	4 flutes
Tool rigidity	Torsional rigidity	○	◎
	Bending rigidity	○	◎
Surface finish	Surface roughness	○	◎
	Machining precision	○	◎
Chip control	Chip clogging	◎	○
	Chip evacuation	◎	○
Grooving	Chip evacuation	◎	○
	Grooving	◎	○
Side facing	Surface finish	○	◎
	Vibration	◎	○

◎-Excellent ○-Good

The differences between general endmills and high speed endmills

General endmills		High speed endmills	
Cross section shape	Features	Cross section shape	Features
	- Applied for Low speed, High depth of cut, Low feed - Low hardness workpiece(general steel, cast iron)		- Applied for high speed, low depth of cut, high feed - Useful for hardened workpiece such as die steel

Calculations of cutting condition

Calculations of Cutting speed

$$vc = \frac{\pi \times D \times n}{1000} \qquad n = \frac{1000 \times vc}{\pi \times D}$$

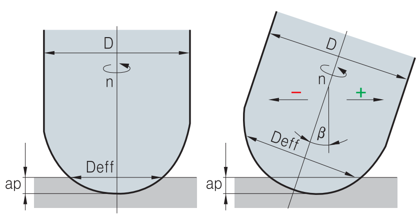
Calculations of feed speed

$$vf = n \times fn \ \text{ or } \ n \times fz \times z$$

$$fn = \frac{vf}{n} \qquad fz = \frac{fn}{z} \ \text{ or } \ \frac{vf}{n \times z}$$

vc : Cutting speed(m/min)
π : Circular constant (3.141592)
D : Endmill diameter(mm)
n : Revolution per minute(min⁻¹)
vf : Feed speed(m/min)
fn : Feed per revolution(mm/rev)
fz : Feed per flute (mm/t)
z : Number of flute

Ball endmills cutting speed calculation formulas

Revolution per minute	$n = \frac{vc \times 1000}{D \times \pi}$
Cutting speed	$vc = \frac{D \times \pi \times n}{1000}$
Feed per tooth	$fz = \frac{vf}{z \times n}$
Feed per revolution	$fn = fz \times z$
Feed speed	$vf = fz \times z \times n$
Chip removal rate	$Q = ae \times ap \times vf$
Effective diameter of Ball Endmill 	$D_{eff} = 2 \times \sqrt{D \times ap - ap^2}$ Calculation Table $D_{eff} = D \times \sin\left[\beta \pm \arccos\left(\frac{D-2ap}{D}\right)\right]$

The affection of flute length

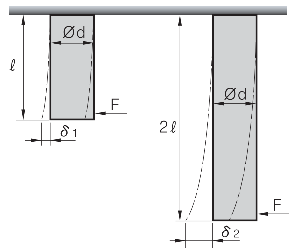
● Expression of aspect ratio

- Aspect ratio
- ℓ/d
- Ex) 3D, 15D, 22D

● Deformation rate according to length

- Deformation rate is reaction force against external force.
- Proportional to the cube of length
- Set flute length and overall length as short as possible
- The more flute the better rigidity
- When flute width rate is narrower drill's rigidity is higher.

$$\delta = \frac{P\ell^3}{3EI}$$



δ = Deformation volume ℓ = Length of cut

P = Cutting force **E** = Elasticity coefficient

I = Inertia moment ($I = \frac{\pi d^4}{64}$)

