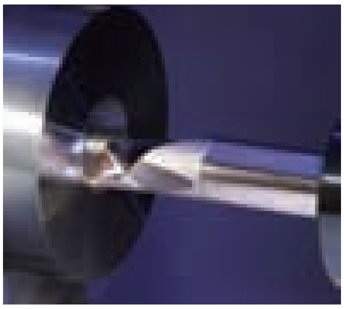
Tungaloy

Keeping the Customer First

Tungaloy Catalogue TE0707-E2

2007

Cutting Tools



www.tungaloy-eu.com

Grades and Technical Data

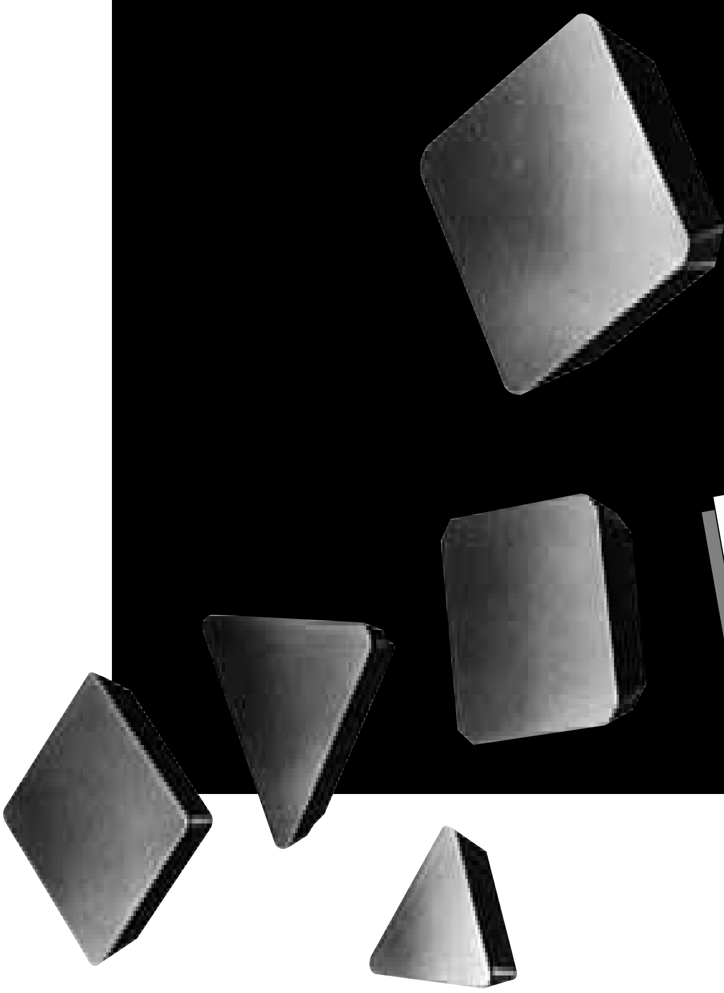
12

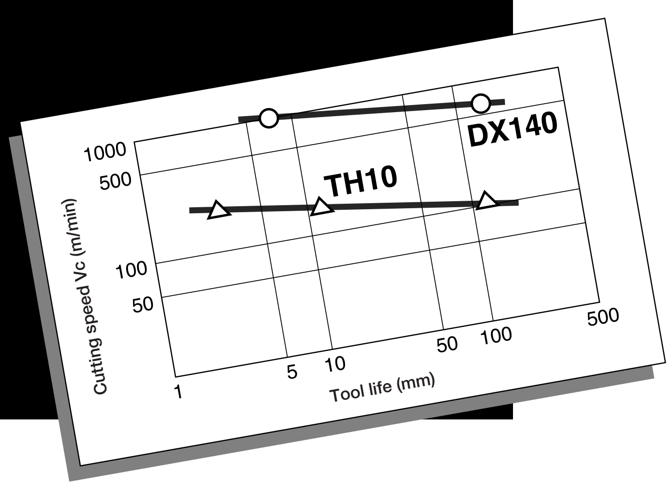
Grades

- Grade Selection 454
- CVD Coated Grades for Turning 456
- CVD Coated Grades for Milling 458
- PVD Coated Grades 459
- Cermet Grades 460
- PCBN (T-CBN) Grades 462
- PCD (T-DIA) Grades 464
- Ceramics Grades 465
- Uncoated Cemented Carbide Grades 466
- Ultra-fine Grain Cemented Carbide Grades 467

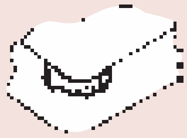
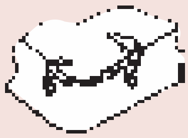
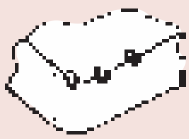
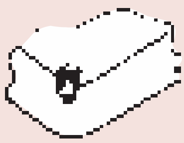
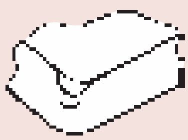
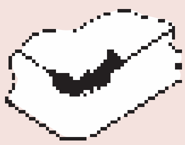
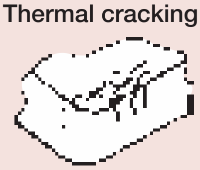
Technical data

- Turning Tools 468
- Chip forming 473
- Milling Tools 476
- Drilling Tools 481
- Appendix 486
- Approximate Conversion Table of Hardness 491
- Surface Roughness 492
- Grade Comparison Charts 493
- Chipbreaker Comparison Charts 499

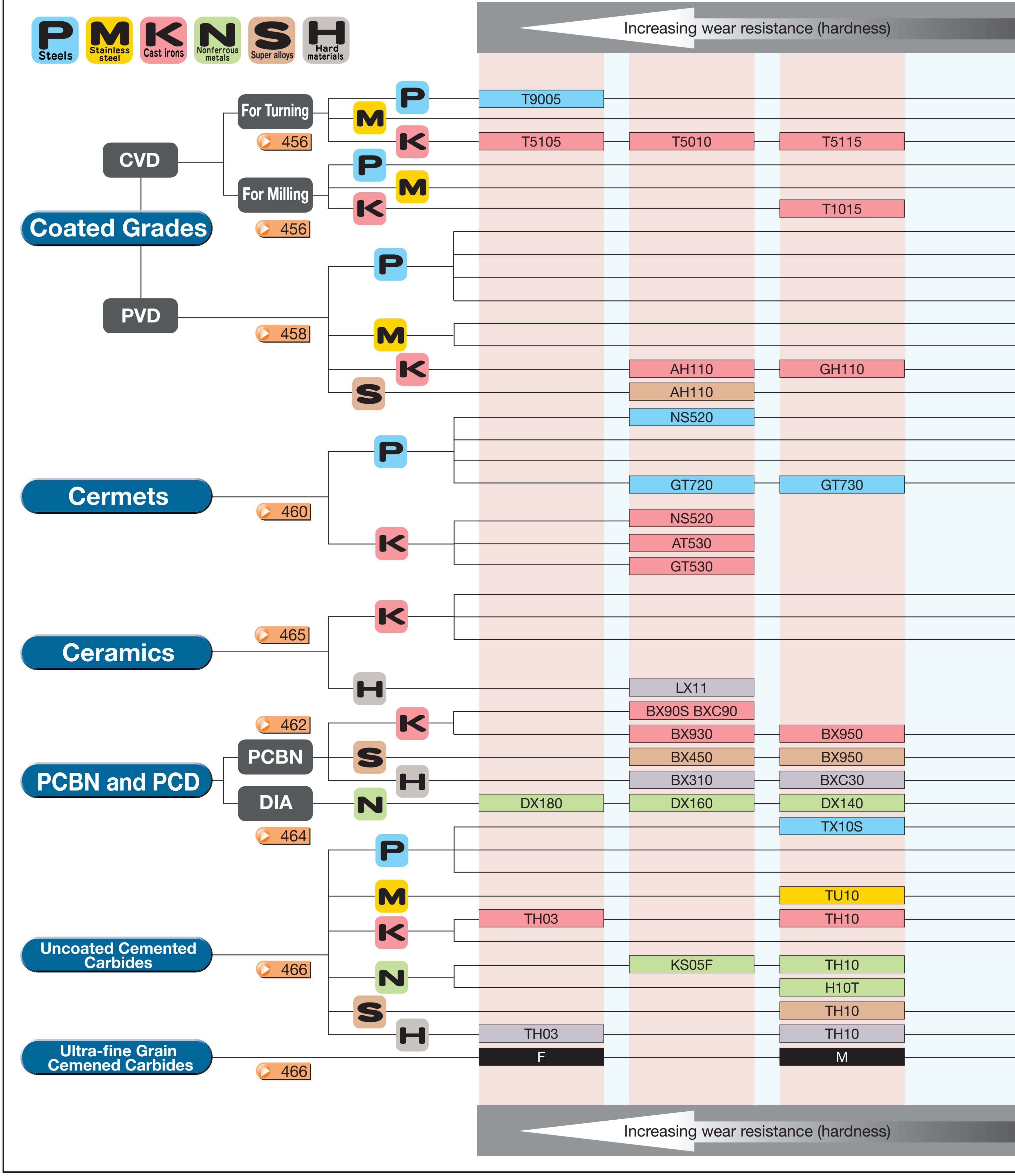




■ Troubleshooting for turning

Typical tool failure	Countermeasures		
	Tool grade	Cutting conditions	Tool geometry
Flank wear 	• Change to more wear resistant grades. P. M. K30 → 20 → 10	• Reduce cutting speed. • Change to appropriate feed.	• Increase relief angle. • Increase end cutting edge angle. • Increase corner radius. • Select free-cutting chipbreaker.
Crater wear 	• Change to more wear resistant grades. P. M. K30 → 20 → 10	• Reduce cutting speed. • Reduce feed.	• Increase rake angle. • Select an appropriate chipbreaker.
Notch wear 	• Change to more wear resistant grades. P. M. K30 → 20 → 10	• Reduce cutting speed. • Reduce feed.	• Increase rake angle. • Increase side cutting edge angle.
Fracture 	• Change to tougher grades. P. M. K10 → 20 → 30	• Reduce feed. • Reduce cutting depth.	• Reduce rake angle. • Select a chipbreaker with high edge strength. • Increase honing width. • Increase side cutting edge angle. • Select larger shank size.
Chipping 	• Change to tougher grades. P. M. K10 → 20 → 30	• Reduce feed. • Increase cutting speed.	• Reduce rake angle. • Select a chipbreaker with high edge strength. • Increase honing width. • Increase side cutting edge angle. • Select larger shank size.
Flaking 	• Change to tougher grades. P. M. K10 → 20 → 30	• Reduce feed. • Reduce cutting speed.	• Reduce rake angle. • Increase corner radius • Increase honing width.
Plastic deformation 	• Change to more wear resistant grade. P. M. K30 → 20 → 10	• Reduce cutting speed. • Reduce feed. • Reduce cutting depth. • Supply cutting fluid in adequate volume.	• Increase relief angle. • Increase rake angle. • Reduce corner radius. • Reduce side cutting edge angle. • Select a free-cutting chipbreaker.
Chip welding 	• Use a grade which has a low tendency to adhere to work material. Cemented carbide → Coated carbide or cermet	• Increase cutting speed. • Increase feed.	• Increase rake angle. • Select a free-cutting chipbreaker.
Thermal cracking 	• Change to more impact resistant grades. P. M. K10 → 20 → 30	• Reduce cutting speed. • Reduce feed. • Use a cutting fluid. • Supply cutting fluid in adequate volume.	• Increase rake angle. • Select a free-cutting chipbreaker.

Grade Selection



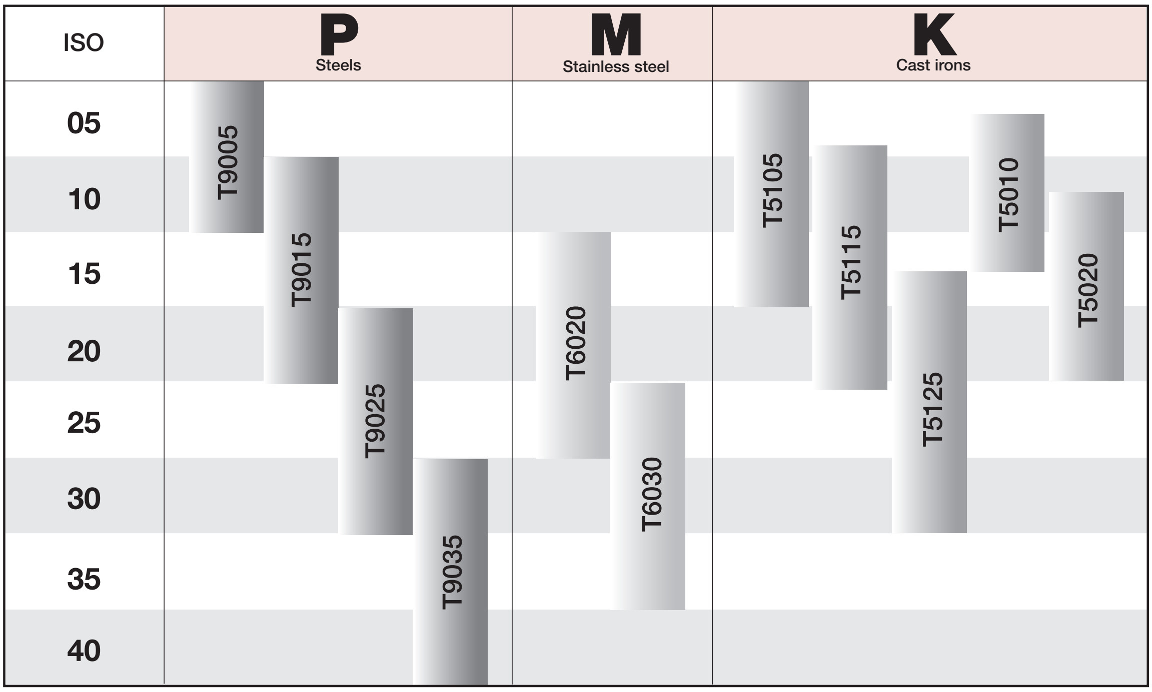
Increasing impact resistance (toughness)

T9015		T9025		T9035	
	T6020		T6030		
T5020	T5125				
			T3030		
			T3030		
		GH730			
			AH330	AH120	
			AH740		
			GH330		
	AH330		AH120		AH140
	GH330 GH730				
	AH120				
	AH120				
NS530	NS730		NS540		
			NS740		
AT530					
GT530					
	FX105				
	CX710				
	CXC73				
BX850					
BX470	BX480				
BX330	BX360	BXC50	BX380		
DX120					
	TX20		TX30		TX40
	UX25		UX30		
	TX25				
	TU20		UX30		TU40
	KS20				
	G2				
	KS20				
	KS20				
	EM10		UM		

Increasing impact resistance (toughness)

Note : The positioning of each grade does not correspond with the hardness of the grade.

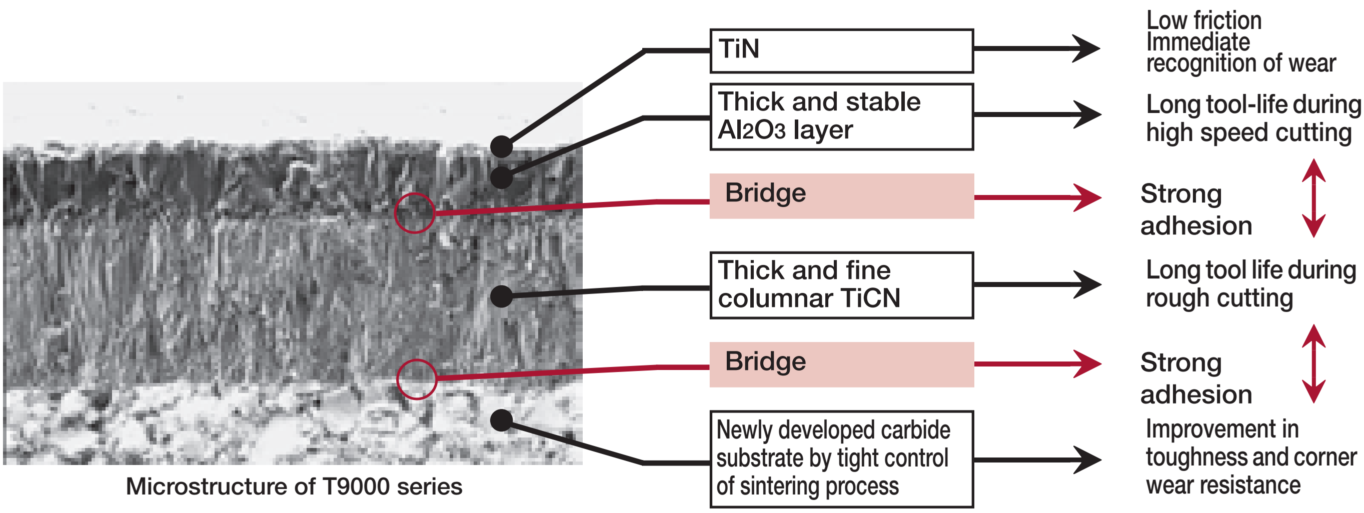
CVD (Chemical Vapor Deposition) Coated Grades for Turning



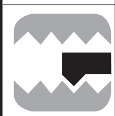
CVD coated carbide grades consist of a cemented carbide substrate over which TiC, TiN, or Al_2O_3, etc. are deposited to about 3 to 16 µm thick by means of a chemical vapor deposition method.
The coating layer is hard and superior in heat and oxidation resistance, and chemically stable. With these advantages, these coated grades ensure longer tool life and high-efficiency machining.

T9000 series

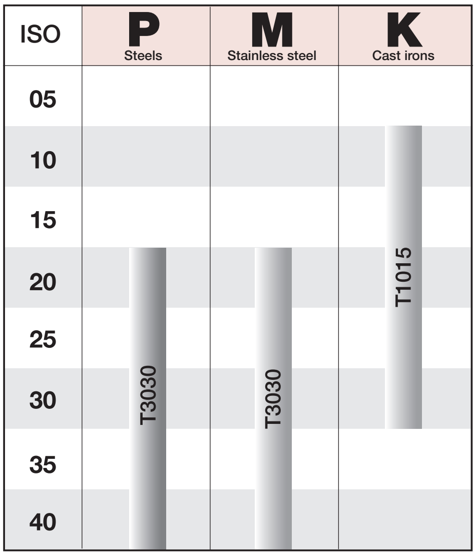
Our new Double-Bridge Technology enables thicker coatings to be applied while preventing the layers from peeling off.