- ℓ → 2ℓ
- δ1 → δ1 = 8δ1 = δ2

Spindle revolution conversion table(RPM) - external diameter

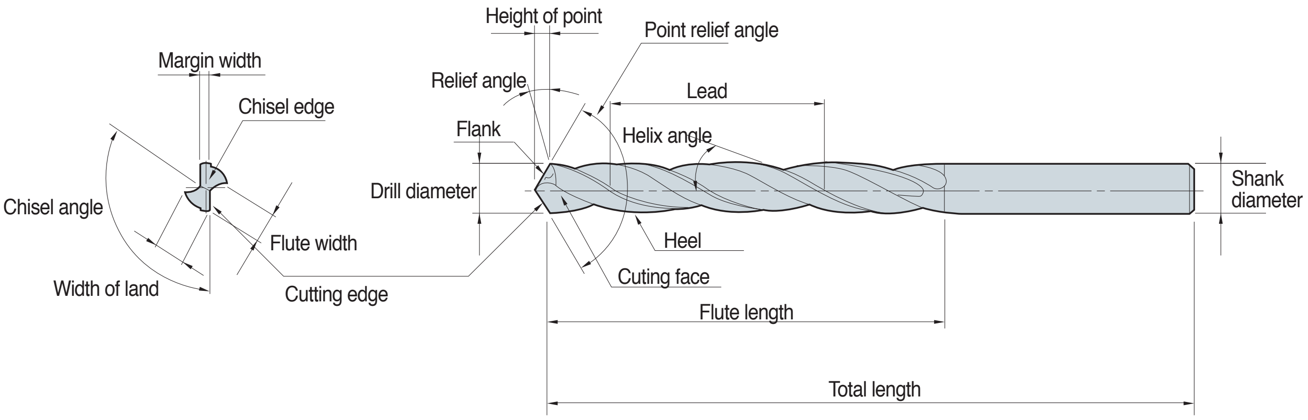
VC / External	Cutting speed (vc, m/min)															
	20	30	40	50	60	70	80	90	100	120	140	150	180	200	250	300
0.2	31,831	47,746	63,662	79,577	95,493	111,408	127,324	143,239	159,155	190,986	222,817	23,872	286,479	318,310	397,887	477,465
0.3	21,221	31,831	42,441	53,052	63,662	74,272	84,883	95,493	106,103	127,324	148,545	159,155	190,986	212,207	265,258	318,310
0.4	15,915	23,873	31,831	39,789	47,746	55,704	63,662	71,620	79,577	95,493	111,408	119,366	143,239	159,155	198,944	238,732
0.5	12,732	19,099	25,465	31,831	38,197	44,563	50,930	57,296	63,662	76,394	89,127	95,493	114,592	127,324	159,155	190,986
0.6	10,610	15,915	21,221	26,526	31,831	37,136	42,441	47,746	53,052	63,662	74,272	79,577	95,493	106,103	132,629	159,155
0.7	9,095	13,642	18,189	22,736	27,284	31,831	36,378	40,926	45,473	54,567	63,662	68,209	81,851	90,946	113,682	136,419
0.8	7,958	11,937	15,915	19,894	23,873	27,852	31,831	35,810	39,789	47,746	55,704	59,683	71,620	79,577	99,472	119,366
0.9	7,074	10,610	14,147	17,684	21,221	24,757	28,294	31,831	35,368	42,441	49,515	53,052	63,662	70,736	88,419	106,103
1	6,366	9,549	12,732	15,915	19,009	22,282	25,465	28,648	31,831	38,197	44,563	47,746	57,296	63,662	79,577	95,793
1.5	4,244	6,366	8,488	10,610	12,732	14,854	16,977	19,099	21,221	25,465	29,709	31,831	38,197	42,441	53,052	63,662
2	3,183	4,775	6,366	7,958	9,549	11,141	12,732	14,324	15,915	19,099	22,282	23,873	28,648	31,831	39,789	47,746
2.5	2,546	3,820	5,093	6,366	7,639	8,913	10,186	11,459	12,732	15,279	17,825	19,099	22,918	25,465	31,831	38,197
3	2,122	3,183	4,244	5,305	6,366	7,427	8,488	9,549	10,610	12,732	14,854	15,915	19,099	21,221	26,526	31,831
3.5	1,819	2,728	3,638	4,547	5,457	6,366	7,276	8,185	9,095	10,913	12,732	13,642	16,370	18,189	22,736	27,284
4	1,592	2,387	3,183	3,979	4,775	5,570	6,366	7,162	7,958	9,549	11,141	11,937	14,324	15,915	19,894	23,873
4.5	1,415	2,122	2,829	3,537	4,244	4,951	5,659	6,366	7,074	8,488	9,903	10,610	12,732	14,147	17,684	21,221
5	1,273	1,910	2,546	3,183	3,820	4,456	5,093	5,730	6,366	7,639	8,913	9,549	11,459	12,732	15,915	19,099
5.5	1,157	1,736	2,315	2,894	3,472	4,051	4,630	5,209	5,787	6,945	8,102	8,681	10,417	11,575	14,469	17,362
6	1,061	1,592	2,122	2,653	3,183	3,714	4,244	4,775	5,305	6,366	7,427	7,958	9,549	10,610	13,263	15,915
6.5	979	1,469	1,959	2,449	2,938	3,428	3,918	4,407	4,897	5,876	6,856	7,346	8,815	9,794	12,243	14,691
7	909	1,364	1,819	2,274	2,728	3,183	3,638	4,093	4,547	5,457	6,366	6,821	8,185	9,095	11,368	13,642
7.5	849	1,273	1,698	2,122	2,546	2,971	3,395	3,820	4,244	5,093	5,942	6,366	7,639	8,488	10,610	12,732
8	796	1,194	1,592	1,989	2,387	2,785	3,183	3,581	3,979	4,775	5,570	5,968	7,162	7,958	9,947	11,937
8.5	749	1,123	1,498	1,872	2,247	2,621	2,996	3,370	3,745	4,494	5,243	5,617	6,741	7,490	9,362	11,234
9	707	1,061	1,415	1,768	2,122	2,476	2,829	3,183	3,537	4,244	4,951	5,305	6,366	7,074	8,842	10,610
9.5	670	1,005	1,340	1,675	2,010	2,345	2,681	3,016	3,351	4,021	4,691	5,026	6,031	6,701	9,377	10,052
10	637	955	1,273	1,592	1,910	2,228	2,546	2,865	3,183	3,820	4,456	4,775	5,730	6,366	7,958	9,549
11	579	868	1,157	1,447	1,736	2,026	2,315	2,604	2,894	3,472	4,051	4,341	5,209	5,787	7,234	8,681
12	531	796	1,061	1,326	1,592	1,857	2,122	2,387	2,653	3,183	3,714	3,979	4,775	5,305	6,631	7,958
13	490	735	979	1,224	1,469	1,714	1,959	2,204	2,449	2,938	3,428	3,673	4,407	4,897	6,121	7,346
14	455	682	909	1,137	1,364	1,592	1,819	2,046	2,274	2,728	3,183	3,410	4,093	4,547	5,684	6,821
15	424	637	849	1,061	1,273	1,485	1,698	1,910	2,122	2,546	2,971	3,183	3,820	4,244	5,305	6,366
16	398	597	796	995	1,194	1,393	1,592	1,790	1,989	2,387	2,785	2,984	3,581	3,979	4,974	5,968
17	374	562	749	969	1,123	1,311	1,498	1,685	1,872	2,247	2,621	2,809	3,370	3,745	4,681	5,617
18	354	531	707	884	1,061	1,238	1,415	1,592	1,768	2,122	2,476	2,653	3,183	3,537	4,421	5,305
19	335	503	670	838	1,005	1,173	1,340	1,508	1,675	2,010	2,345	2,513	3,016	3,351	4,188	5,026
20	318	477	637	796	955	1,114	1,273	1,432	1,592	1,910	2,228	2,387	2,865	3,183	3,979	4,775
21	303	455	606	758	909	1,061	1,213	1,364	1,516	1,819	2,122	2,274	2,728	3,032	9,789	4,547
22	289	434	579	723	868	1,013	1,157	1,302	1,447	1,736	2,026	2,170	2,604	2,894	3,617	4,341
23	277	415	554	692	830	969	1,107	1,246	1,384	1,661	1,938	2,076	2,491	2,768	3,460	4,152
24	265	398	531	663	796	928	1,061	1,194	1,326	1,592	1,857	1,989	2,387	2,653	3,316	3,979
25	255	382	509	637	764	891	1,019	1,146	1,273	1,528	1,783	1,910	2,292	2,546	3,183	3,820

Tool failure and trouble shooting

Trouble		Causes	Solutions																
			Cutting condition					Tool shape						Grade		etc			
			Cutting speed	Feed	Depth of cut	Coolant	Up cut-down cut	Relief angle	Lead angle	Length of flute	Number of flute	Honing	Chip pocket	Toughness	Hardness	Machine rigidity	Machine vibration	Workpiece fixing	Overhang
Damage at cutting edge	Excessive periphery cutting edge	Improper cutting condition	↓	↑		◉											↑		
Damage at cutting edge	Chipping	Improper cutting condition Generating built up edge Weak tool rigidity Improper grade		↓			↓	↓				◉		↑			↓	↑	↓
Damage at cutting edge	Fracture during operation	Improper cutting conditions Excessive cutting load Excessive overhang		↓	↓					↓			↑			↑		↑	↓
Poor surface finish		Generating built-up edge	↑	↑		◉			↑			◉							
Poor surface finish		Chattering	↓				↓			↓						↑	↓	↑	↓
Poor surface finish		Poor straightness		↓	↓		↑		↑	↓									↓
Poor machining precision (Machined size, Perpendicularity)		Improper cutting conditions Improper tool shape	↑	↓			↓			↓	↑					↑	↓		↓
Bad chip evacuation		Excessive cutting volume Improper chip pocket Improper cutting conditions		↓	↓						↓		↑						

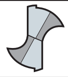
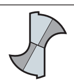
↑ : Increase ↓ : Decrease ● : use ◉ : Correct use

The shape of drills and the names

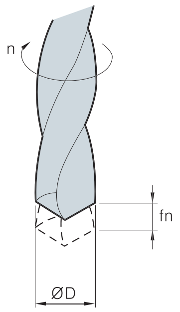


Shape and the feature of cutting

Helix angle	Plays rake angle of cutting edge's role. If helix angle increases Cutting force decreases. On the other hand If helix angle is too big Drill rigidity decreases. Poor machinability ◀ low - Helix angle - high ▶ Smooth chip evacuation Hard workpiece(hardened steel) ◀ low - Helix angle - high ▶ Soft material(aluminum etc)
Length of flute	The path of both chip evacuation and cooling lubricant. Too big length of flute weakens drill rigidity and too small length of flute worsens chip evacuation to breakage.
Point angle	Point angle has big influence on cutting performance. It mainly depends on workpiece. In case of standard drills Point angle is generally 118. thrust resistance decrease ◀ low - Point angle - high ▶ thrust resistance increase Torque increase, Burr on exit increase ◀ low - Point angle - high ▶ Torque decrease, Burr on exit decrease Soft material(aluminum etc) ◀ low - Point angle - high ▶ Hard workpiece(hardened steel)
Margin	While machining Margin is the part of contact between workpiece and drill's external. It prevents bending and plays guide's role . It depends on drill size. Cutting force decrease ◀ small - Margin - big ▶ Cutting force increase Poor guide ◀ small - Margin - big ▶ Good guide
Web thickness	Web is the part of center of drill and drill's rigidity depends on the web. Drill needs cutting edge, chisel edge, at the tip of drill because drill makes a hole at the beginning of drilling . When web thickness is big Thinning is needed to reduce cutting force. Cutting force decrease ◀ small - Web thickness - big ▶ Cutting force increase Rigidity decrease ◀ small - Web thickness - big ▶ Rigidity increase Good chip evacuation ◀ small - Web thickness - big ▶ Bad chip evacuation Soft material(aluminum etc) ◀ small - Web thickness - big ▶ Hard workpiece(hardened steel)
Back taper	Drill diameter size is getting smaller from point to shank in order to avoid the friction between drill periphery and workpiece. The decrease of diameter divided by flute length 100mm generally becomes 0.04~0.1mm. As for high performance drills and drills for hole shrinkage workpiece during operation have big back taper.
Thinning	In general drills Thrust effects on chisel over 50%. Chisel edge length depends on web thickness and chisel angle. But if web is thin Drill rigidity weaken. Therefore without web thickness change Thinning makes chisel edge short or gives rake angle. In other words, Thinning makes rake angle at chisel and improves chip evacuation and decrease thrust.

Types of	Edge shape	Feature	Korloy's drills
X type		Good centering High central thickness Crank shaft	Mach drill(MSD) Vulcan drill(VZD)
S type		For wide use For general Easy regrinding	Solid drill(SSD)

Major cutting formulas



Cutting speed	Feed	Helix angle	Machining time
$vc = \frac{\pi \cdot D \cdot n}{1000}$ (m/min)	$fn = \frac{vf}{n}$ (mm/rev)	$\delta = \tan^{-1}\left(\frac{\pi D}{L}\right)$	$tc = \frac{ld}{n \cdot fn}$ (min)
• vc : Cutting speed (m/min) • D : Drill diameter (mm) • n : Revolution per minute (min-1) • π : Circular constant (3.14)	• fn : Feed per revolution (mm/rev) • vf : Feed per minute (mm/min) • n : Revolution per minute (min^{-1})	• δ : Helix angle • D : Drill diameter (mm) • L : Lead (mm) • π : Circular constant (3.14)	• tc : Machining time (min) • n : Revolution per minute (min-1) • ld : Drilling time (mm) • fn : Feed (mm/rev)

Cutting torque and thrust(calculation formulas)

$$Md = KD^2 \times (0.0631 + 1.686 \times fn)(kg \cdot cm)$$

$$T = 57.95KDfn^{0.85}(kg)$$

• Md : Cutting torque (kg·cm)
• T : Cutting thrust (kg)
• D : Drill diameter (mm)
• fn : Feed per revolution(mm/rev)
• K : Material coefficient

Workpiece material(SAE/AISI)		Tensile strength(kgf)	Hardness(HB)	Material coefficient K
Cast iron	Cast iron (Gray)	21	177	1.00
	Cast iron	28	198	1.39
	Cast iron (Ductile)	35	224	1.88
General steel	1020(carbon steel C 0.2%)	55	160	2.22
	1112(C 0.12, S 0.2%)	62	183	1.42
	1335(Mn 1.75%)	63	197	1.45
Nickel Chrome steel	3115 (Ni 1.25, Cr 0.6, Mn 0.5)	53	163	1.56
	3120 (Ni 1.25, Cr 0.6, Mn 0.7)	69	174	2.02
	3140	88	241	2.32
Chrome molybdenum steel	4115 (Cr 0.5, Mo 0.11, Mn 0.8)	63	167	1.62
	4130 (Cr 0.95, Mo 0.2, Mn 0.5)	77	229	2.10
	4140 (Cr 0.95, Mo 0.2, Mn 0.85)	94	269	2.41
Nickel molybdenum steel	4615 (Ni 1.8, Mo 0.25, Mn 0.5)	75	212	2.12
	4820 (Ni 3.5, Mo 0.25, Mn 0.6)	140	390	3.44
Chrome steel	5150 (Cr 0.8, Mn 0.8)	95	277	2.46
Chrome vanadium steel	6115 (Cr 0.6, Mn 0.6, V 0.12)	58	174	2.08
	6120 (Cr 0.8, Mn 0.8, V 0.1)	80	255	2.22

Cutting torque and thrust (empirical formula)

$$Md = K_1 d^2 \cdot fn^m$$

$$T = K_2 d \cdot fn^n$$

• Md : Cutting torque (kg·cm)
• T : Thrust (kg)
• fn : Feed (mm/rev)
• K1, K2, m, n : Experimental Data Characteristic value
• d : Drill diameter (mm)

Workpiece	K_1	m	K_2	n
Soft steel	5.9	1.00	125.0	0.88
Rolled steel	3.5	1.00	55.0	0.88
7-3 brass	2.5	0.94	44.4	0.87
Aluminum	1.5	0.90	33.3	0.78
Zinc	1.4	0.88	27.0	0.74
Gun metal	2.0	0.94	21.6	0.75
Galvanized Iron	0.3	0.57	6.4	0.55

Tool failures and solutions

Trouble	Causes	Solutions																
		Cutting condition					Tool shape						Grade		etc			
		Cutting speed	Feed	Step feed	Initial feed	Coolant	Relief angle	Point angle	Thinning angle	Honing	Flute width rate	Thinning	Toughness	Hardness	Machine rigidity	Machine vibration	Guide bush	Clamping workpiece
Chipping	• Too sharp cutting edge (too big relief angle) (thinning edge is too sharp)						↓		↓	↑			↑					
Chipping	• Excessive cutting speed	↓				●												
Chipping	• Built-up edge					●	↓		↓	↑			↑					
Chipping	• Vibration and chattering	↓													↑	↓		●
Wear	• Excessive cutting speed (Abnormal wear at margin)	↓				●												
Wear	• Insufficient cutting speed (Abnormal wear at center)	↑				●												
Chip	• Long chip	↑	↑			●				↓								
Chip	• Over lap	↑	↑															
Chip	• Chip burning	↑				●												
Hole precision Burr, Poor surface finish	• Tool clamping precision				↓			↓		↓					↑	↓		●
Hole precision Burr, Poor surface finish	• Excessive feed, sharp point angle		↓					↑		↓								
Hole precision Burr, Poor surface finish	• Excessive cutting speed (Considered tool grade)	↑				●	↓	◉						↑				
Fracture – Breakage on contact	• Poor surface finish			●	↓												●	
Fracture – Breakage on contact	• Insufficient machine rigidity														↑			●
Fracture – Breakage on contact	• Improper cutting condition	↑	↓															
Fracture – Breakage at hole bottom	• Crooked hole	↑						↑				●				↓	●	
Fracture – Breakage at hole bottom	• Chip clogging		↓	●							↑							