Microstructure of T9000 series

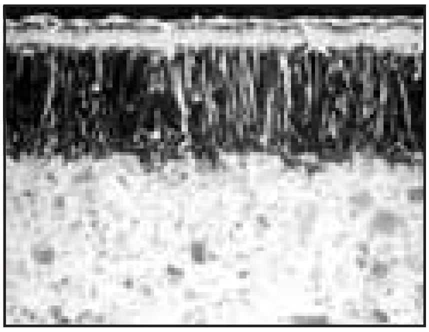
Application	Grade Application code	Substrate			Coating layer		Features
		Specific gravity	Hardness (HRA)	Transverse rupture strength (GPa)	Main composition	Thickness (µm)	
P Steels	T9005 P05 - P10	14.1	91.5	2.4	Fine columnar TiCN + Al_2O_3	16	•Realization of excellent adhesion by "Double-Bridge" effect. •T9005 shows excellent performance during high speed cutting. •T9015 shows good balance of wear resistance and impact resistance. •T9025 shows excellent impact resistance during light to medium interrupted cutting. •T9035 shows extremely high impact resistance during heavy interrupted cutting.
	T9015 P10 - P20	13.8	91.0	2.4		16	
	T9025 P20 - P30	13.7	90.0	2.5		14	
	T9035 P30 - P40	13.5	89.0	2.6		14	
M Stainless steel	T6020 M15 - M25	14.1	90.0	2.5	Special titanium compound (columnar)	6	T6000 series have improved notch wear resistance and chipping resistance by a combination of special substrates and extremely high coating adhesion. •T6020: Applicable for medium to high speed cutting and continuous to light interrupted cutting. •T6030: Applicable for low to medium speed cutting. Has extremely excellent impact resistance. For interrupted cutting.
	T6030 M25 - M35	14.6	89.0	2.6		6	
K Cast irons	T5105 K05 - K15	15.0	92.5	2.4	Fine columnar TiCN + Al_2O_3	16	The coating layer of T5100 features fine-grained and hard columnar crystals of Ti (C, N) and its wear resistance is drastically improved. Moreover, combined with the dedicated cemented carbide substrate, which has fine structure and high-strength, three grades of T5100 series has realized excellent cutting performance in a wide range of cast iron turning. •T5105: Excels in wear and deformation resistance in high-speed, continuos turning. •T5115: General purpose grade which achieves stable machining in a wide range of cutting conditions from continuous to interrupted cutting. •T5125: Espacially excels in heavily interrupted cutting. Very tough grade having high resistance to unpredicted breakage.
	T5115 K10 - K20	14.8	91.5	2.7		16	
	T5125 K15 - K30	14.0	90.5	2.8		16	
	T5010 K05 - K15	14.7	92.0	2.4	Columnar TiCN + Al_2O_3	16	T5000 series have improved adhesion and wear resistance. •T5010: For continuous to light interrupted cutting of cast irons and ductile cast irons. •T5020: For continuous to medium interrupted cutting of cast irons and ductile cast irons.
	T5020 K10 - K25	14.5	91.0	2.8		16	
	T313V —	14.5	90.5	2.3	Special titanium compound (columnar) + Al_2O_3	3	•Features specially engineered substrate with excellent resistance to impacts and plastic deformation and well controlled coating composition and layer thickness.

CVD (Chemical Vapor Deposition) Coated Carbide Grades for Milling



CVD coated carbide grades consist of a cemented carbide substrate over which TiC, TiN, or Al_2O_3, etc. are deposited to about 6 to 8 µm thick by means of a chemical vapor deposition method.

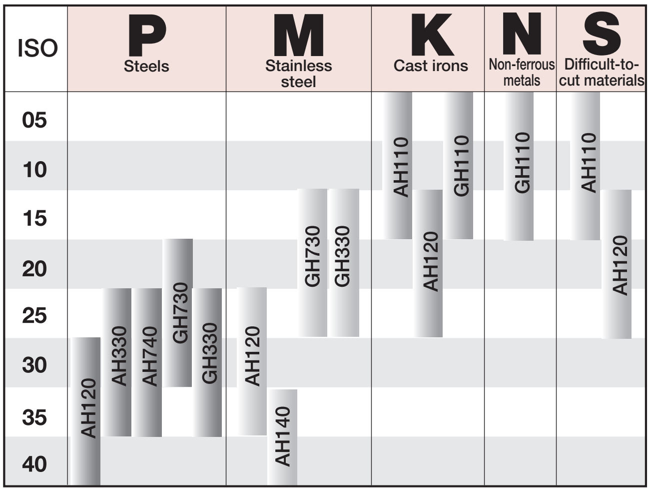
The coating layer is hard and superior in heat and oxidation resistance, and chemically stable. With these advantages, these coated grades ensure longer tool-life and appropriate for high-efficiency machining.



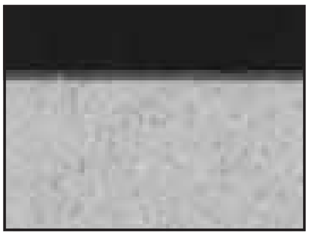
Microstructure of T1015 (SEM)

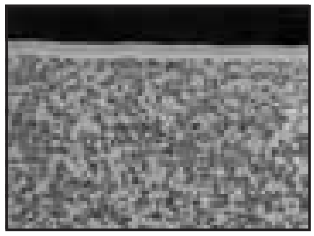
Application	Grade Application code	Substrate			Coating layer		Features
		Specific gravity	Hardness (HRA)	Transverse rupture strength (GPa)	Main composition	Thickness (µm)	
P Steels	T3030 P20 - P40	14.2	89.5	2.8	Columnar TiCN + Al_2O_3	6	•Realization of excellent adhesion by “Double Bridge” effect. •For milling of steels and stainless steels. •Shows good balance of wear resistance and impact resistance.
M Stainless steel	T3030 M20 - M40	14.2	89.5	2.8	Columnar TiCN + Al_2O_3	6	•Realization of excellent adhesion by “Double Bridge” effect. •For milling of steels and stainless steels. •Shows good balance of wear resistance and impact resistance.
K Cast irons	T1015 K10 - K30	14.9	91.5	2.7	Columnar TiCN + Al_2O_3	8	•Features special carbide substrate designed to have high resistance to impacts, thermal cracks and plastic deformation. •Excels in adhesion between coating and substrate.

PVD (Physical Vapor Deposition) Coated Carbide Grades



PVD coated carbides consist of a cemented carbide substrate over which titanium compound such as TiN is covered to about 1 to 5 μm thick by means of a physical vapor deposition PVD) method. Because of the lower coating temperature, the substrate does not form any brittle harmful layer and can retain the original shape and dimension. The Ti(C,N,O) base coating is superior to TiN coating in wear resistance. And, (Ti,Al)N base coating has higher resistance to oxidation. Due to the excellent toughness of both coating and substrate, these grades are suitable for interrupted cutting. Their sharp cutting edge allows the grades to be used for cutting difficult-to-cut materials which tend to be work-hardened.

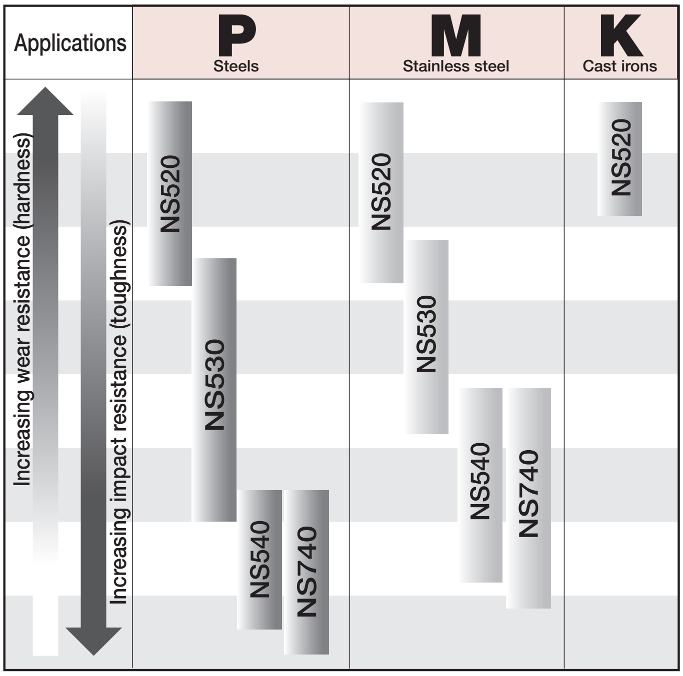

Microstructure of “Flash-Coat”


Microstructure of “Premium Coat”

Application	Grade Application code	Substrate: Specific gravity	Substrate: Hardness (HRA)	Substrate: Transverse rupture strength (GPa)	Coating layer: Main composition	Coating layer: Thickness (μm)	Features
P Steels	AH120 P30 - P40	14.5	90.8	2.8	(Ti,Al)N base	3	• Used for steels, cast irons, stainless steels and heat resisting alloys. • Substrate is K20 carbide. Excels in high-temperature strength.
	AH330 P25 - P35	12.6	91.1	2.3		3	• General purpose grade for steels. • Substrate is P30 carbide. Excels in high-temperature strength.
	AH740 P25 - P35	13.9	91.5	3.5		3	• General purpose grade for steels. • Excels in high temperature strength and chipping resistance.
	GH730 P20 - P30	14.4	91.5	3.0	Ti(C,N,O)base	3	• PVD coated (“Premium Coat”) fine grain cemented carbides. • For grooving and parting at low speed.
	GH330 P25 - P35	12.6	91.1	2.3		3	• General purpose grade for steels and stainless steel. • Substrate is highly reliable P30 grade. Excels in wear resistance.
M Stainless steel	AH120 M25 - M35	14.5	90.8	2.8	(Ti,Al)N base	3	• For continous to medium interrupted cutting of stainless steels.
	AH140 M35 - M40	14.4	89.5	2.6		3	• For milling of stainless steels (at low speed).
	GH730 M15 - M25	14.4	91.5	3.0	Ti(C,N,O)base	3	• PVD coated (“Premium Coat”) fine grain cemented carbides. • For grooving and parting at low speed.
	GH330 M15 - M25	12.6	91.1	2.3		3	• For continuous to medium interrupted cutting of stainless steels (at high speed).
K Cast irons	AH110 K05 - K15	14.7	92.0	2.4	(Ti,Al)N base	3	• Used for steels, cast irons, and heat resisting alloys. • For continuous to medium interrupted cutting of cast irons (at high speed).
	AH120 K15 - K25	14.5	90.8	2.8		3	• General grade for cast irons. For various cutting conditions
	GH110 K05 - K15	14.7	92.0	2.4	Ti(C,N,O)base	3	• For cast irons and non-ferrous metals. Excels wear resistance.
N Non-ferrous metals	GH110 N05 - N15	14.7	92.0	2.4	Ti(C,N,O)base	3	• For cast irons and non-ferrous metals. Excels wear resistance.
S Difficult-to-cut materials	AH110 S05 - S15	14.7	92.0	2.4	(Ti,Al)N base	3	• For cast irons and heat-resistant alloys. Especially excellent plastic deformation resistance.
	AH120 S15 - S25	14.5	90.8	2.8		3	• Excels to both plastic deformation and chipping resistance.
For small lathes	J740 —	13.9	91.5	3.5	TiN base	1	• For small lathes. Ultra-fine grain cemented carbides coated with TiN based compounds.

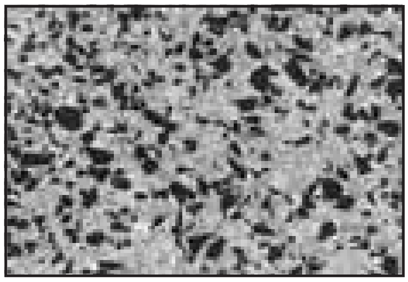
Cermet

■ Uncoated



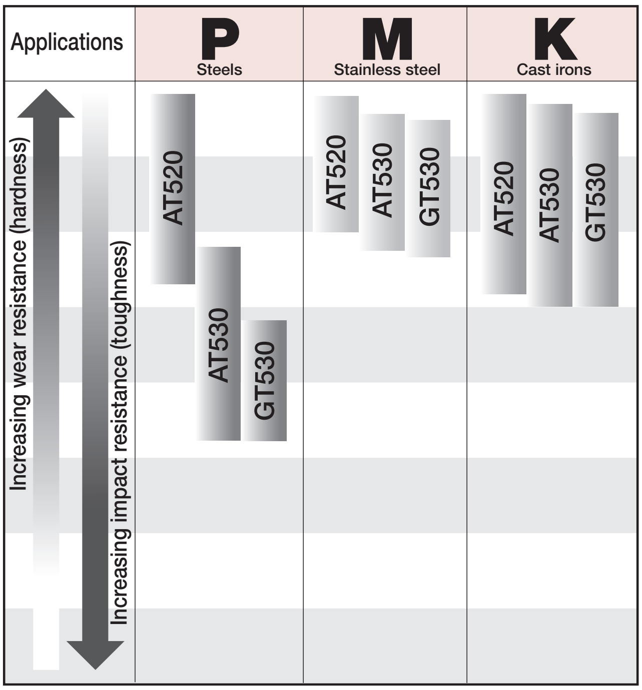
Cermet consists of a hard phase surrounded by binding phase as in the case of cemented carbides. The hard phase consists of mainly titanium carbide (TiC) and titanium nitride (TiN). These carbides and nitrides are superior in the strength and oxidation resistance at high temperature when compared with tungsten carbide (WC).

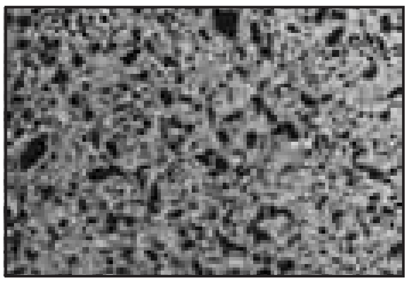
Furthermore, its little tendency to react with the work material ensures high crater resistance. Finally, cermet grades are applicable from high-speed cutting range to low-speed range and feature excellent surface roughness.



Microstructure of NS530 (SEM)

■ Coated





Microstructure of NS540 (SEM)

Cermet

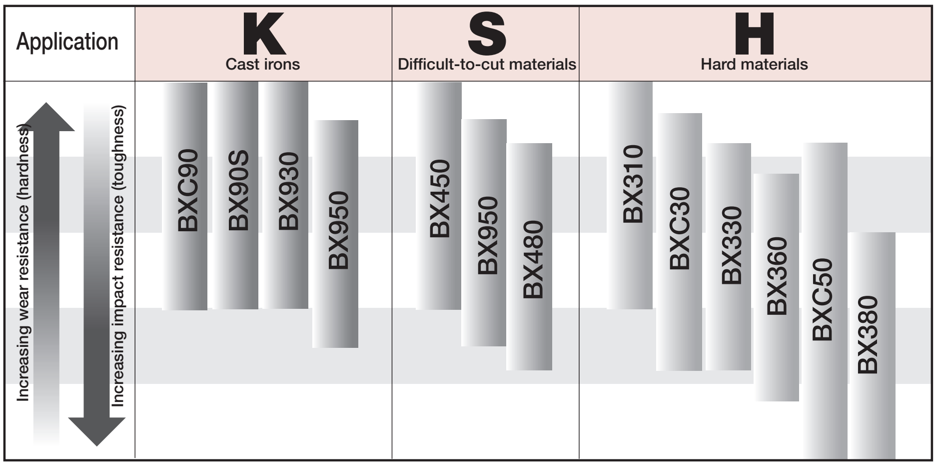
■ Uncoated

Application	Grade Application code	Substrate: Specific gravity	Substrate: Hardness (HRA)	Substrate: Transverse rupture strength (GPa)	Coating layer: Main composition	Coating layer: Thickness (µm)	Features
P Steels	NS520	6.6	92.1	1.7	–	–	• Used for high-speed, high-efficiency cutting of steels and cast irons. • Controlling the size of hard particles give this grade excellent wear and impact resistance.
	NS530	7.2	91.7	2.0	–	–	• General purpose grade for steels, cast irons and stainless steels. • Excels in both excellent wear resistance and toughness.
	NS730	6.8	92.0	2.2	–	–	• Priority on impact resistance • Superior resistance to thermal and mechanical fracture • Excels in cost performance
	NS540	7.0	92.0	2.0	–	–	• A highly tough cermet grade for general purpose. • Excels especially in thermal crack resistance and also provides both wear resistance and toughness.
	NS740	6.8	91.7	2.2	–	–	• High toughness grade for milling. • Excels especially in thermal crack resistance and also provides both wear resistance and excellent impact resistance.
	N308	6.9	91.8	1.7	–	–	• A general purpose grade provided with both excellent wear resistance and toughness. • For milling.
M Stainless steel	NS530	7.2	91.7	2.0	–	–	• General purpose grade for steels, cast irons and stainless steels. • Excels in both excellent wear resistance and toughness.
	NS730	6.8	92.0	2.2	–	–	• Priority on impact resistance • Superior resistance to thermal and mechanical fracture • Excels in cost performance
	NS540	7.0	92.0	2.0	–	–	• A highly tough cermet grade for general purpose. • Excels especially in thermal crack resistance and also provides both excellent wear resistance and toughness.
	NS740	6.8	91.7	2.2	–	–	• High toughness grade for milling. • Excels especially in thermal crack resistance and also provides both excellent wear resistance and excellent impact resistance.
	N308	6.9	91.8	1.7	–	–	• A general purpose grade provided with both excellent wear resistance and toughness. • For milling.
K Cast irons	NS520	6.6	92.1	1.7	–	–	• Used for high-speed, high-efficiency cutting of steels and cast irons. • Controlling the size of hard particles give this grade excellent wear and impact resistance.
	NS730	6.8	92.0	2.2	–	–	• Priority on impact resistance • Superior resistance to thermal and mechanical fracture • Excels in cost performance
	NS530	7.2	91.7	2.0	–	–	• General purpose grade for steels, cast irons and stainless steels. • Excels in both excellent wear resistance and toughness.

■ Coated

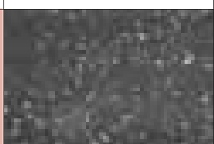
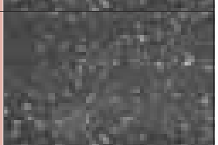
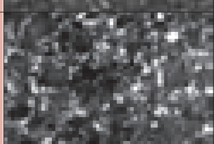
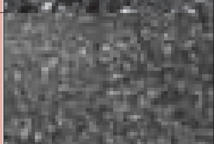
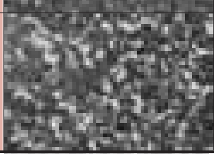
Application	Grade Application code	Substrate: Specific gravity	Substrate: Hardness (HRA)	Substrate: Transverse rupture strength (GPa)	Coating layer: Main composition	Coating layer: Thickness (µm)	Features
P Steels	AT520	6.6	92.1	1.7	(Ti,Al)N base	3	• PVD coated grade for high speed and finish cutting of steels. • Combination of cermet substrate with good wear resistance and coating layer with excellent heat resistance.
	AT530	7.2	91.7	2.0		3	• PVD coated grade for finish to medium cutting of steels. • Provided with plastic deformation resistant substrate and heat resistant coatings.
	GT520	6.6	92.1	1.7	Ti(C,N,O)base	3	• PVD coated grade for high speed and finish cutting of steels and cast irons. • Has improved wear resistance while maintaining excellent mechanical strength of the substrate.
	GT530	7.2	91.7	2.0		3	• PVD coated grade for finishing to medium cutting of steels and stainless steels. • Has improved wear resistance while maintaining excellent mechanical strength of the substrate.
	GT730	6.8	92.0	2.2	Ti(C,N,O)base	3	• PVD coated grade for finishing to medium cutting of steels and stainless steels. • Has improved wear resistance while maintaining excellent mechanical strength of the substrate.
M Stainless steel	GT530	7.2	91.7	2.0	Ti(C,N,O)base	3	• PVD coated grade for finishing to medium cutting of steels and stainless steels. • Increased wear resistance without lowering toughness of substrates.
	GT730	6.8	92.0	2.2	Ti(C,N,O)base	3	• PVD coated grade for finishing to medium cutting of steels and stainless steels. • Increased wear resistance without lowering toughness of substrates.
K Cast irons	GT520	6.6	92.1	1.7	Ti(C,N,O)base	3	• PVD coated grade for finishing to medium cutting of steels and cast irons. • Increased wear resistance without lowering toughness of substrates.
For small lathes	J530	7.2	91.5	2.0	TiN base	1	• For small lathes. • Cermets coated PVD-TiN based compounds.