↑ : Increase ↓ : Decrease ● : use ◉ : Correct use

Hole size for threading

Metric coarse screw threads

Specification			Hole diameter
M1	X	0.25	0.75
M1.1	X	0.25	0.85
M1.2	X	0.25	0.95
M1.4	X	0.3	1.1
M1.6	X	0.35	1.25
M1.7	X	0.35	1.35
M1.8	X	0.35	1.45
M2	X	0.4	1.6
M2.2	X	0.45	1.75
M2.3	X	0.4	1.9
M2.5	X	0.45	2.1
M2.6	X	0.45	2.2
M3	X	0.6	2.4
M3	X	0.5	2.5
M3.5	X	0.6	2.9
M4	X	0.75	3.25
M4	X	0.7	3.3
M4.5	X	0.75	3.8
M5	X	0.9	4.1
M5	X	0.8	4.2
M5.5	X	0.9	4.6
M6	X	1	5
M7	X	1	6
M8	X	1.25	6.8
M9	X	1.25	7.8
M10	X	1.5	8.5
M11	X	1.5	9.5
M12	X	1.75	10.3
M14	X	2	12
M16	X	2	14
M18	X	2.5	15.5
M20	X	2.5	17.5
M22	X	2.5	19.5
M24	X	3	21
M27	X	3	24
M30	X	3.5	26.5
M33	X	3.5	29.5
M36	X	4	32
M39	X	4	35
M42	X	4.5	37.5
M45	X	4.5	40.5
M48	X	5	43

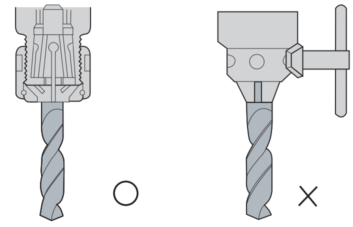
Metric coarse screw threads

Specification			Hole diameter
M2.5	X	0.35	2.2
M3	X	0.35	2.7
M3.5	X	0.35	3.2
M4	X	0.5	3.5
M4.5	X	0.5	4
M5	X	0.5	4.5
M5.5	X	0.5	5
M6	X	0.75	5.3
M7	X	0.75	6.3
M8	X	1	7
M8	X	0.75	7.3
M9	X	1	8
M9	X	0.75	8.3
M10	X	1.25	8.8
M10	X	1	9
M10	X	0.75	9.3
M11	X	1	10
M11	X	0.75	10.3
M12	X	1.5	10.5
M12	X	1.25	10.8
M12	X	1	11
M14	X	1.5	12.5
M14	X	1	13
M15	X	1.5	13.5
M15	X	1	14
M16	X	1.5	14.5
M16	X	1	15
M17	X	1.5	15.5
M17	X	1	16
M18	X	2	16
M18	X	1.5	16.5
M18	X	1	17
M20	X	2	18
M20	X	1.5	18.5
M20	X	1	19
M22	X	2	20
M22	X	1.5	20.5
M22	X	1	21
M24	X	2	22
M24	X	1.5	22.5
M24	X	1	23
M25	X	2	23
M25	X	1.5	23.5
M25	X	1	24
M26	X	1.5	24.5
M27	X	2	25

Cautions

● Selection of drill chuck

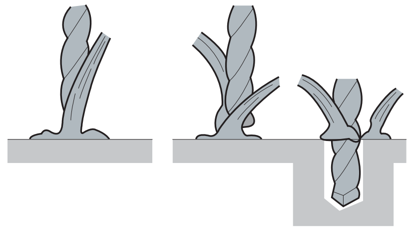
• Collect chuck is favorable Because it has strong grip power
(General drill-chuck and Keyless chuck don't have enough grip power.)



• Collect chuck • General drill-chuck

● Coolant supply

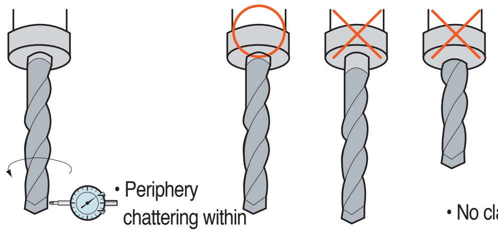
• Supply enough coolant around hole entrance.
• Standard cutting oil pressure : 3~5kg/㎠, Flux : 2~5l/min.



• Supply much coolant at hole entrance

● Mounting drill

• When mounting drill Periphery chattering should be within 0.02㎜.
• Flute should not be clamped.

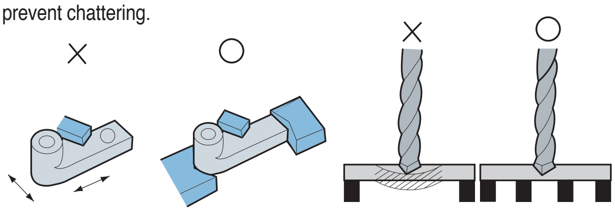


• Periphery chattering within 0.02㎜

• No clamping flute

● How to clamp workpiece

• At high performance drilling High thrust, torque and horizontal cutting force work at the same time so that workpiece should be clamped strongly to prevent chattering.



• Uniformed and strong clamping is needed (Right and left, up and down)

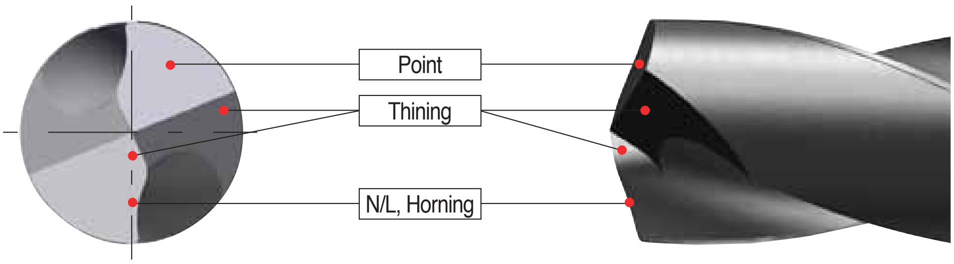
• Strong clamping is needed because bending causes chipping

Notice

1) For better drill's life, small damage and wear are favorable to be regrinding.
2) Damage and wear size should be within 1.5㎜ for regrinding.
3) If drill has crack, regrinding is impossible.
4) Ordering for regrinding is acceptable or purchase regrinding machine

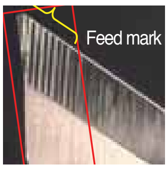
Regrinding procedures

● Regrinding mathod (Mach Drill)



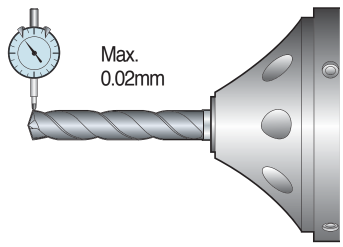
1) Preparation

- Determination of regrinding areas Check the cutting edge for damage and wear If large fracture is found, remove it by rough grinding.



2) Grinding operation

- Drills setting
  Drill is clamped to collet chuck Chattering is kept within 0.02mm.

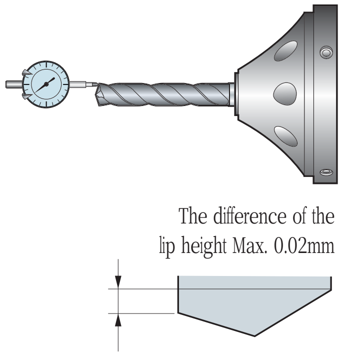


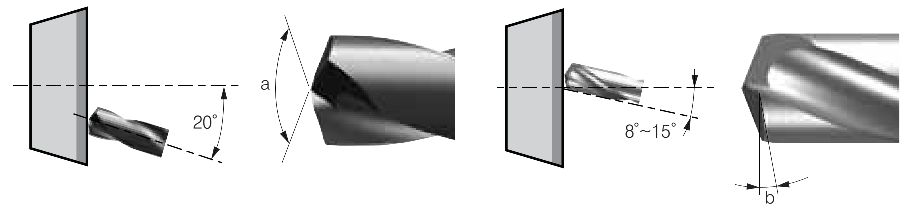
3) Grinding operation-Grinding point

- Check damage and wear at the point and remove it completely.
- The difference of the lip height is kept within 0.02mm.