Polycrystalline Cubic Boron Nitride Compacts (PCBN), T-CBN

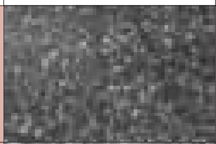
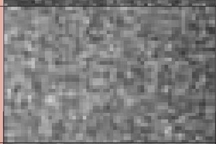
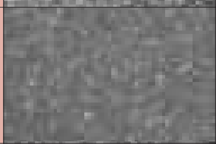
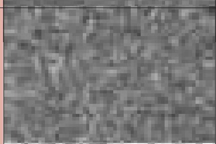
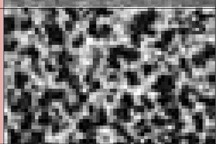
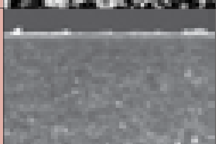
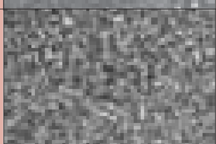
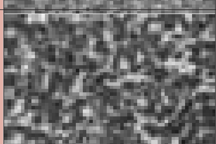
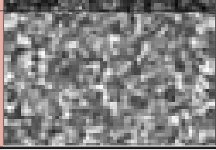


- This is a tool material, in which fine crystals of cubic boron nitride (the hardest material next to diamond) are tightly compacted and sintered on the cemented carbide base using special binder under high temperature and high pressure.
- The hardness is more than twice that of cemented carbide, with the hardness at high temperature exceeding that of cemented carbide.
- CBN has no tendency to react with ferrous materials (which is different from the case with diamond), and is thus suitable for high-speed cutting of cast iron, finishing of the hardened steel, cast iron, ferrous sintered metals (valve seat, etc.). Also, this material is suited for finishing of super heat resistant alloys.
- The use of CBN sintered material enables the finish surface accuracy (expected only through grinding up to now) simply by cutting.

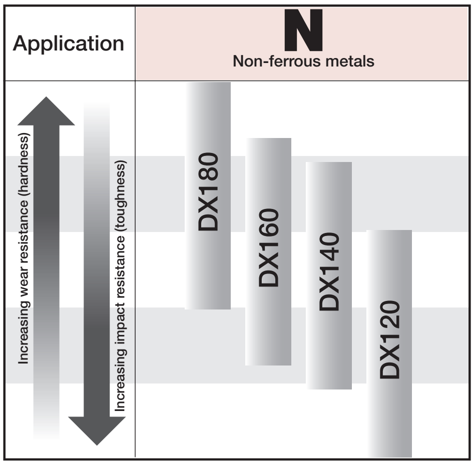
Polycrystalline Cubic Boron Nitride Compacts (PCBN), T-CBN

Application	Grade	Microstructure	Hardness (Hv)	Transverse rupture strength (GPa)	Coating layer		Features
					Main composition	Thickness (µm)	
K Cast irons	BX90S		3900-4100	1.80-1.90	–	–	• For high speed finishing to roughing of cast irons and rolled steels. • Solid CBN. • Higher heat conductivity.
	BXC90				(PVD)	1	• Coated solid CBN. • In addition to feature of BX90S, used corners are known at a glance.
	BX930		3000-3200	0.95-1.20	–	–	• Used for high-speed turning of grey and ductile cast irons. • Features moderate content of CBN sintered with special ceramic binder and excels in impact resistance.
	BX950		3900-4100	1.80-1.90	–	–	• Used for high-speed turning of heat resisting alloys, ferrous metals and cast irons and high-speed milling of cast irons. • Hardest T-CBN grade featuring high content of CBN sintered with cobalt based binder. • Provided with high transverse rupture strength comparable with cemented carbides.
	BX850		3300-3500	0.75-0.85	–	–	• Used for turning of grey cast irons. • Features moderate content of CBN sintered with special ceramic binder and excels in impact resistance.

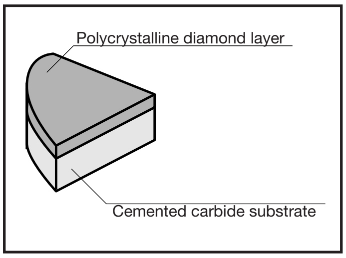
Polycrystalline Cubic Boron Nitride Compacts (PCBN), T-CBN

Application	Grade	Microstructure	Hardness (Hv)	Transverse rupture strength (GPa)	Coating layer		Features
					Main composition	Thickness (μm)	
S Difficult-to-cut materials	BX950		3900-4100	1.80-1.90	–	–	• Used for high-speed turning of heat resisting alloys, ferrous metals and cast irons and high-speed milling of cast irons. • Hardest T-CBN grade featuring high content of CBN sintered with cobalt based binder. • Provided with high transverse rupture strength comparable with cemented carbides.
	BX450		3100-3300	0.95-1.05	–	–	• Applicable for machining ferrous sintered metal (especially for valve seats). • Features fine grained CBN sintered with a special ceramic binder. • Excels in chipping resistance and finished surface roughness.
	BX470		4100-4300	1.90-2.10	–	–	• For ferrous sintered material. Extremely sharp cutting edge for excellent surface finish at minimum burr occurence.
H Hard materials	BX480		4100-4300	1.90-2.10	–	–	• For ferrous sintered material and hardened roll steels. It is highest of CBN contents and hardness in T-CBN grades.
	BX310		2700-2900	0.80-0.90	–	–	• Suitable for high-speed continuous turning of hardened steels and other hard materials with hardness of 54 to 65 HRC. • Features fine grained CBN sintered with a special ceramic binder and especially excels in wear resistance.
	BXC30		2800-3300	0.85-0.95	(PVD)	2	• Suitable for continuous to light interrupted turning of hardened steels and other materials with hardness of 54 to 65 HRC. • Features fine CBN grain sintered with special ceramic binder and smooth surface of newly developed PVD coated layer. Excels wear resistance and good surface roughness
	BX330		2800-3300	0.85-0.95	–	–	• Suitable for continuous to light interrupted turning of hardened steels and other hard materials with hardness of 54 to 65 HRC. • Features fine grained CBN sintered with a special ceramic binder and excels in wear resistance and surface roughness.
	BX360		3200-3400	1.00-1.10	(PVD)	–	• Used for light to heavy interrupted turning of hardened steels and other hard materials with hardness of 54 to 65 HRC. • Features fine to medium sized grain CBN sintered with a special ceramic binder and excels in impact resistance.
	BXC50		3500-3700	1.15-1.30	–	2	• Suitable for light interrupted to heavy interrupted turning of hardened steels and other hard materials with hardness of 54 to 65 HRC. • Features medium grain sized CBN sintered with a special binder. • T-CBN grade with special PVD coating layer.
	BX380		3500-3700	1.15-1.30	–	–	• Used for heavy interrupted turning of hardened steels and other hard materials with hardness of 54 to 65 HRC. • Features medium grained CBN sintered with a special ceramic binder and excels in impact resistance.

Polycrystalline Diamond Compact (PCD), T-DIA



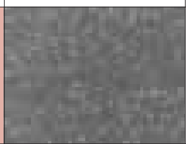
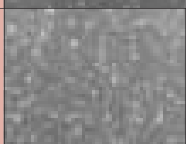
Diamond is the hardest known material on earth. This is an advanced diamond-based tool material, in which tiny diamond crystals are tightly sintered on the cemented carbide alloy base by means of a super high-pressure and -temperature process. When compared with the single-crystal diamond, the hardness is slightly lower, but PCD is uniform in structure. Additionally the heat resistance performance of single-crystal diamond can differ according to the crystal quality and orientation.
PCD is therefore optimum for cutting of non-ferrous and non-metal materials.



Structure of T-DIA

■ Comparison of hardness

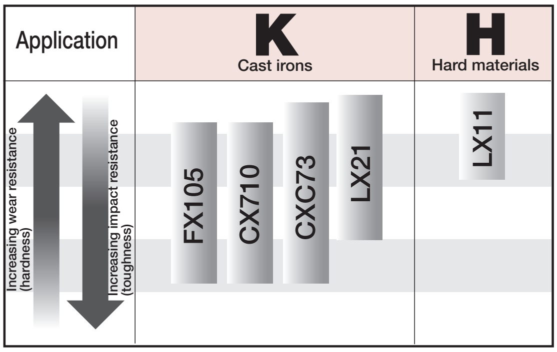
Tool material	Knoop hardness (Hk)
T-DIA	6000 ~ 9000
Natural diamond	8000 ~ 12000

Application	Grade	Microstructure	Diamond content Vol. %	Grain size (µm)	Hardness (Hv)	Strength (GPa)	Features
N Non-ferrous metals	DX120		88.0	4.5	9000	1.8	• For precision machining of non-ferrous metals and nonmetals where high-quality surface finish is required. • Features the finest grain structure in T-DIA series and excels in grindability and cutting edge sharpness.
	DX140		91.0	12.5	10000	1.7	• Used for machining of non-ferrous metals and nonmetals. • Composed of medium and fine grain diamond, provides moderate wear resistance and grindability.
	DX160		94.0	28	11000	1.6	• Can be used for machining half-sintered ceramics and cemented carbides, stones, and non-ferrous metals. • Mixed sintered compact composed of large and fine grain diamond. • Grindability is superior to that of DX180.
	DX180		96.5	45	12000	1.5	• Best suitable for turning half-sintered ceramics and cemented carbides. • Features the highest purity and large grain PCD with excellent wear resistance.

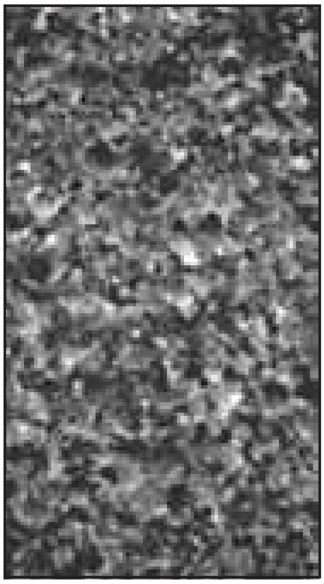
■ Regrinding method

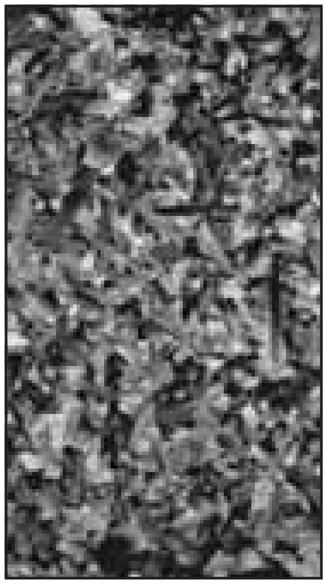
T-DIA Grade	DX180, DX160, DX140, DX120
Wheel	Diamond wheel
Bond	Vitrified bond
Grain size	Roughing: #400~600 Finishing: Finer than #1000
Concentration	100 ~ 125
Grinding speed	900 ~ 1200 m/min

Ceramics



Our ceramics consist of high-purity fine powder oxides, nitrides, and carbides sintered through normal pressure, gas pressure and HIP sintering. The fine and dense structure ensures superiority in wear resistance, adhesion resistance, oxidation resistance and heat resistance.
These grades enable high-speed cutting over a wide range from finishing to light cutting, offering high accuracy and high quality finished surfaces. Ceramics grades are classified into alumina-base and silicon-nitride-base groups, each selectable according to the application.

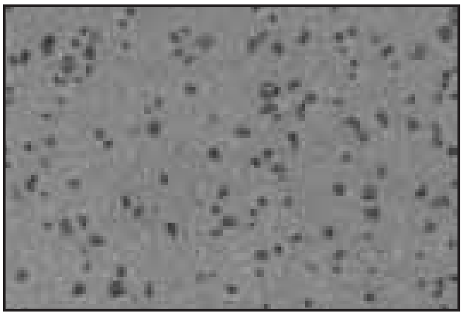

Microstructure of LX11 (SEM)


Microstructure of FX105 (SEM)

Application	Grade (Color)	Specific gravity	Hardness (HRA)	Transverse rupture strength (GPa)	Fracture Toughness K1c (MPa•m$^{1/2}$)	Modulus of elasticity (GPa)	Features
K Cast irons	FX105 Grey	3.24	93.0	1.3	6.1	290	•A silicon nitride based ceramics used for high speed cutting of cast irons. •Has superior strength, toughness and thermal characteristics compared with alumina-base ceramics.
	CX710 Grey	3.20	92.9	1.1	6.3	290	•Si_3N_4-based ceramics for high speed cutting of cast irons. •Higher of toughness and heat conductivity than FX105.
	LX21 Black	4.24	94.0	0.8	4.3	370	•Al_2O_3-based ceramics for continuous cutting of cast irons. •With adding titanium carbide to alumina, its toughness is improved while maintaining excellent wear resistance.
	CXC73 Gold	3.24	93.0	1.3	6.1	290	• CVD coated Si_3N_4 -based ceramics. •Excels good wear resistance and long tool life by thick and stable α-Al_2O_3 layer.
H Hard materials	LX11 Gold	4.35	94.0	0.9	4.3	400	•Al_2O_3-based ceramics used for continuous turning of ferrous hard materials. •Improved strength and toughness by fining down the crystallized particles of alumina and titanium carbonitride.

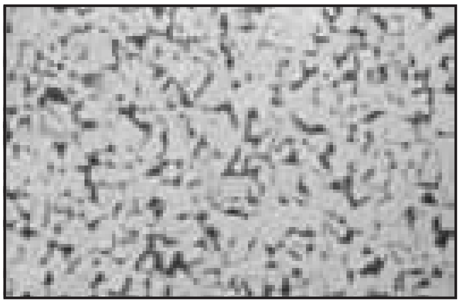
Uncoated Cemented Carbides (Tungaloy Cutting Tool Grades)

Cemented carbide, Tungaloy, is manufactured by sintering refractory carbide such as tungsten carbide (WC), titanium carbide (TiC), and tantulum carbide (TaC) powders with a binder metal like cobalt (Co). Our unique development and manufacturing technologies and stringent quality control ensure that Tungaloy has superior hardness (wear resistance) and strength (toughness) from room to high temperature range. Superiority in mechanical and thermal resistance when compared with the high-speed steel allows this alloy to be widely used in various cutting tools, wear and impact resistant tools and machine parts and civil-engineering or -mining tools.

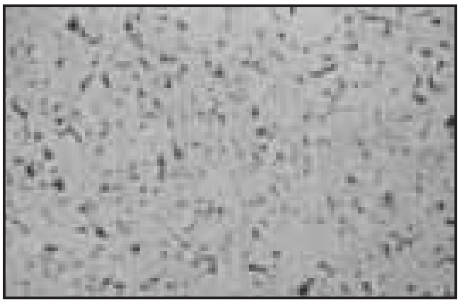

Microstructure of TH10

Application	ISO Application code	Tungaloy Grade	Specific gravity	Hardness (HRA)	Transverse rupture strength (GPa)	Compressive strength (GPa)	Modulus of elasticity (GPa)	Thermal expansion coefficient ($X10^{-6}/K$)	Thermal conductivity (W/m•K)
P Steels	P10	**TX10S**	10.5	91.8	1.9	4.5	500	6.4	18
	P20	**TX20**	11.8	91.5	2.1	4.7	520	5.8	35
	P20	**TX25**	11.8	91.5	2.2	4.7	540	5.7	38
	P20	**UX25**	12.3	90.9	2.5	4.9	530	5.8	34
	P30	**TX30**	12.6	90.8	2.3	4.9	560	5.8	48
	P30	**UX30**	12.6	91.1	2.3	4.9	490	5.8	38
	P40	**TX40**	12.7	89.9	2.4	4.6	520	5.5	52
M Stainless steel	M10	**TU10**	13.0	92.3	2.0	4.9	550	5.8	41
	M20	**TU20**	13.5	91.3	2.4	4.8	580	5.5	57
	M20	**UX25**	12.3	90.9	2.5	4.9	530	5.8	34
	M30	**UX30**	12.6	91.1	2.3	4.9	490	5.8	38
	M40	**TU40**	12.4	88.7	2.7	4.3	520	5.7	31
K Cast irons	K05	**TH03**	13.8	93.8	1.9	6.2	590	5.3	99
	K10	**TH10**	14.7	92.0	2.4	6.1	620	5.4	97
	K10	**G1F**	15.1	92.0	2.6	6.1	660	5.3	101
	K20	**G2F**	14.9	91.5	2.7	5.2	630	5.4	99
	K20	**G2**	15.0	90.8	2.7	5.2	640	5.4	99
	K20	**KS20**	14.5	90.8	2.8	6.1	620	5.4	96
	K30	**G3**	14.8	90.3	3.1	4.8	620	5.4	95
N Non-ferrous metals	N05	**KS05F**	15.0	93.0	2.9	5.9	640	5.4	90
	N10	**TH10**	14.7	92.0	2.4	6.1	620	5.4	97
S Super alloys	S10	**TH10**	14.7	92.0	2.4	6.1	620	5.4	97
	S20	**KS20**	14.5	90.8	2.8	6.1	620	5.4	96
H Hard materials	H05	**TH03**	13.8	93.8	1.9	6.2	590	5.3	99
	H10	**TH10**	14.7	92.0	2.4	6.1	620	5.4	97

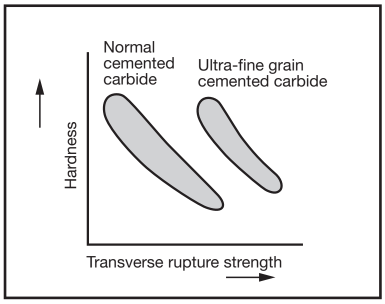
Ultra-fine Grain Cemented Carbides (Micro-Alloy)



Microstructure of EM10 (SEM) 1 μm



Microstructure of F (SEM) 1 μm



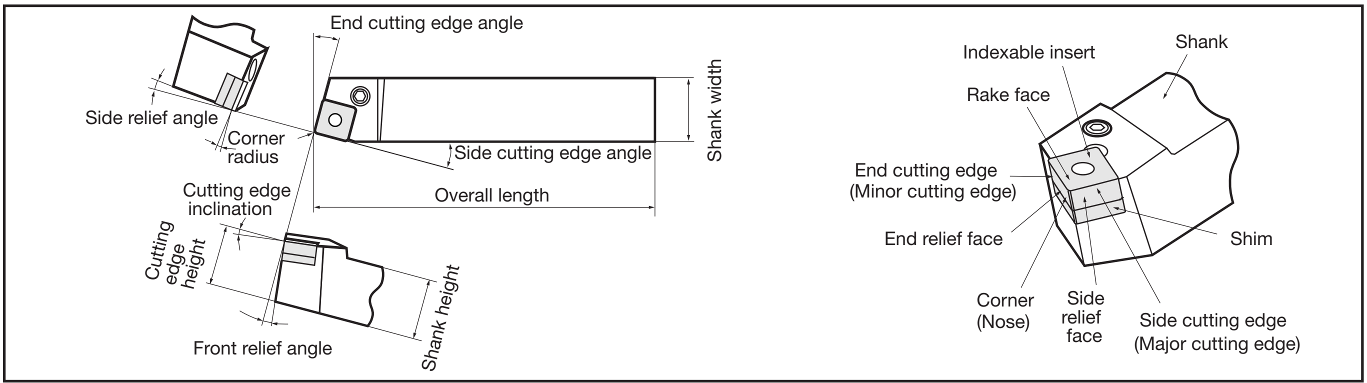
Mechanical properties of ultra-fine grain cemented carbide

Micro-Alloy is characterized by the WC hard phase (major component) which is extremely fine (average particle size 1 μm or less) when compared with normal cemented carbide alloys. This ensures higher strength (toughness) than the usual carbide alloy of the same hardness. Besides, this alloy demonstrates the high performance within the application range of high-speed steel tools. This is appropriate for the cutting tools when the workpiece is too small to achieve the high cutting speed or for a small-diameter end mill or drill.

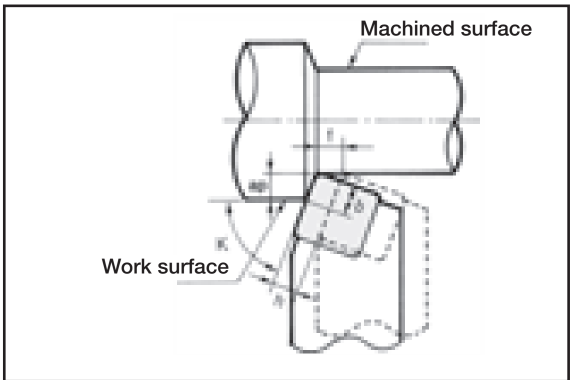
Grade	Specific gravity	Hardness (HRA)	Transverse rupture strength (GPa)	Compressive strength (GPa)	Modulus of elasticity (GPa)	Thermal expansion coefficient ($X10^{-6}$/K)	Thermal conductivity (W/m•K)	Features
F	14.9	93.4	2.5	6.9	640	5.4	85	• Hardest Micro-Alloy excels in wear resistance and cutting edge sharpen-ability. • Suitable for conditions of low speed, small cutting depth, and low feed. Mainly used for small tools such as for automatics.
M	14.5	92.5	2.8	6.4	580	5.6	74	• Used for conditions of low speeds, small to medium cutting depths, and low to medium feeds. • Tougher than F.
EM10	14.0	91.5	3.4	6.4	550	5.7	70	• Used for solid end mills and other milling cutters. • Provided with superior resistance to micro-chipping.
UM	13.9	90.9	3.5	5.8	520	5.8	67	• Toughest Micro-Alloy grade. • Excels in impact resistance. • Can withstand light impacts. Used for milling.

Turning Tools

■ Name of tool parts



■ Relating angles between tool and workpiece



ap: Cutting depth (Distance between work surface and machined surface)

b: Length of cutting edge engaging in cutting.

K: Cutting edge angle (Angle to be made by cutting edge and work surface)

f: Feed per revolution

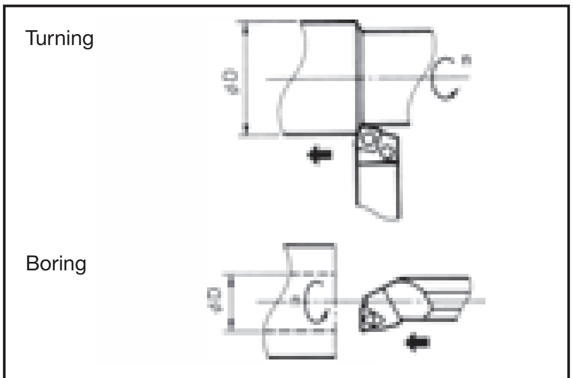
h: Thickness to be cut per revolution

Machined surface: Workpiece surface after having machined.

Work surface: Workpiece surface to be cut.

■ Calculation formulas for turning

● Cutting speed



When calculating cutting speed from number of revolutions:

$$Vc = \frac{D \times \pi \times n}{1000}$$

V_c : Cutting speed (m/min)
n : Number of revolutions (rpm)
D : Diameter of work piece (mm)
π : 3.14

Example:

$$V_c = \frac{3.14 \times 150 \times 250}{1000} = 117 \text{ m/min}$$

Calculating the cutting speed when turning a 150 mm-diameter workpiece at 250 rpm

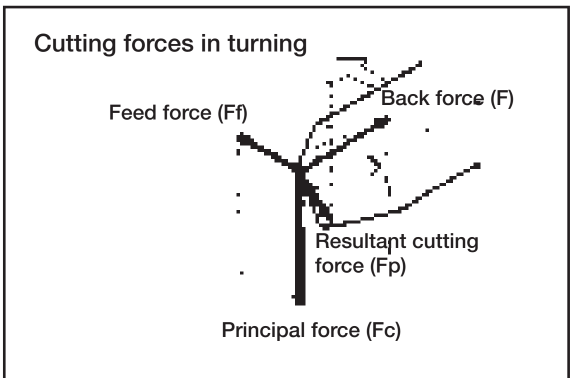
When calculating required number of revolutions from cutting speed:

$$n = \frac{1000 \times Vc}{\pi \times D}$$

● Cutting forces

(1) Finding from the diagram based on experimental data.

(2) In case determining by simplified equation:



$$Fc = ks \times ap \times f$$

Fc : Cutting force (kgf)(N)
ks : Specific cutting force MPa (N/mm^2)
ap : Cutting depth (mm)
f : Feed (mm/rev)

Example:
Calculating the cutting force when cutting a high carbon steel (Ck55) at feed f = 0.2 (mm/rev) and cutting depth ap = 3 (mm)
Fc = 4500 x 3 x 0.2 = 2700N

Values of ks

Work materials	MPa (N/mm^2)	kgf/mm^2
Carbon steels	2500~4500	250~450
Alloy steels	2500~4500	250~450
Cast irons	1500~3500	150~300

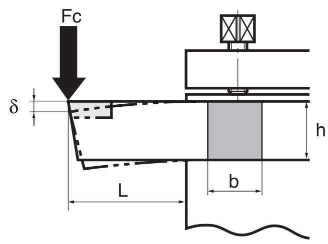
● Calculation of power consumption

$$Pc = \frac{Fc \times Vc}{60000 \times \eta}$$

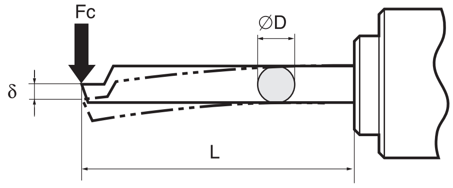
Pc : Power requirement (kw)
Fc : Cutting force (N)
Refer to previous page
V_c : Cutting speed (m/min)
η : Efficiency of machine (0.7 ~ 0.85)

● Bending stress and tool deflection

Square shank



Round shank



Bending stress

(1) Square shank

$$S = \frac{6 \times Fc \times L}{b \times h^2}$$

(2) Round shank

$$S = \frac{32 \times Fc \times L}{\pi \times D^3}$$

S : Bending stress in shank (MPa(N/mm²))
Fc: Cutting force (N)
L : Overhang length of tool (mm)
b : Width of shank (mm)
h : Height of shank (mm)
D : Diameter of shank (mm)
E : Modulus of elasticity of shank material (N/mm²)
δ : Bending (mm)
π : 3.14

Deflection of toolpoint (mm)

(1) Square shank

$$\delta = \frac{4 \times Fc \times L^3}{E \times b \times h^3}$$

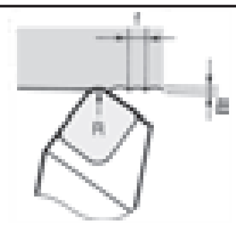
(2) Round shank

$$\delta = \frac{64 \times Fc \times L^3}{3 \times \pi \times E \times D^4}$$

(Ref.) Values of E

Material	MPa (N/mm²)	kgf/mm²
Steel	210000	21000
Cemented Carbide	560000-620000	56000-62000

● Theoretical surface finish



$$Rt = \frac{f^2}{8R} \times 1000$$

Rt: Surface finish (µm)
f : Feed (mm/rev)
R : Nose radius (mm)

● Tool Geometry

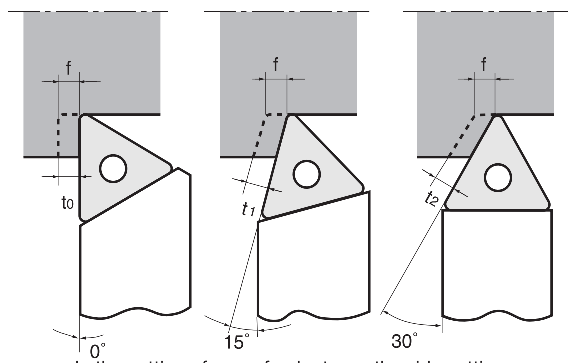
• Effects of tool geometry on cutting phenomena

Phenomena / Increasing	Flank wear	Crater wear	Edge strength	Cutting force	Surface finish	Chattering	Cutting temperature	Chip flow
Cutting edge inclination	–	Decrease	Lower	Radial force decrease	–	Less tendency	Lower	Effect on flow direction
Side rake angle	–	Decrease	Lower	Decrease	–	–	Lower	Effect on shape
Relief angle	Decrease	–	Lower	Decrease	–	Likely to occur	Lower	–
End cutting edge angle	Decrease	–	Lower	Radial force decrease	Roughen	Less tendency	Lower	–
Side cutting edge angle	Decrease	Decrease	Increase	Radial force increase	–	Likely to occur	Increase	Decrease thickness
Nose radius	Decrease to some level		Increase	Increase	Improve	Likely to occur	Increase	Effect on flow direction
Honing width	Increase	–	Increase	Increase	–	Likely to occur	Increase	–

● General recommendation for tool geometry

Angle	Operation	Angle
Cutting edge inclination	General turning (TAC tools)	-6° ~ +6°
	(Brazed tools)	0° ~ +6°
	Interrrupted turning	-6° ~ -3°
	Planing, shaping	-15° ~ -5°
Side cutting edge angle	General turning (TAC tools)	-6° ~ +5°
	(Brazed tools)	+6°
	Hard materials	-10° ~ 0°
	Soft materials	+15° ~ +30°
	Interrupted turning	-5° ~ -15°
Relief angle	General turning (TAC tools)	5° ~ 8°
	(Brazed tools)	6°
	Non-ferrous metals	7°
	Glass, ceramics	5°
	Wood	5° ~ 8°
End cutting edge angle		Variable
Side cutting edge angle		Variable

● Effect of side cutting edge angle



In the cutting of same feed rate, as the side cutting edge angle increases the chip thickness decreases.

$t_0 > t_1 > t_2$

● General recommendation for nose radius

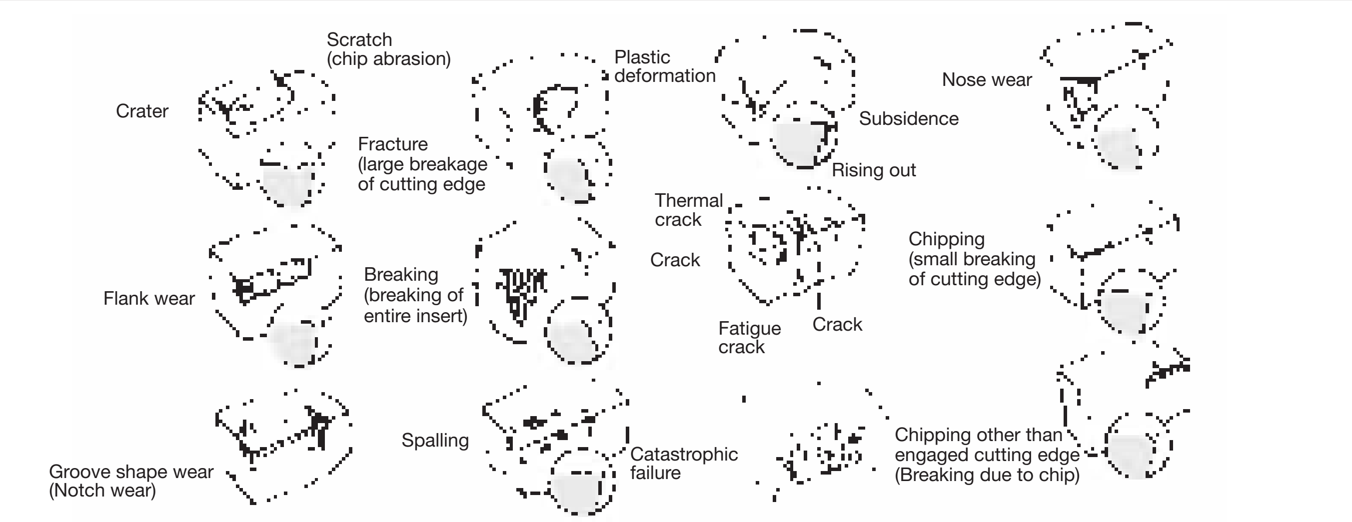
	Work material / Cutting depth (mm)	Steels, aluminium alloys, copper alloys	Cast iron, non-metals
Guidelines	~ 3	0.4	0.8
	4 ~ 9	0.8	1.6
	10 ~ 19	1.6	2.4
	20 ~	2.4	3.2
Formula (mm)		Cutting depth ap ÷ 8 = a Feed f x 2 = b Larger size of a a or b	Cutting depth ap ÷ 4 = a Feed f x 4 = b Larger size of a or b

● Honing

TAC indexable inserts of steel cutting grades are honed. Honing specifications are shown in the following table.

Symbol	Edge condition	Shape
F	Sharp edge	
E	Round honing	
W•T	Chamfered honing	
S	Chamfered and round honing	

● Types of tool failure (respresentative)



Tool failure			
Tool failure	Wear	Flank wear	A typical form of wear is mechanical wear (plowing). There is no effect of heat, rather it is a phenomenon of gradual scraping off by abrasion, resulting in a rough face as if scraped with a plow.
		Face wear Crater wear	The main cause of thermal wear is the cutting temperature. High temperature and temperature adhesion will diffuse with part of the cutting face.
		Nose wear	Mechanical or thermal wear occured on tool nose.
		Notch wear	Wear occurring at contact boundary (side cutting edge and end cutting edge) between the work material and tool.
	Chipping		Small fractures on cutting edge, such as due to mechanical shock, thermal shock, chip welding and chip recutting.
	Fracture		Large fracture on cutting edge.
	Breaking		Complete damage to insert.
	Breaking in two		Breaking of long tools such as drill and endmills.
	Flaking	(Spalling)	Shell-like damage on rake face and flank.
	Plastic deformation		Softening of the tool material due to rise in tip temperature, unable to withstand cutting force and cutting edge deformation by subsiding or building up.
	Crack	Thermal crack	Occurs mainly on the rake face but also noted on flanks. Initially occurs at right angle to the cutting edge but as the number increases is generated in parallel direction and chips off in “U” shape.
		Fatigue crack	Cracks occurring parallel to the cutting edge as the result of repetitive mechanical stress being applied due to impact and cutting force accompanying interrupted cutting. In comparison with themal crack, occurs immediately adjacent to cutting edge.
	Catastrophic failure		With the advancement of wear, complete loss occurs over a considerable part of the cutting cross section and cutting becomes impossible.

● Tool life criterion on JIS

Width of flank wear	0.2 mm	Precision light cutting, finishing of non-ferrous metal alloys, etc.
Width of flank wear	0.4 mm	Cutting of special steels
Width of flank wear	0.7 mm	Ordinary cutting of cast iron and steels
Width of flank wear	1 ~ 1.2 mm	Rough cutting of grey cast iron
Depth of crater		Normally 0.05 - 0.1 mm

● Tool life criterion on ISO

Tool life criterion	Application
Catastrophic failure	High speed steel tools (VB can also be applied)
Flank wear width VB = 0.3 mm	Cemented carbide and ceramic tools displaying uniform flank wear
VB max = 0.5 mm	In case of uneven flank wear is caused
Depth of crater KT = 0.06 + 0.3 f (mm) (where f represents feed mm/rev)	Cemented carbide tools
Determination according to roughness 1, 1.6, 2.5, 4, 6.3, 10 μm Ra	In case roughness is essential

Chip forming

■ Chip control performance

(1) Necessity

As machining is rationalized more and more, the necessity of controlling chips has also changed in details.
To ensure improvement of productivity and to reduce costs, controlling measures must be implemented to prevent following problems:

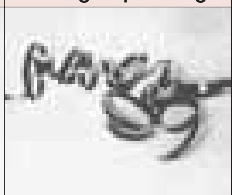
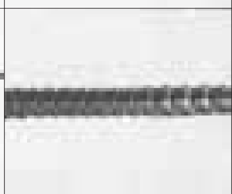
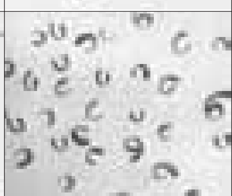
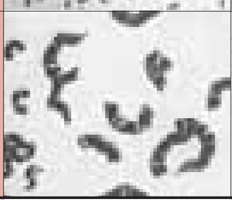
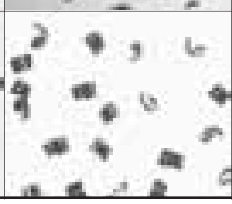
Problems:

- Scattering of chips
- Entangling of chips to the workpiece and tool
- Accumulation of chips around the tool

Troubles:

- Hindrance to unmanned and automatic operation
- Hindrance for multi-cutting edge tooling, higher speed, and higher efficiency operation
- Hindrance to the accuracy of machine tools
- Deterioration of product quality
- Trouble according the safety of operators
- Shorter tool life
- Lower operation rate

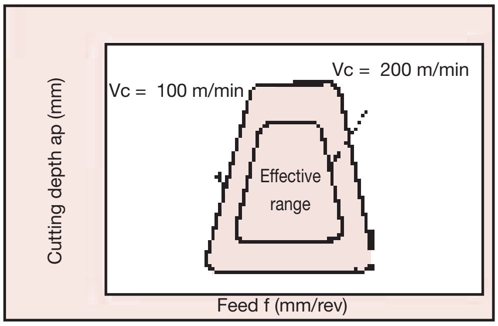
■ Chip shape classification and effects

Classi-fication	Chip shape: Cutting depth: small	Chip shape: Cutting depth: large	Description of chip shape	Acceptability	Effect
Shape A			Chips irregularly entangled	Not acceptable	• Wrapping around the tool or workpiece or accumulation around the cutting point, hindering cutting • Possible damage to the machined surface
Shape B			Long continuous spiral chips $\ell > 50$ mm		• Bulky during transport in the automatic line • May be preferred when one operator handles one machine
Shape C			Short spiral chips $\ell < 50$ mm	Acceptable	• Smooth chip flow • Difficult to scatter • Favorable shape
Shape D			"C" or "9" shaped chips (Around one coiling)		• Favorable shape if not scattering • Not bulky and easy to transport
Shape E			Excessively broken chips. Thin pieces or connected in a form of wave as shown in the figure left	Not acceptable	• Readily scattering. If scattering is the only trouble, it may be acceptable because the chip cover, etc. may be used. • Tend to cause chatter, causing harms on the finished surface roughness or tool life.

■ Factors affecting chip control

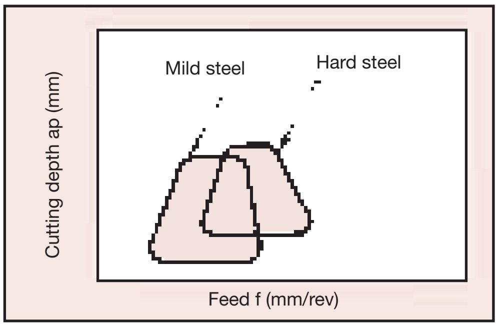
(1) Cutting condition
① Feed f
② Cutting depth ap
③ Cutting speed Vc

- Of these, feed has the greatest effect followed by cutting depth and cutting speed in order listed.
- Feed is proportionate to the thickness of chips.
- Cutting depth is proportionate to the width of chips.
- There are optimum values (effective range) in feed and cutting depth.
- Cutting speed is in inverse proportion to chip thickness. Effective range becomes narrow at high speed.