Point angle(a) : 140°

Point relief angle(b)t : 8°~ 15°



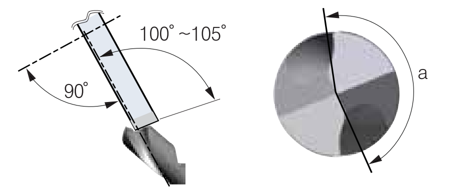


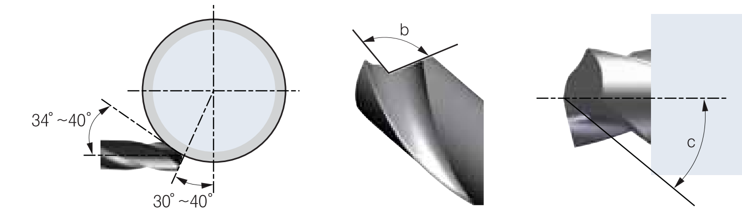
4) Grinding operation-Thinning grinding

- Considering N/L width Cutting edge length from the center of drill axis should be 0.03~0.08mm for balancing.
- Set the wheel to tilt drill axis by 34°~ 40°.

Thinning angle(a)° : 155°~ 160°/ Thining open angle(b) : 100°~ 105°

Thinning relief angle(c) : 34°~ 40°

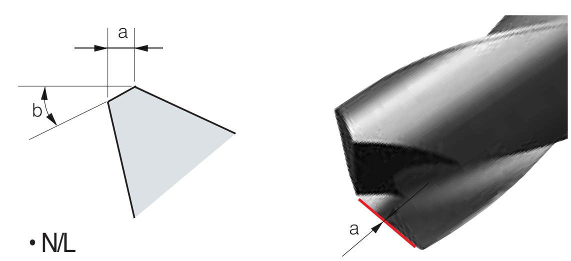




5) Grinding - N/L grinding and honing

- Using diamond chisel Grinds the width flat along point cutting edge.
- After negaland operation Finishes with brush or handstone.

N/L width(a) : 0.05mm~0.16mm / N/L angle(b) : 24°~26°



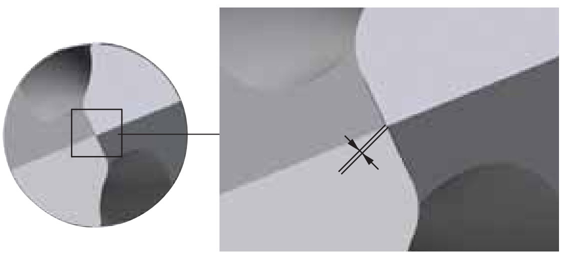
● TIP

· Making point

- Without center drill, the point width should be below 0.10mm.

· Recommended grinding condition

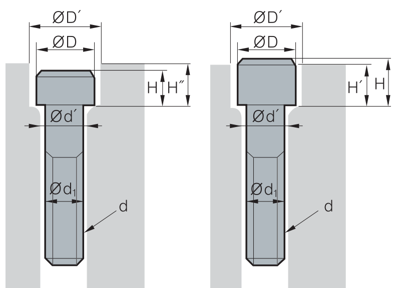
- Diamond wheel : 240~400 mesh
- Diamond chisel : 400~600 mesh
- Diamond hand stone : 800~1500 mesh



Hexagonal socket bolt(Clamping screw) size

● Counter boring and size of bolt hole for hexagonal socket bolt

ISO (d)	M3	M4	M5	M6	M8	M10	M12	M14	M16	M18	M20	M22	M24	M27	M30
Ød₁	3	4	5	6	8	10	12	14	16	18	20	22	24	27	30
Ød′	3.4	4.5	5.5	6.5	8.5	11	14	16	18	20	22	24	26	30	33
ØD	5.5	7	8.5	10	13	16	18	21	24	27	30	33	36	40	45
ØD′	5	8	9.5	11	14	17.5	20	23	26	29	32	35	39	43	48
H	3	4	5	6	8	10	12	14	16	18	20	22	24	27	30
H′	2.7	3.6	4.6	5.5	7.4	9.2	11.0	12.8	14.5	16.5	18.5	20.5	22.5	25	28
H″	3.3	4.4	5.4	6.5	8.6	10.8	13.0	15.2	17.5	19.5	21.5	23.5	25.5	29	32



The comparison of chip breakers

		APPLICATION		KORLOY	KYOCERA	TAEGUTEC	SUMITOMO	SANDVIK	KENNAMETAL	ISCAR	WLATER	MITSUBISHI	SECO
NEGATIVE	P	Steel	Ultra-Finishing	- VL	DP (G) GP, PP	- FA	- FA, FL	- QF	FF(G) UF	- SF	- NF3	PK(G) FH,FS	- FF1
			Finishing	VF VB	HQ -	FG SF	LU, SU SE	PF 61	FN -	NF F3M	NF4 PF5	SH, C LP	FF2 -
			Medium to finishing	VQ, HC VC	CQ PQ	MC FC	SX -	- -	LF, CT -	TF -	NS6 MP3	SA, C() MV	MF2, MF3 MF5
			Medium machining	GM, HM, VM -	HK, CS GS HS, PS -	MP, MT PC	GU, UX GE	QM, SM PM	MP, MN -	GN M3M	NM4, NP5 NM5,NM6	MA,MH MP	M3, M5 -
			Roughing	B25 HR, GR	PT,GT, HT, PH	RT	- MU,ME, MX	- PR	- RN	- NR, R3M	- NM9, PP5	GH, RP	M5 MR5,MR6, MR7
			Heavy duty machining	GH VH VT	PX HX -	RH, RX HZ HT, HY	HG, MP HP HU,HW,HF	PR QR HR	RH RM MM	NM HR -	NR4, NRF NR8 -	HZ HV, HX, HAX HBS,HCS, HDS,HXD	R4,R5 R6, R7, R8 RR6, PR9, R56,R57,R68
		Low carbon steel	Soft steel	VL -	XF, XP, XP-T XQ, XS	SF -	FL -	LC -	- -	- -	- -	FY SY	- -
		High feed	High feed cutting	VW LW -	WP WQ -	WS WT -	LUW,SEW GUW -	WF,WL WM,WMX WR	FW MW RW	WF WG -	NF NM -	SW MW -	FF2, MF2 MF5, M3 R4,R7
		Application	Shaft (long bar)	SH KNUX-	CJ, ST KNMX-	FS, VF, FX KNUX-	HM -	K KNUX-71	- -	- -	- -	ES KNMX-19	UX -
	M	Stainless steel		HA, VP2 GS, HS VM	MQ, GU HU, TK, MU MS	EA MP, EM ET	SU EX, GU MU, HM	MF MM MR	FP MP RP	F3P M3M R3M	NF4 NM4 NR4	LM MA, GM, MM RM	MF1 MF3 M5
	K	Cast iron		VM GR, VK -MA	C ZS -MA, GC	MT RT KT -MA	UZ UX, GZ -MA	KF KM KR	FN RP UN	TF GN -MA	NM, MK5 NM5, RK5 -MA, MK5	LK MA, MK GH, -MA, RK	M4 M5 MR7
	S	HRSA		VP1 VP2 VP3 VM	MQ TK MS,MU -	EA ML EM ET	EF UP, EG EX MU	- 23.SR Xcel-SM -	FS, LF MS MP RP	PF PP VL -	NF4 - NM4 NR4	FJ(G), LS MJ MS, MS GJ, RS	M1 MF1 MF4 MR4
	N	Aluminium		HA	AH	ML	UP (GX), AG	23	MS	PP	-	MJ	MF1
POSITIVE	P M K	Application	Finishing	VL VF	XP GP	FA -	LU FP, FC, SI	PF UF	UF -	- PF	PF PF, PF2	FV SV	FF1 F1
			Medium machining	- HMP	XQ HQ,CK	FG PC	- SU, SC	PM UM	LF -	14 SM	- PF4,PF5	- MV	MF2 F2
			Roughing	C25		MT	MU	PR, UR	MF	-	PM5		M5
		High feed		- -	- -	- WT	LUW -	WF WM	FW MW	WF -	PF PM	SW MW	F1 F2
	M,S	Stainless steel For HRSA		VP1 -	CF,GF,GQ MQ	FG SA	FC -	KF KM	LF MF	PF SM	PM PM5	FJ, LM AM, MM	F1 MF2
	K	Cast iron		HMP C25	GK HQ	PC MT	MU C/B	UM KR	LF MF,UF	17 19	- C/B	C/B	M3 M5
	N	Aluminium		AK, AR	AH	FL	AW, AG	AL	HP	AS, AF	PM2	F	AL
		High precision bar turning (tolerance class G&E)		KF, KM	FSF,USF	GF, FF	FY, FX,FZ	UM	-GH	LF,RF,XL	-	F, SR, SS, SM	UX