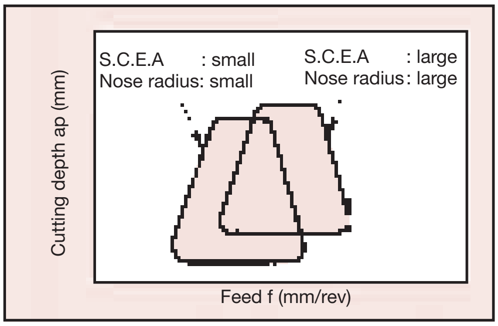
(2) Work material
① Alloy element
② Hardness
③ Heat treatment condition

- These are related to thickness of chips and ease of curling.
- Mild steel chips are thicker than those of hard steel.
- Hard steel chips liable to curl more than those of mild steel.
- Chips that do not curl are thin. As an exception, in case of mild steel even if thick, may not curl.



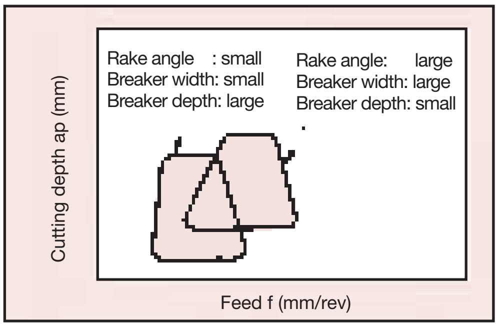
(3) Shape of tool
① Side cutting edge angle
② Nose radius

- Side cutting edge angle is relative to chip thickness and width
- Side cutting edge angle is preferably small.
- Nose radius is relative to thickness and width and the direction of flowing out.
- In finishing, small nose radius, while for rough cutting, large nose radius is better.



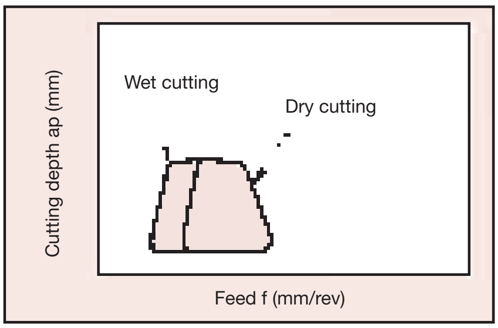
(4) Shape of chipbreaker
① Rake angle
② Chipbreaker width
③ Chipbreaker depth

- Rake angle is in inverse proportion to chip thickness.
- Depending on the work material, there is an optimum value.
- Chipbreaker width is selected proportionately to feed.
- Narrow at low feed and wide at high feed.
- Chipbreaker depth is to be selected so as to be inversely proportionate to feed.
- Deep at low feed and shallow at high feed.



(5) Cutting fluid

- Effective range is wider with wet cutting.
- Especially at low feed range is liable to curl.



Factors effecting chip control

Factor	Measures
Cutting conditions	• Increase feed (If chip packing occurs, reduce feed) • Increase cutting depth (When cutting at large cutting depth, reduce it) • Reduce cutting speed
Work material	• Use free-cutting steel • Increase a tendency to curl by heat treatment.
Tool geometry	• Reduce side cutting edge angle • Select smaller corner radius
Chipbreaker shape	• Reduce rake angle (For mild steels, increase it) • Reduce chipbreaker width (For chip packing, increase it) • Increase chipbreaker depth (For chip packing, reduce it)
Cutting fluid	• Wet cutting (especially at low feed)
Machine tool	• Use a chip cover • Use of a slant bed lathe • Use the tool upside down

Chipbreaker selection

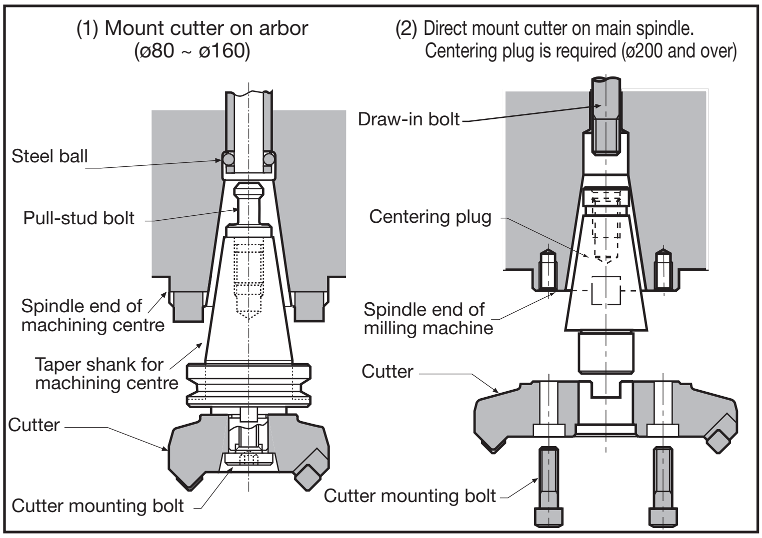
The most effective method among the factors listed above is a control with a chipbreaker.
For selecting a proper chipbreaker type for the operation, refer to the relating pages shown below.

TAC turning tools	• Chipbreaker selection guide: P. 27 ~ 36 • Chipbreaker comparison chart: P. 499 ~ 500

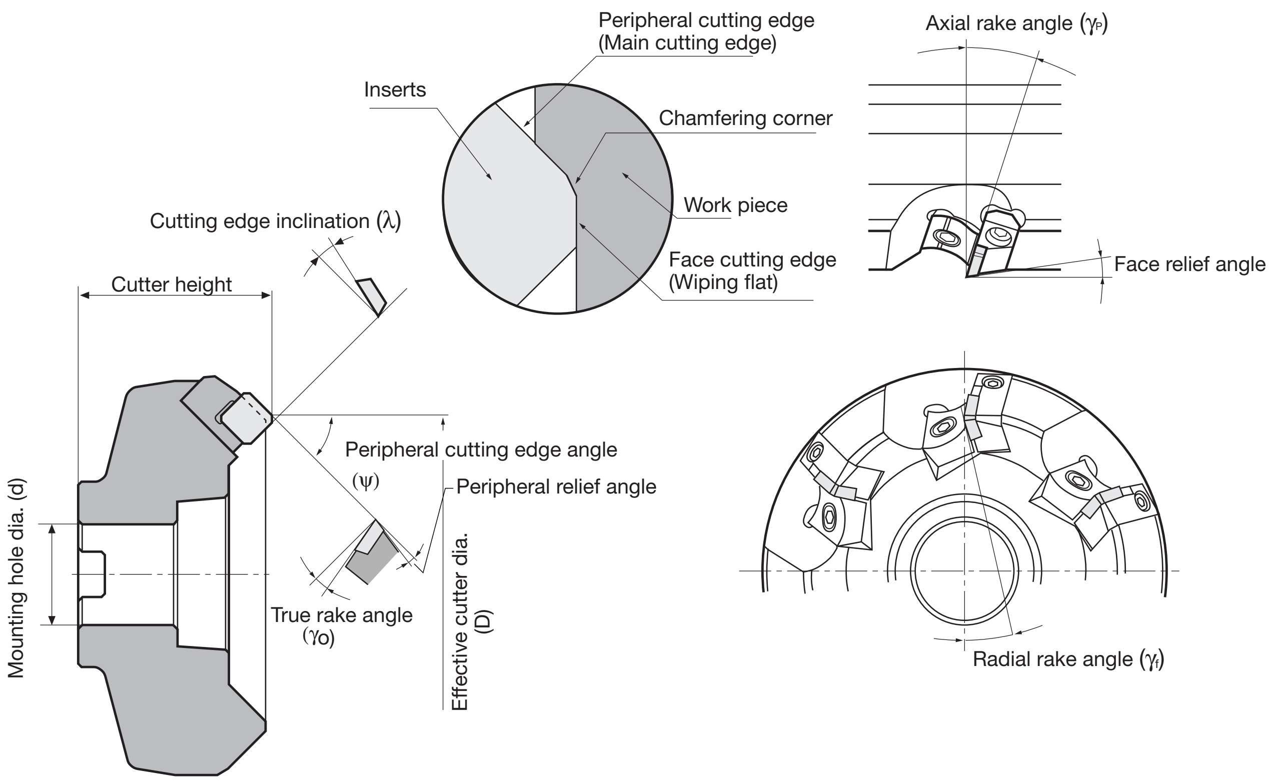
Milling Tools

■ Mounting face mill

- In mounting to end of the main spindle of the milling machine, there are two methods shown in figures at right.
- In case using at machining center, use exclusive arbor (BT shank···MAS standard) enabling ATC.
- Shank type TAC mill (E series), same as endmill, is mounted on the machine with a milling chuck available on the market.



■ Nomenclature for face milling cutter (Symbols conformed to JIS)



Relations of various rake angles are according to the following equations.

$\tan \gamma_o = \tan \gamma_f \cos \psi + \tan \gamma_p \sin \psi$

$\tan \lambda = \tan \lambda_p \cos \psi - \tan \gamma_f \sin \psi$

■ Cutter geometry and applications

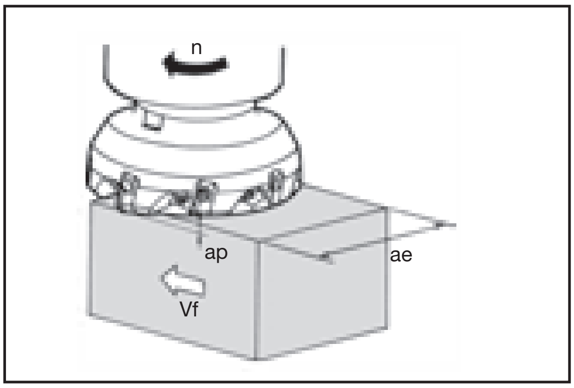
Work material		Rake angle combination and applicability: Negative-Negative, Negative true rake angle	Negative-Positive: Negative true rake angle	Negative-Positive: Positive true rake angle	Positive-Positive: Positive true rake angle
Cast irons Ductile cast irons		◎	○	○	◎
Low to medium carbon steels		△	○	◎	◎
Special steels (< 400 HB)	Stainless steels	×	△	◎	○
	Heat resisting steels	×	△	◎	○
	Tool steels	△	△	◎	○
Aluminium alloys		×	×	○	◎
Copper and its alloys		×	△	○	◎
Titanium and its alloys		×	△	○	○

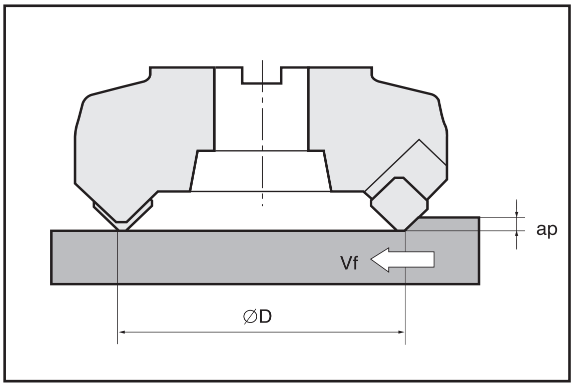
◎ : Excellent ○ : Good △ : Fair × : Not recommended

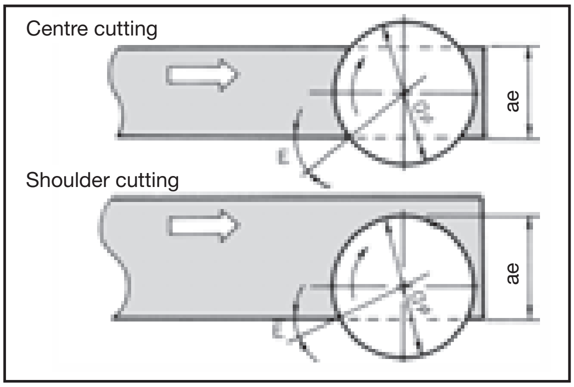
Type	Rake angle γ_f	Rake angle γ_p	Rake angle γ_o	Features	Typical examples of TAC mills
Negative type (Negative-Negative)	−	−	−	• Usable cutting edges are doubled and economical	TGN4200-A
Negative-positive type	−	+	+	• Excellent chip removal	TME4400I TAD12
	−	+	−	• Higher cutting edge strength	TPN6400I (not shown in this catalogue)
Positive type (Positive-positive)	+	+	+	• Freer cutting action	TMD4100I

γ_f : Radial rake angle γ_p : Axial rake angle γ_o : True rake angle

■ Cutting conditions







● Cutting speed

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

Vc : Cutting speed (m/min)
D : Effective diameter (mm)
n : Number of revolutions (rpm)
π : 3.14

● Number of revolutions (Calculated from cutting speed)

$$n = \frac{1000 \times Vc}{\pi \times D} \text{ (rpm)}$$

● Feed speed and feed rate

Feed speed is relative speed of cutter and work material and in the normal milling machine, it is the table speed.

In milling, the feed per tooth is very important. The recommended cutting condition is expressed by Vc and ft and using the above equation calculate n and Vf and input in the machine.

$$Vf = ft \times t \times n \text{ (mm/min)}$$

Vf : Table feed (mm/min)
ft : Feed rate per tooth (mm/t)
t : No. of teeth of the cutter
n : Number of revolutions (rpm)

● Cutting depth

Determine by required allowance for machining and capacity of the machine. In case of TAC mill, there are cutting limits according to shape and size of the insert.

● Cutting width and engage angle

There is an appropriate engage angle depending on the cutter diameter, cutting position, work material, etc., and ordinarily the values in the table below are used as a guide.

Work material	Appropriate E	Cutter dia. and ae
Steel	0 ~ 20° (on small side for shoulder cutting)	ae = 2/3D
Cast iron	under 40°	ae = 4/5D

D : Cutter diameter (mm)
E : Engage angle (°)
ae : Cutting width (mm)

■ Roughness of finished surface

(1) Theoretical surface roughness

Theoretical roughness as shown in Fig. 1
is the same as for single point turning

● With corner R

$$Rt = \frac{ft^2}{8R} \times 1000$$

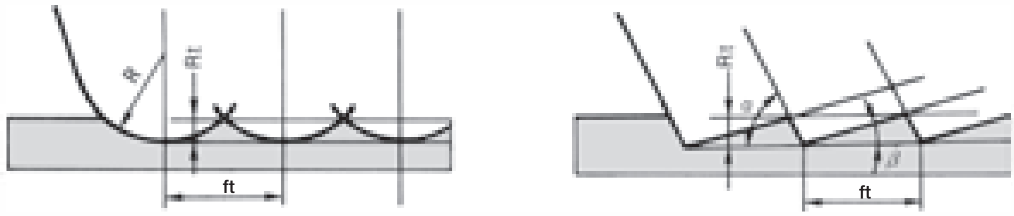
● Without corner R

$$Rt = ft \left(\frac{\tan\alpha \cdot \tan\beta}{\tan\alpha + \tan\beta} \right) \times 1000$$

Rt : Theoretical roughness (μm)
ft : Feed per tooth (mm/t)
R : Corner radius (mm)
α : Corner angle
β : Face cutting edge angle

Fig. 1

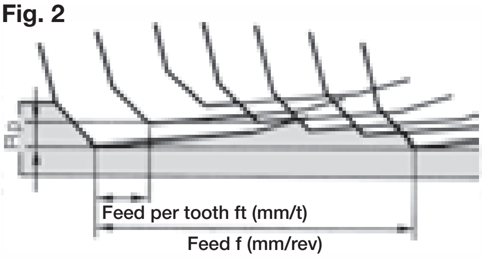
● With corner R ● Without corner R



(2) Practical surface roughness

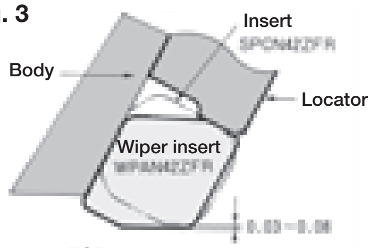
However, in case of practical milling, there are many teeth and naturally differences in levels of edges occur. The maximum difference is called “run out”.
In the actual face milling, finished surface roughness, as shown in Fig. 2, is worse than the single point cutting. In case only one tooth is projecting, it will be similar to the single point shown in Fig. 1 but of a large value substituting f (mm/rev) for ft (mm/tooth).

Fig. 2



■ Improving surface roughness

Fig. 3



Example of TGP4100, wiper insert assembled

Preferably face run out to be minimized and low feed at high speed. Also, in order to attain good finished surface at high efficiency, there are the following methods:

(1) In case of ordinary TAC mill
Use wiper insert as shown in the figure at left.

(2) Use of TAC super finish mill for finishing
Cut with TAC mill exclusively for finishing such as MS cutters.

■ Calculating power requirement

$$Pc = \frac{ks \times ap \times ae \times Vf}{60 \times 1000 \times 1000} \text{ (kW)}$$

Pc : Net power requirement (kW)
ks : Specific cutting force MPa (N/mm^2)
(Refer to the Table below)
ap : Cutting depth (mm)
ae : Cutting width (mm)
Vf : Table feed (mm/min)

Because practical power requirements depend on the type of TAC mill (proportional to the true rake angle) and the motor efficiency of the machine used, the result calculated from the above formula should be considered as a rough guide.

● Values of specific cutting force (ks)

Work material	Tensile strength		Feed per tooth ft (mm/t)				
	MPa (N/mm^2)	{kgf/mm^2}	0.1	0.15	0.2	0.3	0.4
Mild steel USt42-2	520	52	2150	2000	1900	1750	1650
Carbon steel Ck55	770	77	1970	1860	1800	1760	1620
Cr-Mo steel	730	73	2450	2350	2200	1980	1710
Alloy tool steel 55NiCrMoV6	(352HB)	(352HB)	2030	2010	1810	1680	1590
Steel casting GS-45	520	52	2710	2530	2410	2240	2120
Grey cast iron GG25	(200HB)	(200HB)	1660	1450	1320	1150	1030
Aluminium silicon alloy	200	20	660	580	522	460	410
Brass	500	50	1090	960	877	760	680

Note: Values in parenthesis show hardness.

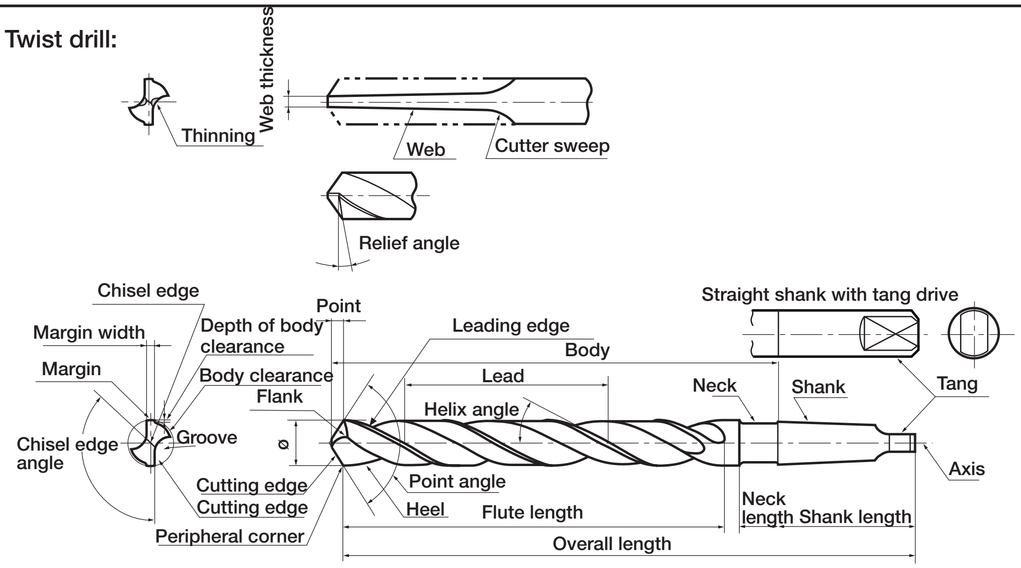
■ Troubleshooting in milling

Trouble	Possible causes	Countermeasures
Rapid wear of cutting edge	• Improper insert grade selection (Insufficient wear resistance)	• P30 → P20 → cermet, coated grade (steel cutting) • K20 → K10 → coated grade (cast iron cutting)
	• Excessive cutting speed	• Select cutting speed suited for work material and insert grade
	• Inadequate feed	• Use standard cutting condition in catalog as guide
Rapid chipping of cutting edge	• Improper insert grade selection	• Cermet → P20, P30 (steel cutting), K10 → K20 (cast iron cutting)
	• Cutting hard material and unfavorable surface condition	• Decrease cutting speed • Use cutter with strong cutting edge
	• Excessive feed	• Select proper feed conditions as per recommendation in catalogue
	• Excessive pressure applied on cutting edge	• Proper selection of engaging angle
	• Machining difficult-to-cut material	• Use a negative-positive type cutter with large corner angle (Ex. TAW)
Fracturing	• Cracking due to thermal shock	• Select insert grade of stronger thermal shock resistance such as T3030 • Decrease cutting speed
	• Too thin insert against cutting force	• Change from 3.18 mm into 4.76 mm insert thickness
	• Continuous use of excessively worn insert	• Shorten replacement standard time of insert
	• Cutting hard material	• Use cutter of stronger tip • Use cutter of larger corner angle such as TMD
	• Obstruction to chip flow • Recutting of chips after chip welding	• Use cutter with good chip discharge properties such as TMD • Select insert grades difficult for chips to adhere Cemented carbides → cermets, coated grades • Use cutting fluid or air
	• Excessively slow cutting, too fine feed	• Select cutting speed and feed optimized for insert grade and work material
Excessive chip welding or build-up on cutting edge	• Cutting soft material such as aluminium, copper, mild steel	• Use cutter with large rake angle such as THF
	• Cutting stainless steel	• P30 → Cermet
	• Use of cutter with negative rake or too small rake angle	• Use cutter with large rake angle such as TAW
Rough finish	• Effect of built - up edge	• Increase cutting speed • Appropriate cutting depth (finish allowance) • Change insert grade, K grade→M grade→P grade→cermet For cast irons : P grade → coated grade → cermet For steels : K grade → coated grade
	• Effect of face cutting edge run-out	• Proper installing of inserts • Use insert of high dimensional accuracy Class K → class E
	• Continuous use of excessively worn insert	• Shorten replacement standard time of insert
	• Remarkable feed marks	• Feed per revolution to be set within flatland width • Use wiper insert type cutter such as TAW • Use cutter exclusively for finishing such as SFP4000
Chattering	• Unstable clamping of workpiece	• Check clamping method of workpiece
	• Cutting of welded construction of thin steel plate	• Adopt cutter of large rake angle and small corner angle such as TAW
	• Excessive cutting condition	• Re-examine allowable chip removal rate according to motor HP
	• Face milling of narrow width workpiece	• Use cutter of small cutter diameter and with many teeth
	• Too many simultaneous cutting teeth engagement	• Reduce No. of teeth or adopt irregular pitch cutter

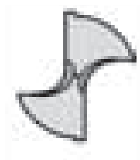
Drilling Tools

■ Nomenclature for drills

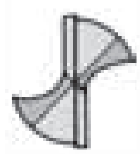
Twist drill:



Examples of thinning



S-type thinning



Combination of four facet point and cross thinning

Cutting forces and power requirement

(1) Twist drill

● Power requirement

$$Pc = K \cdot D^2 \cdot n\,(0.647 + 17.29f) \times 10^{-6}\ (kW)$$

● Thrust force

$$T = 570K \cdot D \cdot f^{0.85}\ (N)$$

● Torque

$$M = K \cdot D^2\,(0.630 + 16.84f)\ (N \cdot cm)$$

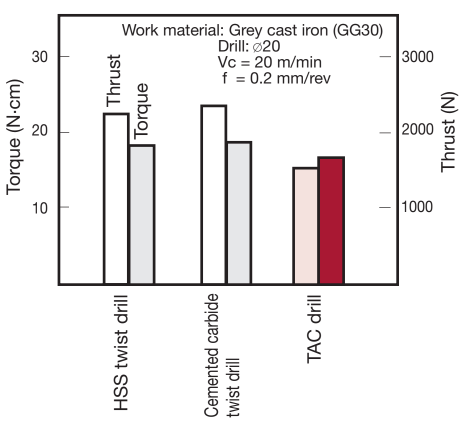
Pc : Power requirement (kw)
T : Thrust force (N)
M : Torque (N·cm)
D : Drill diameter (mm)
f : Feed (mm/rev)
n : No. of revolutions (rpm)
K : Material constant.... Refer to the Table at right

Material constant compensating for power requirement and thrust force

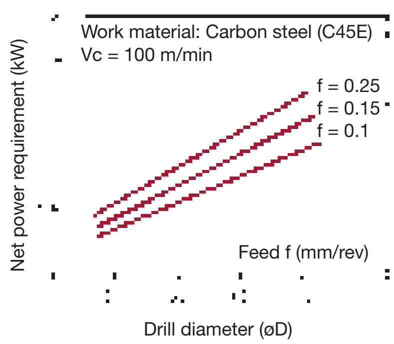
Work material	Tensile strength		Brinell hardness (HB)	Material constant (K)
	MPa (N/mm^2)	{kgf/mm^2}		
Cast iron	210	21	177	1.00
Cast iron	280	28	198	1.39
Cast iron	350	35	224	1.88
Aluminium	250	25	100	1.01
Low carbon steel (Ck22)	550	55	160	2.22
Free cutting steel (15S22)	620	62	183	1.42
Manganese steel (36Mn5)	630	63	197	1.45
Nickel chromium steel (36NiCr6)	690	69	174	2.02
4115 steel Cr0.5, Mo0.11, Mn0.8	630	63	167	1.62
Chromium molybdenum steel (25CrMo4)	770	77	229	2.10
Chromium molybdenum steel (42CrMo4)	940	94	269	2.41
Nickel chromium molybdenum steel	750	75	212	2.12
Nickel chromium molybdenum steel	1400	140	390	3.44
Chromium vanadium steel				
Cr0.6, Mn0.6, V0.12	580	58	174	2.08
Cr0.8, Mn0.8, V0.1	800	80	255	2.22

(2) TAC drill

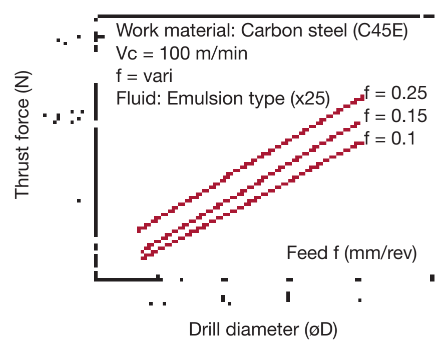
Comparison of cutting forces



Net power requirement for TAC drills



Thrust forces of TAC drills



■ Troubleshooting for the solid drill and soldering drill

Problem		Cause	Countermeasure
Abnormal wear	Relief surface	Inappropriate cutting speed	• Increase the cutting speed by 10% within standard conditions if abnormal wear is around the centre. • Lower the cutting speed by 10% within standard conditions if abnormal wear is on the periphery.
		Inappropriate cutting fluid	• Check the filter. • Use the cutting fluid superior in lubricity (increase the dilution rate).
	Margin	Inappropriate cutting speed	• Lower the cutting speed by 10%.
		Regrinding timing, insufficient reground amount	• Shorten the regrinding timing.
		Insufficient rigidity of the machine and workpiece	• Change the clamp method to the one with rigidity.
		Insufficient drill rigidity	• Use smallest possible overhang.
		Inappropriate cutting fluid	• Check the filter. • Use the cutting fluid superior in lubricity. (increase the dilution rate)
		Intermittent cutting when entering	• Avoid interruption at entry and exit. • Lower the feed rate by about 50% during entering into and leaving from the workpiece.
Chipping and fracture	Chisel section (centre of drill cutting edge)	Insufficient rigidity of the drill	• Reduce the drill overhang as much as possible. • Increase the feed at entry when the low speed feed is selected in standard cutting condition range. • Use a bushing or a centre drill.
		Insufficient rigidity of the machine and workpiece	• Change the clamp method to the one with rigidity.
		Inappropriate entry into the workpiece	• Avoid interruption at entry into the workpiece. • Lower the feed rate by 10% at entry.
		High workpiece hardness	• Lower the feed rate by 10%.
		Inappropriate honing	• Check if honing has been made to the centre of cutting edge.
	Peripheral cutting edge	Insufficient drill rigidity	• Lower the cutting speed by 10%. • Increase the feed at entry when the low speed feed is selected in standard cutting condition range.
		Inappropriate drill mounting accuracy	• Check the runout accuracy after drill installation (0.03 mm or less).
		Insufficient machinery and workpiece rigidity	• Change the clamp method to the one with rigidity. • Lower the feed during entering into and leaving from the workpiece.
		Inappropriate honing	• Check if honing has been made to the cutting edge periphery.
	Margin	Insufficient machine and workpiece rigidity	• Change the clamp method to the one with rigidity.
		Insufficient drill rigidity	• Use smallest possible overhang. • Use a bushing or centre drill.
		Regrinding timing and insufficient amount of reground stock	• Shorten the regrinding timing.
		Intermittent cutting when entering or exiting the cut.	• Avoid interruption at entry and exit. • Lower the feed rate by about 50% during entering into and leaving from the workpiece.
Breakage		Tendency to cause chipping or develop abnormal wear	• Check the failure mode condition before breakage and find out the wear and chip countermeasures.
		Chip packing in the drill flutes	• Review the cutting conditions. • For internal coolant supply, raise the supply pressure of cutting fluid. • Use drill pecking for deep holes.
		Insufficient machine output	• Review the cutting conditions. • Use the machine with high power.
Insufficient hole accuracy		Insufficient rigidity of the machinery and workpiece	• Change to the clamp method with rigidity
		Inappropriate drill installation accuracy	• Check the runout accuracy of drill mounting. (0.03 mm or less)
		Chip packing in the flutes.	• Review the cutting conditions. • Raise the cutting oil supply pressure. • Use peck-feed for deep holes.
		Inappropriate edge sharpening accuracy	• Check the edge shape accuracy.
Prolonged chips		Inappropriate cutting conditions	• Increase the feed rate by 10% within standard conditions.
		Inappropriate honing	• Provide the appropriate honing.
		Cutting edge with chipping or breakage	• Lower the cutting speed by 10%.

■ Troubleshooting for TAC drill

Problem			Cause	Countermeasure
Abnormal wear	Central cutting edge	Relief surface	Inappropriate cutting conditions	• Increase the cutting speed by 10% within standard conditions. • Lower the feed rate by 10%.
	Peripheral cutting edge	Relief surface	Inappropriate cutting conditions	• Increase the cutting speed by 10% within standard conditions. • When the feed rate is extremely low or high, set it up within standard conditions.
	Common	Relief surface	Varieties and supplying of cutting fluid	• Confirm that the cutting fluid flow is higher than 7 l/min. • The concentration of cutting fluid must be higher than 5%. • Use the cutting fluid superior in lubricity. • Change from external to internal cutting fluid supply.
			Vibration in drilling	• Change to the machine with higher torque. • Change to the clamp method with rigidity. • Change the drill setting method.
			Unsuitable for selection of grade	• Change the grade to T1015.
			Looseness of screws	• Tighten the screw.
		Crater	Cutting heat is too high	• Change from external to internal cutting fluid supply. • Increase the supply rate of the cutting fluid. (Higher than 10 l/min) • Lower the feed rate by 20% within standard conditions. • Lower the cutting speed by 20% within standard conditions.
			Excessive chip welding	• Lower the feed rate by 20% within standard conditions. • Lower the cutting speed by 20% within standard conditions.
		Chipbreaker	Chip packing	• Increase the cutting speed by 20% and lower the feed rate by 20 % within standard conditions. • Raise the fluid pressure. (for higher than 1.5 MPa)
Chipping and fracture	Central cutting edge	The rotation center of drill	The misalignment for workpiece rotation	• Set the misalignment to 0 ~ 0.2 mm.
			Large offset	• Check the manual and use the tool in the allowable offset range.
			No flatness of machined surface	• Flatten the entry surface in pre-machining. • Set the feed rate for lower than 0.05 mm/rev in rough surface area.
			High feed rate	• Lower the feed rate by 20 ~ 50% within standard conditions.
			Using a chipping corner	• Confirm the corner when exchanging inserts.
	Peripheral cutting edge	Peripheral corner area	Using inserts in excess of tool life	• Exchange the corner or the insert before the nose wear reaches 0.3 mm.
			No flatness of machined surface	• Flatten the entry surface in pre-machining. • Set the feed rate for lower than 0.05 mm/rev at rough surface area.
			The existence of interrupted area on the way of machining	• Set the feed rate for lower than 0.05 mm/rev in interrupted area.
			Using a chipping corner	• Confirm the corner when exchanging inserts.
	Common	The unused corner area and cutting edge	High hardness of workpiece	• Increase the cutting speed by 20% and lower the feed rate by 20% within standard conditions. • Raise the fluid pressure (for higher than 1.5 MPa).
			Chip packing	• Lower the feed rate by 20% within standard conditions.
			Machinery impact	• Change to the continuous feed in case of pick feeding.
		Contact boundary	Using inserts in excess of tool-life	• Exchange the corner or the insert before the nose wear reaches 0.3 mm.
			Vibration in drilling	• Change to the machine with higher rigidity. • Change to the clamp method with rigidity. • Change the drill setting method.
		Flaking	High hardness of workpiece	• Set the feed rate for lower than 0.05 mm/rev.
			Thermally impact	• Change from external to internal cutting fluid supply. • Lower the feed rate by 20% within standard conditions.
		Common	Unsuitable for selection of grade	• Change the grade to GH730.
			Looseness of screws	• Tighten the screw.

Problem		Cause	Countermeasure
Scratch marks on the tool	The tool periphery	The misalignment for workpiece rotation	• Set the misalignment to 0 ~ 0.2 mm.
		Offset machining in exceed of allowable range	• Use the tool in the allowable offset range.
		Offset direction reduced diameter of workpiece	• Set offset direction extended diameter of workpiece
		No flatness of the entry surface	• Flatten the entry surface in pre-machining. • Set the feed rate for lower than 0.05 mm/rev in rough surface area.
		Chipping of peripheral cutting edge	• Exchange the insert.
		Bend of workpiece	• Change to the clamp method with rigidity.
		High hardness of workpiece	• Increase the cutting speed by 20% and lower the feed rate by 20% within standard conditions. • Raise the fluid pressure (for higher than 1.5 MPa).
Inappropriate hole accuracy	Hole diameter	The misalignment for workpiece rotation	• Set the misalignment to 0 ~ 0.2 mm.
		Inappropriate offset contents	• Adjust offset contents.
		No flatness of the entry surface	• Flatten the entry surface in pre-machining. • Set the feed rate for lower than 0.05 mm/rev at rough surface area.
		Bend of workpiece	• Change to the clamp method with rigidity.
	Roughness	Varieties and supplying of cutting fluid	• The concentration of cutting fluid must be higher than 5 %. • Use the cutting fluid superior in lubricity. • Change to internal cutting fluid supply from external one.
		Inappropriate cutting conditions	• Increase the cutting speed by 20% within standard conditions. • Lower the feed rate by 20% within standard conditions.
	Common	Failures of inserts	• Exchange the insert.
		Chip packing	• Increase the cutting speed by 20 % and lower the feed rate by 20% within standard conditions. • Raise the fluid pressure. (for higher than 1.5 MPa)
		Looseness of screws	• Tighten the screw.
Chip control	Prolonged and twisted chips	Inappropriate cutting conditions	• Work within standard conditions. • Increase the cutting speed by 10% within standard conditions. • Increase the feed rate by 10% within standard conditions.
		Failures of inserts	• Exchange inserts.
		Machining by external fluid supply	• Change to internal cutting fluid supply from external one. • Work by step feed. • Insert the dwell for approximate 0.1 second before twisted of chips.
		Chips around the central cutting edge	• There is a tendency to shorten the chips when shifted higher speed and feed.
	Chip packing	Fluid supply	• Change to internal cutting fluid supply from external one. • Raise the fluid pressure. (for higher than 1.5 MPa)
		Inappropriate cutting conditions	• Increase the cutting speed by 20% and lower the feed rate by 20% within standard conditions. • Raise the fluid pressure. (for higher than 1.5 MPa)
	Common	Large failure of drill holder	• Exchange the drill holder.
		Looseness of screws	• Tighten the screw.
Others	Chatter	Inappropriate cutting conditions	• Lower the cutting speed by 20% within standard conditions. • Increase the feed rate by 10% within standard conditions.
		Large wear of inserts	• Exchange the insert.
		Vibration in drilling	• Change to the machine with higher torque rigidity. • Change to the clamp method with rigidity. • Change the drill setting method.
		Looseness of screws	• Tighten the screw.
	Machine stop	Cutting edge with chipping or breakage	• Use the range of number of revolutions suited machine spec. Lower the feed rate by 20 ~ 50%.
		Burned inserts	• Exchange inserts before the failure becomes larger. • Check that the fluid flows powerfully from the drill. • Lower the cutting speed and the feed rate by 20% within standard conditions.
	Large burr	Failures of inserts	• Exchange the insert.
		Inappropriate cutting conditions	• Lower the feed rate by 20 ~ 50% just before leaving from the workpiece.