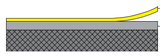
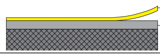
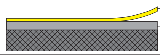
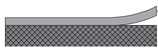
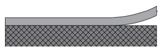
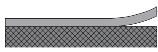
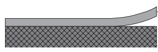
KORLOY Grades

Cat.	ISO	Grade	Range	Workpiece Application	Turning	Milling	Facing	Grooving	Threading	Parting	Index Drill	Solid Drill	Endmill	Coating layer
CVD	P	NC3010	P05-P15	High speed Cutting for Steel	●			●		●				Al_2O_3, MT−TiCN
		NC3220 (New)	P15-P25	Medium for Steel	●			●		●				TiN, Al_2O_3, MT−TiCN, TiN
		NC3120	P15-P25	Medium for Steel	●		●	●		●				Al_2O_3, TiC, MT−TiCN
		NC3030	P25-P35	Roughing & Intermittent Cutting for stael	●			●		●				TiN, Al_2O_3, TiC, MT−TiCN
		NC5330 (New)	P30-P40	General Cutting for Mild Steel & Forging Steel	●	●	●	●		●	●			TiN, Al_2O_3, MT−TiCN
		NC500H	P25-P35	Heavy Cutting for Steel	●					●				Al_2O_3, MT−TiCN
		NCM325	P20-P30	High speed milling Cutting for Steel		●			●		●			TiN, Al_2O_3, MT−TiCN
		NCM335	P30-P40	Roughing & Intermittent Milling Cutting for stael High speed Cutting for castiron		●								TiN, Al_2O_3, MT−TiCN
	K	NC6205 (New)	K01-K10	General Cutting for gray castiron & ductile castiron	●			●						Al_2O_3, MT−TiCN
		NC6210 (New)	K05-K15	General Cutting for gray castiron & ductile castiron	●			●						Al_2O_3, MT−TiCN
		NC315K	K10-K20	Low speed & intermittent Cutting for castiron	●			●						Al_2O_3, MT−TiCN
		NC5330	K20-K30	General stainless Steel	●	●		●		●				TiN, Al_2O_3, MT−TiCN
	M	NC9025	M25-M35	Stainless Steel	●									TiN, Al_2O_3, MT−TiCN
		NC5330	M25-M35	General Steel(1st Rec.)		●	●	●		●	●			TiN, Al_2O_3, MT−TiCN
		NCM325	M20-M30	High speed Milling Cutting for stainless Steel		●				●	●			TiN, Al_2O_3, MT−TiCN
		NCM335	M30-M40	Roughing & Intermittent Milling Cutting for stainless stael		●								TiN, Al_2O_3, MT−TiCN
	S	NC5330	S20-S30	Intermittent Cutting for Heat resistance Alloy	●		●	●		●	●			TiN, Al_2O_3, MT−TiCN
PVD	P	PC230	P15-P30	Finishing, Medium Cutting for Steel		●			●		●			TiAℓN
		PC3600	P25-P35	Medium, Roughing Milling Cutting (1st Rec.) for Steel		●	●	●	●		●			TiN, ★New TiAℓN film
		PC5300	P30-P40	Medium, Roughing Milling Cutting for Steel	●	●	●	●	●	●				★New TiAℓN film (High hardness / Oxidation resistance)
		PC3545	P35-P45	Medium, Roughing, Heavy Intermittent Milling Cutting for Steel		●								TiN, TiAℓN
		PC3030T	P20-P30	Threading Cutting for Steel					●					TiAℓN
		PC203F	P01-P10	High speed E/M Cutting for Steel										★New TiAℓN film (High hardness / Oxidation resistance)
		PC210F	P10-P20	General & Alloy Steel, High speed Milling Cutting										★New TiAℓN film (High hardness / Oxidation resistance)

KORLOY Grades

Cat.	ISO	Grade	Range	Workpiece Application	Turning	Milling	Facing	Grooving	Threading	Parting	Index Drill	Solid Drill	Endmill	Coating layer
PVD	P	PC3600 (New)	P15-P35	General milling for steel		●								★New TiAlN film (High hardness / Oxidation resistance)
	P	PC220	P15-P35	General E/M Cutting for Steel									●	★New TiAlN film (High hardness / Oxidation resistance)
	P	PC205F	P15-P30	Drill Cutting (general)/ under Ø20 for Solid Drill								●		TiAlN
	K	PC8110	K01-K15	Milling, Turning Cutting Finishing for cast iron	●	●		●						★New TiAlN film (High hardness / Oxidation resistance)
	K	PC6510	K01-K15	High speed Milling Cutting for castiron		●			●		●			TiN / TiAlN
	K	PC5300	K15-K25	Medium & Roughing Turning/Milling Cutting for castiron	●	●	●	●	●	●	●			★New TiAlN film (High hardness / Oxidation resistance)
	K	PC203F	K01-K10	High speed I E/M Cutting for castiron									●	★New TiAlN film (High hardness / Oxidation resistance)
	K	PC220	K15-K35	General E/M Cutting for castiron									●	★New TiAlN film (High hardness / Oxidation resistance)
	K	PC205F	K10-K20	Drill Cutting(General)/ under ϕ20 for Solid Drill								●		TiAlN
	K	PC215K	K15-K30	Medium & Roughing Milling Cutting for castiron		●	●	●	●					TiAlN
	M	PC8110	M01-M10	Finishing to Medium Cutting for stainless Steel	●			●		●				★New TiAlN film (High hardness / Oxidation resistance)
	M	PC5300	M20-M35	Medium, Roughing Turning/Milling Cutting for stainless Steel	●	●	●	●	●	●	●			★New TiAlN film (High hardness / Oxidation resistance)
	M	PC9030	M20-M35	Medium, Roughing & Intermittent Turning Cutting for stainless Steel	●		●	●		●				TiAlN
	M	PC9530	M20-M35	Medium, Roughing & Intermittent Milling Cutting for stainless Steel		●					●			TiAlN
	M	PC3545	M30-M50	Roughing/ Heavy Inermittent Milling Cutting stainless Steel		●								TiN / TiAlN
	M	PC3030T	M20-M30	Threading Cutting for stainless Steel					●					TiAlN
	M	PC210	M15-M30	General E/M Cutting for stainless Steel									●	★New TiAlN film (High hardness / Oxidation resistance)
	M	PC205F	M15-M30	Drill Cutting(General)/ under ϕ20 for Solid Drill								●		TiAlN
	S	PC8110	S01-S20	Medium to Finishing Turning Cutting for Heat resistant Alloy Steel	●			●		●				★New TiAlN film (High hardness / Oxidation resistance)
	S	PC5300	S15-S25	Medium to Roughing Turning/Milling Cutting for Heat resistant Alloy Steel	●	●	●	●	●	●	●		●	★NewTiAlN film (High hardness / Oxidation resistance)
	S	PC3545	S30-S50	Roughing/ Heavy Intermittent Milling Cutting for Heat resistant Alloy Steel		●								TiN / TiAlN
	S	PC210	S15-S30	General E/M Cutting for Heat resistant Alloy Steel									●	★New TiAlN film (High hardness / Oxidation resistance)
	S	PC205F	S15-S25	Drill Cutting(General)/ under ϕ20 for Solid Drill								●		TiAlN