Appendix

P		Great Britain		Sweden	U.S.A.	Germany		France	Italy	Spain	Japan
		BS	EN	SS	AISI/SAE	W. No.	DIN	AFNOR	UNI	UNE	JIS
Steel	Carbon steel	4360 40 C		1311	A570.36	1.0038	RSt.37-2	E 24-2 Ne			STKM 12A;C
		030A04	1A	1325	1115	1.0038	GS-CK16	-	-	-	-
		4360 40 B		1312	A573-81 65	1.0116	St.37-3	E 24-U	Fe37-3		
		080M15	-	1350	1015	1.0401	C15	CC12	C15C16	F.111	-
		050A20	2C/2D	1450	1020	1.0402	C22	CC20	C20C21	F.112	-
		230M07	-	1912	1213	1.0715	9SMn28	S250	CF9SMn28	11SMn28	SUM22
		-	-	1914	12L13	1.0718	9SMnPb28	S250Pb	CF9SMnPb28	11SMnPb28	SUM22L
		-	-	-	-	1.0722	10SPb20	10PbF2	CF10SPb20	10SPb20	-
		240M07	1B	-	1215	1.0736	9SMn36	S 300	CF9SMn36	12SMn35	-
		-	-	1926	12L14	1.0737	9SMnPb36	S300Pb	CF9SMnPb36	12SMnP35	-
		080M15	32C	1370	1015	1.1141	Ck15	XC12	C16	C15K	S15C
		-	-	-	1025	1.1158	Ck25	-	-	-	S25C
		4360 55 E		2145	A572-60	1.8900	StE 380	-	FeE390KG		
		4360 55 E		2142	A572-60	-	17 MnV 6	NFA 35-			
								501 E 36	-	-	
		060A35	-	1550	1035	1.0501	C35	CC35	C35	F.113	-
		080M46	-	1650	1045	1.0503	C45	CC45	C45	F.114	-
		212M36	8M	1957	1140	1.0726	35S20	35MF4	-	F210G	-
		150M36	15	-	1039	1.1157	40Mn4	35M5	-	-	-
		-	-	2120	1335	1.1167	36MN5	40M5	-	36Mn5	SMn438(H)
		150M28	14A	-	1330	1.1170	28Mn6	20M5	C28Mn	-	SCMn1
		060A35	-	1572	1035	1.1183	Cf35	XC38TS	C36	-	S35C
		080M46	-	1672	1045	1.1191	Ck45	XC42	C45	C45K	S45C
		060A52	-	1674	1050	1.1213	Cf53	XC48TS	C53	-	S50C
		070M55	-	1655	1055	1.0535	C55	-	C55	-	-
		080A62	43D	-	1060	1.0601	C60	CC55	C60	-	-
		070M55	-	-	1055	1.1203	Ck55	XC55	C50	C55K	S55C
		080A62	43D	1678	1060	1.1221	Ck60	XC60	C60	-	S58C
		060 A 96		1870	1095	1.1274	Ck 101	XC 100	-	F-5117	
		BW 1A		1880	W 1	1.1545	C 105 W1	Y105	C36KU	F-5118	SK 3
		BW2	-	2900	W210	1.1545	C105W1	Y120	C120KU	F.515	SUP4
	Low carbon steel	4360 43C		1412	A573-81	1.0144	St.44-2	E 28-3	-	-	SM 400A;B;C
		4360 50B		2132	-	1.0570	St.52-3	E36-3	Fe52BFN/Fe52CFN	-	SM490A;B;C;YA;YB
		150 M 19		2172	5120	1.0841	St.52-3	20 MC 5	Fe52	F-431	
		250A53	45	2085	9255	1.0904	55Si7	55S7	55Si8	56Si7	-
		-	-	-	9262	1.0961	60SiCr7	60SC7	60 SiCr8	60 SiCr8	-
		534A99	31	2258	52100	1.3505	100Cr6	100C6	100Cr6	F.131	SUJ2
		1501-240	-	2912	ASTM A204Gr.A	1.5415	15Mo3	15D3	16Mo3KW	16Mo3	_
		1503-245-420	-	-	4520	1.5423	16Mo5	-	16Mo5	16Mo5	_
		-	-	-	ASTM A350LF5	1.5622	14Ni6	16N6	14Ni6	15Ni6	-
		805M20	362	2506	8620	1.6523	21NiCrMo2	20NCD2	20NiCrMo2	20NiCrMo2	SNCM220(H)
		311-Type 7	-	-	8740	1.6546	40NiCrMo22	-	40NiCrMo2(KB)	40NiCrMo2	SNCM240
		820A16	-	-	-	1.6587	17CrNiMo6	18NCD6	-	14NiCrMo13	-
		523M15	-	-	5015	1.7015	15Cr3	12C3	-	-	SCr415(H)
		-	-	2245	5140	1.7045	42Cr4	-	-	42Cr4	SCr440
		527A60	48	-	5155	1.7176	55Cr3	55C3	-	-	SUP9(A)
		-	-	2216	-	1.7262	15CrMo5	12CD4	-	12CrMo4	SCM415(H)
		1501-620Gr27	-	-	ASTM A182	1.7335	13CrMo4 4	15CD3.5	14CrMo4 5	14CrMo45	-
					F11;F12			15CD4.5			
		1501-622	-	2218	ASTM A182	1.7380	10CrMo910	12CD9, 10	12CrMo9, 10	TU.H	-
		Gr.31;45	-		F.22			-			-
		1503-660-440	-	-	-	1.7715	14MoV6 3	-	-	13MoCrV6	-
		722 M 24		2240	-	1.8515	31 CeMo 12	30 CD12	30 CrMo12	F-1712	
		897M39	40C	-	-	1.8523	39CrMoV13 9	-	36CrMoV12	-	-
		524A14	-	2092	L1	1.7039	34MoCrS4 G	-	105WCR 5	-	-
		605A32	-	2108	8620	1.5419	20MoCrS4	-	-	F520.S	-
		823M30	33	2512	-	1.7228	55NiCrMoV6G	-	653M31	-	-
		-	-	2127	-	1.7139	16MnCr5	-	-	-	-
		830 M 31		2534	-	-	31NiCrMo134	-	-	F-1270	
		-		2550	L6	1.2721	50NiCr13	55NCV6	-	F-528	
		640A35	111A	-	3135	1.5710	36NiCr6	35NC6	-	-	SNC236
		-	-	-	3415	1.5732	14NiCr10	14NC11	16NiCr11	15NiCr11	SNC415(H)
		655M13; A12	36A	-	3415;3310	1.5752	14NiCr14	12NC15	-	-	SNC815(H)
		-	-	2090	9255	1.0904	55Si7	55S7	-	-	-

P		Great Britain		Sweden	U.S.A.	Germany		France	Italy	Spain	Japan
		BS	EN	SS	AISI/SAE	W. No.	DIN	AFNOR	UNI	UNE	JIS
Steel	Low carbon steel	816M40	110	-	9840	1.6511	36CrNiMo4	40NCD3	38NiCrMo4(KB)	35NiCrMo4	-
		817M40	24	2541	4340	1.6582	35CrNiMo6	35NCD6	35NiCrMo6(KB)	-	-
		530A32	18B	-	5132	1.7033	34Cr4	32C4	34Cr4(KB)	35Cr4	SCr430(H)
		530A40	18	-	5140	1.7035	41Cr4	42C4	41Cr4	42Cr4	SCr440(H)
		(527M20)	-	2511	5115	1.7131	16MnCr5	16MC5	16MnCr5	16MnCr5	-
		1717CDS110	-	2225	4130	1.7218	25CrMo4	25CD4	25CrMo4(KB)	55Cr3	SCM420;SCM430
										AM26CrMo4	
		708A37	19B	2234	4137;4135	1.7220	34CrMo4	35CD4	35CrMo4	34CrMo4	SCM432;SCCRM3
		708M40	19A	2244	4140;4142	1.7223	41CrMo4	42CD4TS	41CrMo4	42CrMo4	SCM 440
		708M40	19A	2244	4140	1.7225	42CrMo4	42CD4	42CrMo4	42CrMo4	SCM440(H)
		722M24	40B	2240	-	1.7361	32CrMo12	30CD12	32CrMo12	F.124.A	-
		735A50	47	2230	6150	1.8159	50CrV4	50CV4	50CrV4	51CrV4	SUP10
		905M39	41B	2940	-	1.8509	41CrAlMo7	40CAD6, 12	41CrAlMo7	41CrAlMo7	-
		BL3	-	-	L3	1.2067	100Cr6	Y100C6	-	100Cr6	-
		-	-	2140	-	1.2419	105WCr6	105WC13	10WCr6	105WCr5	SKS31
									107WCr5KU		SKS2,SKS3
		-	-	-	L6	1.2713	55NiCrMoV6	55NCDV7	-	F.520.S	SKT4
	Alloy steel	1501-509;510	-	-	ASTM A353	1.5662	X8Ni9	-	X10Ni9	XBNi09	-
		-	-	-	2515	1.5680	12NI19	Z18N5	-	-	-
		832M13	36C	-	-	1.6657	14NiCrMo134	-	15NiCrMo13	14NiCrMo131	-
		BD3	-	-	D3	1.2080	X210Cr12	Z200C12	X210Cr13KU	X210Cr12	SKD1
									X250Cr12KU		
				2314		1.2083					
		BH13	-	2242	H13	1.2344	X40CrMoV5 1	Z40CDV5	X35CrMoV05KU	X40CrMoV5	SKD61
									X40CrMoV511KU		
		BA2	-	2260	A2	1.2363	X100CrMoV5 1	Z100CDV5	X100CrMoV51KU	X100CrMoV5	SKD12
		-	-	2312	-	1.2436	X210CrW12	-	X215CrW12 1KU	X210CrW12	SKD2
		BS1	-	2710	S1	1.2542	45WCrV7	-	45WCrV8KU	45WCrSi8	-
		BH21	-	-	H21	1.2581	X30WCrV9 3	Z30WCV9	X28W09KU	X30WCrV9	SKD5
							X30WCrV9 3KU		X30WCrV9 3KU		
		-	-	2310	-	1.2601	X165CrMoV 12	-	X165CrMoW12KU	X160CrMoV12	-
		401S45	52	-	HW3	1.4718	X45GrSi93	Z45CS9	X45GrSi8	F322	SUH1
		4959BA2	-	2715	D3	1.3343	S6-5-2	Z40CSD10	15NiCrMo13	-	SUH3
		BM 2		2722	M 2	1.3343	S6/5/2	Z 85 WDCV	HS 6-5-2-2	F-5603.	SKH 51
		BM 35		2723	M 35	1.3243	S6/5/2/5	6-5-2-5	HS 6-5-2-5	F-5613	SKH 55
		-		2782	M 7	1.3348	S2/9/2	-	HS 2-9-2	F-5607	-
		-	-	2736	HNV3	1.2379	X210Cr12 G	-	-	-	-
	Steel Casting	-	-	2223	-	-	-	-			
		Z120M12	-	-	-	1.3401	G-X120Mn12	Z120M12	XG120Mn12	X120Mn12	SCMnH/1
		BW 10		2183		1.3401		2120 M12	GX120 Mn12	F-8251	SEMn H1

Technical Data

M		Great Britain		Sweden	U.S.A.	Germany		France	Italy	Spain	Japan
		BS	EN	SS	AISI/SAE	W. No.	DIN	AFNOR	UNI	UNE	JIS
Stainless steel	Ferritic - Martensitic	403S17	-	2301	403	1.4000	X7Cr13	Z6C13	X6Cr13	F.3110	SUS403
						1.4001	X7Cr14	-	-	F.8401	-
		416 S 21		2380	416	1.4005	X12CrS13	Z11CF13	X12 CrS 13	F-3411	SUS 416
		430S15	960	2320	430	1.4016	X8Cr17	Z8C17	X8Cr17	F3113	SUS430
		410S21	56A	2302	410	1.4006	X10Cr13	Z10C14	X12Cr13	F.3401	SUS410
		430S17	60	2320	430	-	X8Cr17	Z8C17	X8Cr17	F.3113	SUS430
		420S45	56D	2304	-	1.4034	X46Cr13	Z40CM	X40Cr14	F.3405	SUS420J2
								Z38C13M			
		405S17	-	-	405	1.4002	-	Z8CA12	X6CrAl13	-	-
		420S37	-	2303	420	1.4021	-	Z20C13	X20Cr13	-	-
		431S29	57	2321	431	1.4057	X22CrNi17	Z15CNi6.02	X16CrNi16	F.3427	SUS431
		-	-	2383	430F	1.4104	X12CrMoS17	Z10CF17	X10CrS17	F.3117	SUS430F
		434S17	-	2325	434	1.4113	X6CrMo17	Z8CD17.01	X8CrMo17	-	SUS434
		425C11	-	2385	CA6-NM	1.4313	X5CrNi13 4	Z4CND13.4M	(G)X6CrNi304	-	SCS5
		403S17	-	-	405	1.4724	X10CrA113	Z10C13	X10CrA112	F.311	SUS405
		430S15	60	-	430	1.4742	X10CrA118	Z10CAS18	X8Cr17	F.3113	SUS430
		443S65	59	-	HNV6	1.4747	X80CrNiSi20	Z80CSN20.02	X80CrSiNi20	F.320B	SUH4
		-	-	2322	446	1.4762	X10CrA124	Z10CAS24	X16Cr26	-	SUH446
		349S54	-	-	EV8	1.4871	X53CrMnNiN21 9	Z52CMN21.09	X53CrMnNiN21 9	-	SUH35, SUH36
		_		2326	S44400	1.4521	X1CrMoTi18 2		-	-	-
		-		2317	-	1.4922	X20CrMoV12-1	-	X20CrMoNi 12 01	-	-
		-	-	-	630	1.4542/ 1.4548	-	Z7CNU17-04	-	-	-
	Austenitic	304S11	-	2352	304L	1.4306	-	Z2CN18-10	X2CrNi18 11	-	-
		304S31	58E	2332/2333	304	1.4350	X5CrNi189	Z6CN18.09	X5CrNi18 10	F.3551 F.3541 F.3504	SUS304
		303S21	58M	2346	303	1.4305	X12CrNiS18 8	Z10CNF 18.09	X10CrNiS 18.09	F.3508	SUS303
		304S15	58E	2332	304	1.4301	X5CrNi189	Z6CN18.09	X5CrNi18 10	F.3551	SUS304
		304C12		2333				Z3CN19.10	-	-	SUS304L
		304S12	-	2352	304L	1.4306	X2CrNi18 9	Z2CrNi18 10	X2CrNi18 11	F.3503	SCS19
		-	-	2331	301	1.4310	X12CrNi17 7	Z12CN17.07	X12CrNi17 07	F.3517	SUS301
		304S62	-	2371	304LN	1.4311	X2CrNiN18 10	Z2CN18.10	-	-	SUS304LN
		316S16	58J	2347	316	1.4401	X5CrNiMo18 10	Z6CND17.11	X5CrNiMo17 12	F.3543	SUS316
		-	-	2375	316LN	1.4429	X2CrNiMoN18 13	Z2CND17.13	-	-	SUS316LN
		316S13		2348	316L	1.4404	-	Z2CND17-12	X2CrNiMo1712	-	-
		316S13	-	2353	316L	1.4435	X2CrNiMo18 12	Z2CND17.12	X2CrNiMo1712	-	SCS16
								-	-	-	SUS316L
		316S33	-	2343 2347	316	1.4436	-	Z6CND18.12-03	X8CrNiMo1713	-	-
		317S12	-	2367	317L	1.4438	X2CrNiMo18 16	Z2CND19.15	X2CrNiMo18 16	-	SUS317L
		-		2562	UNS V 0890A	1.4539	X1NiCrMo	Z2 NCDU25-20	-	-	-
		321S12	58B	2337	321	1.4541	X10CrNiTi18 9	Z6CNT18.10	X6CrNiTi18 11	F.3553 F.3523	SUS321
		347S17	58F	2338	347	1.4550	X10CrNiNb18 9	Z6CNNb18.10	X6CrNiNb18 11	F.3552 F.3524	SUS347
		320S17	58J	2350	316Ti	1.4571	X10CrNiMoTi18 10	Z6NDT17.12	X6CrNiMoTi17 12	F.3535	-
		-	-	-	318	1.4583	X10CrNiMoNb18 12	Z6CNDNb17 13B	X6CrNiMoNb17 13	-	-
		309S24	-	-	309	1.4828	X15CrNiSi20 12	Z15CNS20.12	-	-	SUH309
		310S24	-	2361	310S	1.4845	X12CrNi25 21	Z12CN25 20	X6CrNi25 20	F.331	SUH310
		301S21	58C	2370	308	1.4406	X10CrNi18.08	Z1NCDU25.20	-	F.8414	SCS17
		-		2387	-	1.4418	X4 CrNiMo16 5	Z6CND16-04-01			
		316S111	-	-	17-7PH	1.4568/ 1.4504	-	Z8CNA17-07	X2CrNiMo1712	-	-
		-	-	2584	NO8028	1.4563	-	Z1NCDU31-27-03	-	-	-
		-	-	2378	S31254	-	-	Z1NCDU20-18-06AZ	-	-	-
	Austenitic-Ferritic (Duplex)	-	-	2376	S31500	1.4417	X2CrNiMoSi19 5	-	-	-	-
		-	-	2324	S32900	-	X8CrNiMo27 5	-	-	-	-
		-	-	2327	S32304	-	X2CrNiN23 4	Z2CN23-04AZ	-	-	-
		-	-	2328	-	-	-	-	-	-	-
		-	-	2377	S31803	-	X2CrNiMoN22 53	Z2CND22-05-03	-	-	-

K		Great Britain		Sweden	U.S.A.	Germany		France	Italy	Spain	Japan
		BS	EN	SS	AISI/SAE	W. No.	DIN	AFNOR	UNI	UNE	JIS
Cast iron	Malleable cast iron	8 290/6		0814			-	MN 32-8			FCMB310
		B 340/12		0815	32510		GTS-35	MN 35-10			FCMW330
		P 440/7		0852	40010	0.8145	GTS-45	Mn 450	GMN 45		FCMW370
		P 510/4		0854	50005	0.8155	GTS-55	MP 50-5	GMN 55		FCMP490
		P 570/3		0858	70003		GTS-65	MP 60-3			FCMP540
		P570/3		0856	A220-70003	0.8165	GTS-65-02	Mn 650-3	GMN 65		FCMP590
		P690/2		0862	A220-80002	0.8170	GTS-70-02	Mn700-2	GMN 70		FCMP690
	Grey cast iron			0100							
				0110	No 20 B		GG10	Ft 10 D			FC100
		Grade 150		0115	No 25 B	0.6015	GG 15	Ft 15 D	G 15	FG 15	FC150
		Grade 220		0120	No 30 B	0.6020	GG 20	Ft 20 D	G 20		FC200
		Grade 260		0125	No 35 B	0.6025	GG 25	Ft 25 D	G 25	FG 25	FC250
					No 40 B						
		Grade 300		0130	No 45 B	0.6030	GG 30	Ft 30 D	G 30	FG 30	FC300
		Grade 350		0135	No 50 B	0.6035	GG 35	Ft 35 D	G 35	FG 35	FC350
		Grade 400		0140	No 55 B	0.6040	GG 40	Ft 40 D			
		L-NiCuCr202		0523	A436 Type 2	0.6660	GGL-NiCr202	L-NC 202	-	-	
	Ductile cast iron	SNG 420/12		0717-02	60-40-18	0.7040	GGG 40	FGS 400-12	GS 370-17	FGE 38-17	FCD400
		SNG 370:17		0717-12	-		GGG 40.3	FGS 370-17			
		-		0717-15	-	0.7033	GGG 35.3	-			
		SNG 500/7		0727-02	80-55-06	0.7050	GGG 50	FGS 500-7	GS 500	FGE 50-7	FCD500
		Grade S6		0776	A43D2	0.7660	GGG-NiCr202	S-NC 202	-	-	
		SNG 600/3		0732-03	-		GGG 60	FGS 600-3			FCD600
		SNG 700/2		0737-01	100-70-03	0.7070	GGG 70	FGS 700-2	GS 700-2	FGS 70-2	FCD700

N	Great Britain		Sweden	U.S.A.	Germany		France	Italy	Spain	Japan
	BS	EN	SS	AISI/SAE	W. No.	DIN	AFNOR	UNI	UNE	JIS
Non-ferrous metals	-	-	4251	SC64D	3.2373	G-AISI9MGWA	A-S7G	-	-	C4BS
	LM5	-	4252	GD-AISI12	-	G-ALMG5	A-SU12	-	-	AC4A
	LM25		4244	356.1						A5052
			4247	A413.0		GD-AISi12				A6061
	LM24		4250	A380.1		GD-AISi8Cu3				A7075
	LM20		4260	A413.1		G-AISi12 (Cu)				ADC12
	LM6		4261	A413.2		G-AISi12				
	LM9		4253	A360.2		G-AISi10Mg(Cu)				