KORLOY Grades

Cat.	ISO	Grade	Range	Workpiece Application	Turning	Milling	Facing	Grooving	Threading	Parting	Index Drill	Solid Drill	Endmill	Coating layer
Uncoated	P	A30	P25-P35	General Cutting for Steel	●		●		●	●				
Uncoated	K	H01	K05-K15	Finishing Cutting for castiron, Nonferrous Metal(Al. etc)	●			●			●		●	
Uncoated	K	H05	K05-K15	Finishing for cast iron	●	●								
Uncoated	K	G10	K15-K25	Medium Cutting for castiron	●	●		●						
Uncoated	N	H01	N05-K15	Finishing Cutting for castiron, Nonferrous Metal(Al. etc)	●			●			●		●	
Cermet	P	CC105	P01-P10	High speed light Cutting for Steel (optimal precise boring)	●									 TiN TiAℓN
Cermet	P	CC115	P10-P20	Medium, High speed light Cutting for Steel	●									 TiN TiAℓN
Cermet	P	CC125	P15-P25	Medium, Roughing Milling Cutting for Steel	●									 TiN TiAℓN
Cermet	P	CN1000	P05-P15	Highspeed Cutting for Steel(Sintered Metal Cutting)	●									
Cermet	P	CN20	P15-P25	General Turning/Milling Cutting for Steel	●	●		●	●	●				
Cermet	P	CN2000	P10-P20	Medium, Roughing Turning/ Milling Cutting for Steel	●	●		●		●				
Cermet	P	CN30	P20-P30	Roughing Milling Cutting for Steel	●									
Cermet	K	CN1000	K05-K10	High speed Cutting for Castiron	●									
cBN	H	KB410	H01-H10	High speed continuous Cutting for Heat treatment steel	●									
cBN	H	KB420	H05-H15	High Efficiency Cutting for Heat treatment steel	●									
cBN	H	DBN210	H10-H20	High speed continuous/light intermittent Cutting for Heat treatment steel	●									
cBN	H	KB425	H15-H25	High speed intermittent Cutting for Heat treatment steel	●									
cBN	H	KB320	H15-H25	Continuous, intermittent Cutting for Heat treatment steel	●									
cBN	H	DBN350	H25-H35	Intermittent Cutting for Heat treatment steel(Heavy intermittent)	●									
cBN	K	KB350	K01-K10	High Hardness cutting for castiron	●									
cBN	K	KB370	K05-K15	High speed cutting for castiron	●	●								
PCD	N	DP90	N01-N10	Cemented carbide, Ceramic roughing, High Si-Al alloy, Rock, Stone	●									
PCD	N	DP150	N05-N15	High Si-Al alloy, copper Alloy, Rubber, Wood, Carbon	●									
PCD	N	DP200	N10-N20	Plastic, Wood, Al precise finishing Cutting	●									
DLC	N	PD1000	N01-N20	Nonferrous(Al. etc) Turing cutting	●									 DLC
DLC	N	PD2000	N01-N20	Nonferrous(Al. etc) Milling cutting		●								 DLC
DLC	N	PD3000	N01-N20	Nonferrous(Al. etc) E/M cutting									●	 DLC
Diamond Coating	N	ND1000	N01-N20	Nonferrous(graphite, Al, Bronze) Turning cutting	●									 Dia Coating
Diamond Coating	N	ND2000	N01-N20	Nonferrous(graphite, Al, Bronze) Milling cutting		●								
Diamond Coating	N	ND3000	N01-N20	Nonferrous(graphite, Al, Bronze) E/M cutting									●	

The comparison of grade for turning

WC

ISO	KORLOY	SUMITOMO	KYOCERA	ISCAR	SANDVIK	SECO	KENNAMETAL	TOSHIBA	MITSUBISHI	HITACHI	VALENITE	WALTER	TAECUTEC	NTK	DIJET
Turning P	ST50E ST10P ST20E MA2 ST30E A30 ST30N ST40E	ST10P ST20E A30 ST40E	PW30	IC50M IC54	S1P SM30 S30T S6	TTX TTM TTR	K45 KM K420	TX10S TX20 TX30 TX40	STi10T STi20T UTi20T	SRN5 WS20B EX35 EX40 EX45	S1F VC6 VC5 VC56		P10 P20 P30 P40		
Turning M	U10E U2 A40	U10E U2 A30 A40			H13A H10F	AT10 AT15 TTR	K2885 K2S	TU10 TU20 TU40	UTi20T	WAM10B EX35	VC27 VC28		M10 M20 M40		
Turning K	H2 H01 H05 H10 G10E	H1 G10E	KW10H	IC4 IC20 IC28	H1P H10F	THM THR	K68 K8735	TH03 TH10 KS20	HTi10T HTi20T	WH05 W10 WH20	VC3 VC2 VC1		K10 K20 K20M K30		

CVD Coated

ISO	KORLOY	SUMITOMO	KYOCERA	ISCAR	SANDVIK	SECO	KENNAMETAL	TOSHIBA	MITSUBISHI	HITACHI	VALENITE	WALTER	TAECUTEC	NTK	DIJET
Turning P	NC3010 NC3220★ NC3120 NC3030 NC5330★ NC500H	AC810P AC820P AC830P	CA5505 CA5515 CA5525 CA5535	IC8150 IC8250 IC8350	GC4205 GC4215 GC4225 GC4235	TP0500 TP1500 TP2500 TP3500	KCP05 KCP10 KCP25 KU30 KCP40	T9105 T9115 T9125 T9135	UE6105 UE6110 UE6020 UE6035	HG8010 HG8025 GM8035	VP5515 VP5525 VP5535	WPP01 WPP05 WPP10 WPP20 WPP30	TT8115 TT8125 TT8135 TT7100	CP5	JC110V JC215V JC325V JC450
Turning M	NC9020 NC9025	AC610M AC630M	CA6515 CA6525	IC8250 IC8350	GC2015 GC2025	TM2000 TM4000	KCM15 KCM25 KCM35	T6020 T6030	US7020 US735	GM25 GX30	VP8515 VP8525	WAM10 WAM20	TT9215 TT9225 TT9235		TT9215 TT9225 TT9235
Turning K	NC6205★ NC6210★ NC315K NC5330★	AC410K AC420K	CA4505 CA4515 CA4120	IC5005 IC5010	GC3205 GC3210 GC3215	TK1001 TK2001	KCK05 KCK15 KCK20	T5105 T5115 T5125	UC5105 UC5115	HG3505 HG3515	VP1505 VP1510 VP1515	WAK10 WAK20	TT1300 TT7310	CP2 CP5	JC105V JC110V JC215V

PVD Coated

ISO	KORLOY	SUMITOMO	KYOCERA	ISCAR	SANDVIK	SECO	KENNAMETAL	TOSHIBA	MITSUBISHI	HITACHI	VALENITE	WALTER	TAECUTEC	NTK	DIJET
Turning P	PC230 PC5300★ PC3545		PR1005 PR915 PR1115 PR930 PR1025 PR630 PR660	IC507 IC808★ IC830★ IC908 IC3028 IC330★	GC1025 GC4125	CP200 CP250 CP500	KU10T KU25T	AH710 GH730 AH330 AH740 AH120 GH330	VP15TF VP20MF	IP2000 IP3000	VC907 VC927 VC905	WTA43 WTA41	TT5030		JC5003 JC5015
Turning M	PC8110★ PC5300★ PC9030	AC510U EH510Z AC520U EH520Z AC530U★	PR915 PR930 PR1125 PR630 PR660	IC808★ IC907 IC3028 IC830★ IC330★	GC1005 GC1105★ GC1020 GC1025 GC4125	CP200 CP250 CP500	KC5010 KC5510★ KC5025 KC5525	AH330 GH330 AH120 GH730 AH140	VP05RT VP10RT VP15TF VP20MF	IP50S★ IP100S★	VC929 VC927 VC902 VC901 VC905		TT5030	ZM3 QM3 VM1 TAS	JC5003 JC5015
Turning K	PC5300★	EH510Z EH520Z		IC5100★ IC810★ IC220 IC908 IC228		CP200 CP250 CP500		AH110 GH110 AH120		CY110H	VC929 VC903 VC927 VC902 VC901 VC907		TT5030		
Turning S	PC8110★ PC5300★	AC510U AC520U	PR915 PC660	IC808★ IC907 IC3028	GC1105 GC1025	TS2000★ CP500 TS2500★	KC5010 KC5025	AH110 AH120	VP05RT VP10RT VP15TF				TT5030		

CERMET

ISO	KORLOY	SUMITOMO	KYOCERA	ISCAR	SANDVIK	SECO	KENNAMETAL	TOSHIBA	MITSUBISHI	HITACHI	VALENITE	WALTER	TAECUTEC	NTK	DIJET
Turning P	CN1000 CC115★ CN2000 CN20	T110A T2000Z★ T1500A★ T3000Z★	PV30★ TN30 PV60★ TN60 TN6020 TN90	IC20N IC520N IC30N IC530N	CT5015 CT525 GC1525★	CM C15M TP1020 TP1030★	HT2 KT125 HT5 KT175 KT195M	NS520 GT530★ NC530 NC540 NC730	NX2525 NX3035 UP35N★ AP25N★ NX335	CH350 CZ25★ CH530 CH550 CH570	VC83	WTA43★ WTA41★	PV3010★ CT3000	T3N T15 N20 C30 N40	LN10 CX50 CX75 CX90 CX99
Turning M		T1500A★							NX2525						LN10 CX75 CX99
Turning K	CN1000	T110A T1500A★							NX2525				CT3000	T15	LN10 CX75

★ : PVD Coating cermet ★ : New Grade

The comparison of grade for milling

CVD Coated

ISO		KORLOY	SUMITOMO	KYOCERA	ISCAR	SANDVIK	SECO	KENNAMETAL	TOSHIBA	MITSUBISHI	HITACHI	VALENITE	WALTER	TAECUTEC	NTK	DIJET
Milling	P	NC5330★ NCM325 NCM335	ACP100		IC5400	GC4220 GC4230 GC4240	MP1500 MP2500 T25M T350M		T3130	FH7020 F7030		SM245	WQM15 WKP25 WQM25 WKP35 WQM35	TT7400 TT7800		
	M	NC5330★ MCM325 NCM335				GC2040	MP2500 GC2040		T3130	F7030			WQM25 WTP35			
	K	NC5330★	ACK200		IC5100	GC3220	MK1500 MK3000	KC992M	T1115 T1015	MC5020		V01 VN8	WAK15 WKP25 WKP35	TT6800		

PVD Coated

ISO		KORLOY	SUMITOMO	KYOCERA	ISCAR	SANDVIK	SECO	KENNAMETAL	TOSHIBA	MITSUBISHI	HITACHI	VALENITE	WALTER	TAECUTEC	NTK	DIJET
Milling	P	PC210F PC3600 PC3500 PC5300★ PC3545	ACZ310 ACP200 ACZ330 ACP300 ACZ350	PR730 PR830 PR630 PR660	IC903 IC908 IC950 IC1008 IC928	GC1010 GC1025 GC1030 GC1030	MP3000★ F25M F30M F40M T60M	KC522M KUC20M KC525M KUC30M KC935M KC7140 KC720	GH330 AH120	AP20M GP20M VP15TF UP20M VP30RT	ATH80D PCA08M ACS05E PCA12M PC20M JX1005 TB6005 JX1020 CY9020 TB6045 CY250 PTH30E PTH40H	VC935		TT7070 TT7080 TT7030 TT8020	QM3 ZM3	JC5003 JC5015 JC5030 JC5040
	M	PC5300★ PC9530 PC3545	ACP200 ACP300 ACZ350	PR730 PR1025 PR630 PR660	IC903 IC900 IC250 IC928 IC328	GC1125 GC1025 GC2030 GC1030	F25M F30M F40M	KC5510 KC7020 KC522M KC725M KC735M KC7030 KC722	AH120 AH140		JX1020 CY9020 JX1015 TB6020 CY250 JX1045 TB6045 JX1060 TB6060	VC928 VC902 VC901	WQM35 WSP45	TT9030 TT9080 TT8020	QM3 ZM3	JC5003 JC5015 JC5030 JC5040
	K	PC8110★ PC6510 PC5300★		PR510 PR905	DT7150 IC900 IC910 IC950 IC350			KC510M KC915M KC520M	AH120	VP10MF VP15TF VP20RT		VC903 VC928 VC902 VC901		TT6290 TT6030 TT6060		JC5003 JC5015
	S	PC5300★	AC520U	PC660	IC328	GC1025	TS2500	KC510M		VP15TF	ACS05E			TT9030		

CERMET

ISO		KORLOY	SUMITOMO	KYOCERA	ISCAR	SANDVIK	SECO	KENNAMETAL	TOSHIBA	MITSUBISHI	HITACHI	VALENITE	WALTER	TAECUTEC	NTK	DIJET
Milling	P	CN2000 CN20 CN30	T250A	TN100M TC60M	IC30N			KT195M	NS540 NS740	NX2525 NX4545	CH550 CH570			CT3000 CT7000	C50	
	M		T250A			CT530										
	K									NX2525						

★ : PVD Coating cermet ★ : New Grade