S		Great Britain		Sweden	U.S.A.	Germany		France	Italy	Spain	Japan
		BS	EN	SS	AISI/SAE	W. No.	DIN	AFNOR	UNI	UNE	JIS
Difficult-to-cut materials	Ni-based alloys	-	-	-	330	1.4864	X12NiCrSi36 16	Z12NCS35.16	F-3313	-	SUH330
		330C11	-	-	-	1.4865	G-X40NiCrSi38 18	-	XG50NiCr39 19	-	SCH15
		-	-	-	5390A	2.4603	-	NC22FeD	-	-	
		-	-	-	5666	2.4856	NiCr22Mo9Nb	NC22FeDNB	-	-	
		HR5,203-4	-	-	-	2.4630	NiCr2OTi	NC20T	-	-	
		-	-	-	5660	LW2.4662	NiFe35Cr14MoTi	ZSNCDT42	-	-	
		3146-3	-	-	5391	LW2 4670	S-NiCr13A16MoNb	NC12AD	-	-	
		HR8	-	-	5383	LW2.4668	NiCr19Fe19NbMo	NC19eNB	-	-	
		3072-76	-	-	4676	2.4375	NiCu30Al	-	-	-	
		Hr401,601	-	-	-	2.4631	NiCr2OTiAk	NC20TA	-	-	
		-	-	-	AMS 5399	2.4973	NiCr19Co11MoTi	NC19KDT	-	-	
		-	-	-	AMS 5544	LW2.4668	NiCr19Fe19NbMo	NC20K14	-	-	
		-	-	-	AMS 5397	LW2 4674	NiCo15Cr10MoAlTi	-	-	-	
		-	-	-	5537C	LW2.4964	CoCr20W15Ni	KC20WN	-	-	
		-	-	-	AMS 5772	-	CoCr22W14Ni	KC22WN	-	-	
	Titanium alloys	TA14/17	-	-	AMS R54520	-	TiAl5Sn2.5	T-A5E	-	-	
		TA10-13/TA28	-	-	AMS R56400	-	TiAl6V4	T-A6V	-	-	
		TA11	-	-	AMS R56401	-	TiAl6V4ELI	-	-	-	
		-	-	-	-	-	TiAl4Mo4Sn4Si0.5	-	-	-	

H	Great Britain		Sweden	U.S.A.	Germany		France	Italy	Spain	Japan
	BS	EN	SS	AISI/SAE	W. No.	DIN	AFNOR	UNI	UNE	JIS
Hard materials	-	-	2258-08	440A	1.4108	X100CrMo13	-	-	-	C4BS
	-	-	2534-05	610	1.4111	X110CrMoV15	-	-	-	AC4A
	-	-	2541-06	0-2	-	X65CrMo14	-	-	-	AC4A

Approximate Conversion Table of Hardness

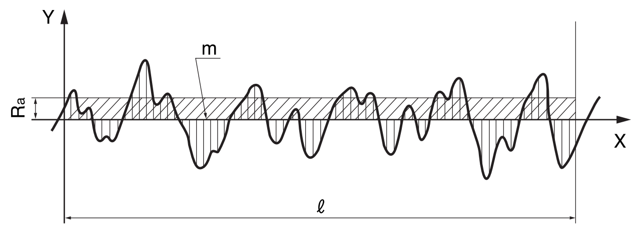
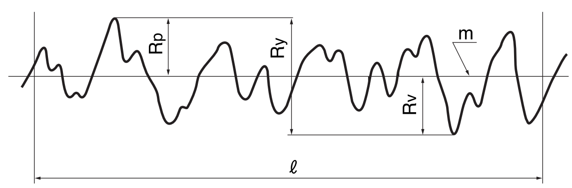
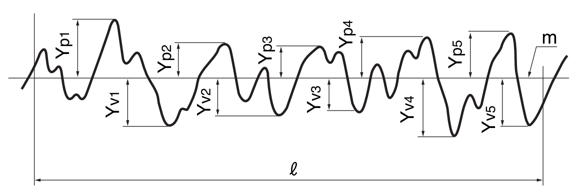
Brinell, 10 mm ball, Load 3000 kg, Standard ball HB	Vickers HV	Rockwell		Shore HS
		B Scale, Load 100 kg, Diameter 1/16 in. Steel ball HRB	C Scale, Load 150 kg, brale diamond HRC	
-	940	-	68.0	97
-	920	-	67.5	96
-	900	-	67.0	95
(767)	880	-	66.4	93
(757)	860	-	65.9	92
(745)	840	-	65.3	91
(733)	820	-	64.7	90
(722)	800	-	64.0	88
(712)	-	-	-	-
(710)	780	-	63.3	87
(698)	760	-	62.5	86
(684)	740	-	61.8	-
(682)	737	-	61.7	84
(670)	720	-	61.0	83
(656)	700	-	60.1	-
(653)	697	-	60.0	81
(647)	690	-	59.7	-
(638)	680	-	59.2	80
-	677	-	59.1	-
(630)	670	-	58.8	-
(627)	667	-	58.7	79
(601)	640	-	57.3	77
-	640	-	57.3	-
(578)	615	-	56.0	75
-	607	-	55.6	-
(555)	591	-	54.7	73
-	579	-	54.0	-
(534)	569	-	53.5	71
-	553	-	52.5	-
(514)	547	-	52.1	70
495	539	-	51.6	-
-	530	-	51.1	-
-	528	-	51.0	68
477	516	-	50.3	-
-	508	-	49.6	-
-	508	-	49.6	66
461	495	-	48.8	-
-	491	-	48.5	-
-	491	-	48.5	65
444	474	-	47.2	-
-	472	-	47.1	-
-	472	-	47.1	63

Note: Figures in ( ) under Brinell indicate values using tungsten carbide ball.

Brinell, 10 mm ball, Load 3000 kg, Standard ball HB	Vickers HV	Rockwell		Shore HS
		B Scale, Load 100 kg, Diameter 1/16 in. Steel ball HRB	C Scale, Load 150 kg, brale diamond HRC	
429	455	-	45.7	61
415	440	-	44.5	59
401	425	-	43.1	58
388	410	-	41.8	56
375	396	-	40.4	54
363	383	-	39.1	52
352	372	110.0	37.9	51
341	360	109.0	36.6	50
331	350	108.5	35.5	48
321	339	108.0	34.3	47
311	328	107.5	33.1	46
302	319	107.0	32.1	45
293	309	106.0	30.9	43
285	301	105.5	29.9	-
277	292	104.5	28.8	41
269	284	104.0	27.6	40
262	276	103.0	26.6	39
255	269	102.0	25.4	38
248	261	101.0	24.2	37
241	253	100.0	22.8	36
235	247	99.0	21.7	35
229	241	98.2	20.5	34
223	234	97.3	18.8	-
217	228	96.4	17.5	33
212	222	95.5	16.0	-
207	218	94.6	15.2	32
201	212	93.8	13.8	31
197	207	92.8	12.7	30
192	202	91.9	11.5	29
187	196	90.7	10.0	-
183	192	90.0	9.0	28
179	188	89.0	8.0	27
174	182	87.8	6.4	-
170	178	86.8	5.4	26
167	175	86.0	4.4	-
163	171	85.0	3.3	25
156	163	82.9	0.9	-
149	156	80.8	-	23
143	150	78.7	-	22
137	143	76.4	-	21
131	137	74.0	-	-
126	132	72.0	-	20
121	127	69.8	-	19
116	122	67.6	-	18
111	117	65.7	-	15

■ Surface roughness

According to JIS B 0601, 1994 and its explanation

Type	Symbol	How to determine	Example (Fig.)
Arithmetic mean roughness	**Ra**	Extract the reference length in the direction of mean line from the roughness curve. Take the X axis in the vertical magnification direction. Express the roughness curve by Y = f(x). In this case, the value determined by the following equation is expressed in micrometer (μm) and called the arithmetic mean roughness. $$Ra=\frac{1}{l}\int_0^l \lvert f(x)\rvert\, dx$$	
Maximum height	**Ry**	Extract the reference length in the direction of mean line from the roughness curve. Measure the distance between crest and bottom lines of the extracted portion in the direction of the vertical magnification direction of the roughness curve. Express this value in micrometer (μm) and call it the maximum height. $$R_y=R_p+R_v$$	
Ten point mean roughness	**Rz**	Extract the reference length in the direction of mean line from the roughness curve. Determine the sum of the average of the absolute value of the height (Yp) of the fifth crest from the average line and the average of the absolute value of the height (Yv) of the fifth bottom from the lowest bottom. Express this value in micrometer (μm) and call it the ten-point mean roughness. $$Rz=\frac{\lvert Yp1+Yp2+Yp3+Yp4+Yp5\rvert+\lvert Yv1+Yv2+Yv3+Yv4+Yv5\rvert}{5}$$	 $Y_{p1}, Y_{p2}, Y_{p3}, Y_{p4}, Y_{p5}$: Height of the fifth crest from the highest crest of the sampled portion equivalent to the reference length. $Y_{v1}, Y_{v2}, Y_{v3}, Y_{v4}, Y_{v5}$: Height of the fifth bottom from the lowest crest of the sampled portion equivalent to the reference length.

Grade Comparison Charts

●CVD Coated Grades

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Sandvik	Kyocera	Hitachi Tool	Dijet	NTK	Seco Tool	Kennametal	Iscar
P Steels	P01	**T9005**	UE6005	AC700G	GC4005	CA5505	HC5000	JC110V		TP1000 TK1000		IC9015
	P10	**T9005** **T9015**	UE6005 UE6010 UC6010 UE6020	AC700G AC2000	GC4005 GC4015 GC3115	CA5505 CA5515	GM10 GM8015 HG8010	JC110V JC215V JC730U	CP2 CP5	TP1000 TP2000 TK1000	KC9110 TN7005 TN7010 TN2510 TN25M	IC9015
	P20	**T9015** **T9025**	UE6010 UC6010 UE6020 F7030	AC2000 AC3000	GC4015 GC4020 GC2015 GC4225	CA5515 CA5525 CA9025	GM8020 HG8025	JC110V JC215V JC730U	CP2 CP5	TP2000 TP200 T200M T250M TK2000	KC9125 CM4 TN7015 TN7525	IC9015 IC9025
	P30	**T9025** **T9035** **T3030**	UH6400 UE6035 F7030 US735	AC3000 AC630M AC230	GC4030 GC4035 GC2025 GC2135 GC4225	CA5525 CA5535 CR9025	GM25	JC215V JC325V		TP2000 TP3000 T250M T350M T25M	KC8050 KC930M TN8025 TN7535 TN7025	IC9025
	P40	**T9035**	UH6400 UE6035 US735	AC630M AC230	GC4035 GC4240 GC235	CA5535	GM8035 GX30 GF30 GX2030	JC325V JC450V		TP3000 TP400 TP40 T350M	KC7935 KC9040 TPC35	
M Stainless steel	M10	**T9015**	US7020	AC610M	GC2015	CA6015	GM10	JC110V	CP2 CP5	TP200	TN25M TN7010	
	M20	**T6020** **T9025**	US7020 F7030	AC610M AC630M	GC2025	CA6015	GM8020	JC110V JC215V JC730U	CP2 CP5	TP200 TP3000 T250M T25M	KC9225 KC925M TN7015 TN7025	IC9025
	M30	**T6030** **T3030**	US735 F7030	AC630M	GC2040 GC2135 GC235		GM25 HG8025	JC215V JC325V		TP3000 TP400 TP40 T350M T25M	KC8050 KC9040 KC930M TN7025 TN8025 TN7535	IC9025 IC9054
	M40						GX30 GF30	JC325V JC450V		TP400 TP40	KC9240 KC9245 TPC35	IC9025
K Cast irons	K01	**T5105** **T5010**	UC5105	AC300G	GC3205 GC3210	CA4010	GM3005	JC105V JC600		TK1000		IC9007 IC428
	K10	**T5105** **T5115** **T5010** **T5020** **T1015**	UC5115 F5010	AC700G AC211	GC3205 GC3210 GC3115	CA4010 CA4115	GM8015 HG8010	JC110V JC600 JC610	CP2 CP5	TK1000 TK2000	KC9315 TN5015 TN5505 TN2510 KC915M TN5515 TN7010	IC9015
	K20	**T5125** **T5020** **T5115**	F5020 UC5115	AC700G	GC3215 GC3220 K20W K20D	CA4010 CA4120	GM8020 HG8025	JC110V JC215V JC610	CP2 CP5	TP200 T200M TK2000 T150M	KC9325 KC925M TN7015 TN5020 TN5520	IC9015
	K30	**T5125**			GC3040		GM25	JC215V JC610		TP200 T200M	KC8050 KC9040 KC930M TN7025	

Note: The above chart is based on published data and not authorized by each manufacturer.

●PVD Coated Grades

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Sandvik	Kyocera	Hitachi Tool	Dijet	NTK	Seco Tool	Kennametal	Iscar
P Steels	P01					PR915	PTH08M PCA08M PCS08M TB6005	JC5003				
	P10	**AH710**	VP10MF	ACZ310	GC1025 GC1030 P10A	PR630 PR730 PR830 PR930	CY9020 PCA12M PCA15M PC20M JX1020	JC5003 JC5030		CP200	KC5010 KC792M KC715M KC637M	IC570 IC950
	P20	**AH710**	VP20MF VP15TF VP20RT	ACZ310 ACZ330	GC1020 GC4125 GC1025 P20A GC1030	PR630 PR730 PR830 PR930	TB6020 CY150 CY15	JC5015 JC5030 JC5040	VM1 QM1 TA1 TAS	CP250 F25M	KC7215 KC7315 KC522M KC625M KC635M KC525M	IC570 IC908 IC950
	P30	**GH330 GH730 AH120 AH330 AH740**	VP15TF VP30RT VP20RT	ACZ330 ACZ350		PR660	TB6045 CY250 CY25 HC844	JC5015 JC5040	ZM3 QM3 TA3	CP500 F25M F30M	KC7015 KC7020 KC7235 KC725M	IC908 IC1008 IC328 IC3028 IC354 IC950
	P40	**AH120 AH140**	VP30RT	ACZ350	GC2145		PTH30E TB6060 PTH40H	JC5040	ZM3 QM3 TA3	CP500 F40M T60M	KC7030 KC7040 KC7140 KC735M	IC3028 IC328 IC354
M Stainless steel	M01			EH510Z			PCS08H					
	M10	**AH710**	VP10MF	EH510Z	GC1005 GC1105	PR630 PR730 PR915 PR925	CY9020	JC5003		CP200	KC5010 KC6005 KC6105 KC792M KC715M	IC907 IC507
	M20	**GH330 GH730**	VP20MF VP15TF VP20RT	EH520Z ACZ310	GC1025 GC4125 GC1030	PR630 PR730 PR915 PR925	TB6020 CY150 CY15	JC5015 JC8015	VM1 QM1 TA1 TAS	CP200 CP500 F25M	KC7020 KC7025 KC522M KC633M KC525M	IC907 IC507 IC328/3028 IC908 IC1008 IC1028
	M30	**AH120**	VP15TF VP20RT VP30RT	ACZ330 ACZ350	GC1020 GC2030 GC2035	PR660	TB6045 CY250 CY25 HC844	JC5015 JC8015	ZM3 QM3 TA3	CP500 F30M F40M	KC5025 KC7030 KC720 KC7225 KC725M KC735M	IC507 IC328/3028 IC908 IC1008 IC1028 IC928
	M40	**AH140**	VP30RT	ACZ350	GC2145		PTH30E TB6060 PTH40H		ZM3 QM3 TA3			IC328/3028 IC1028 IC928
K Cast irons	K01	**AH110**		EH10Z EH510Z		PR510	PTH08M PCA08M TB6005 PTH05A	JC5003				
	K10	**GH110 AH110**		EH10Z EH510Z		PR510 PR905	CY9020 PTH13S	JC5015 JC5003		CP200	KC5010 KC7210 TN2505 KC510M	IC507 IC910
	K20	**AH120**	VP15TF VP20RT	EH20Z ACZ310 EH520Z	GC1020	PR905	TB6020 CY150 CY15	JC5015	QM1 TA1	CP200 CP250	KC7015 KC7215 KC7315 KC520M KC522M KC525M	IC507 IC328 IC908 IC910
	K30		VP15TF VP20RT	ACZ310			TB6045 CY250 PTH40H		QM3 TA3	CP500	KC7225 KC725M	IC328 IC908

Note: The above chart is based on published data and not authorized by each manufacturer.

●PVD Coated Grades

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Sandvik	Kyocera	Hitachi Tool	Dijet	NTK	Seco Tool	Kennametal	Iscar
N Nonferrous metals	N01	**GH110**		ACZ305 DL1000			PCS08M					
	N10			EH10Z EH510Z			CY100H CY10H				KC5410 KC510M KC637M	
	N20			EH20Z EH520Z						F15M F17M	KC631M	IC308 IC908 IC328
S Super alloys	S01	**AH110**	VP05RT					JC5003	TAS			
	S10	**AH120**	VP05RT VP10RT	EH510Z	GC1005 GC1105	PR915	PCS08M	JC5015 JC8015	QM1 TA1 TAS	CP200 CP250 CP500	KC5410 KC6005 KC7030 KC510M KC5510	IC507 IC907
	S20		VP10RT VP15TF	EH520Z EH20Z	GC4125 GC1025 GC1030		CY100H CY10H		QM1 TA1 ZM3 TA3 TAS	CP250 CP500	KC7020 KC730 KC522M KC625M KC5525 KC525M	IC507 IC907 IC328 IC908 IC1008 IC1028
	S30		VP15TF		GC2030					F40M	KC720 KC725M	IC328/3028 IC1028 IC928
H Hard materials	H01	**AH710**						JC5003				
	H10	**AH110** **AH120**	VP15TF	EZ510Z			PTH08M PCA08M TB6005 PTH80D	JC5015 JC8008 JC8015		F15M	KC6312 TN2505	
	H20		VP15TF							CP200 F15M	KC635M	
	H30									F30M		

●Cermet/Coated Cermet Grades

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Sandvik	Kyocera	Hitachi Tool	Dijet	NTK	Seco Tool	Kennametal	Iscar
P Steels	P01	**GT720** **NS520** **GT520**	AP25N	T110A T2000Z		TN30 PV30		LN10 CX50	T3N T15			IC20N IC520N
	P10	**GT720** **GT730** **NS520** **AT530**	NX2525 AP25N	T1200A T2000Z	CT5015 GC1525	TN60 TN6020 PV60 PV7020	CZ25	CX50 CX75	T15 C7X	CM C15M CMP	KT315 KT6215 TTI25	IC20N IC520N IC530N IC75T
	P20	**NS730** **GT730** **NS530** **AT530** **GT530**	NX2525 NX3035 AP25N UP35N	T1200A T2000Z T3000Z	CT530 GC1525	TN90 TN100M TN6020 PV90 PV7020	MZ1000 CH550 MZ2000 CH7030	CX75 CX90	C7X	C15M	KT325 KT530M HT7 KT605M	IC20N IC520N IC530N IC75T IC30N
	P30	**NS730** **NS740** **NS530** **NS540**	NX4545 VP45N	T3000Z T250A			MZ3000 CH7035	CX90 CX99	N40			IC30N IC75T

Note: The above charts are based on published data and not authorized by each manufacturer.

●Cermet/Coated Cerment Grades

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Sandvik	Kyocera	Hitachi Tool	Dijet	NTK	Seco Tool	Kennametal	Iscar
M Stainless steel	M01											
	M10	**GT730 NS520 AT530 GT530**	NX2525 AP25N	T110A T2000Z	GC1525	TN60 TN6020 PV60 PV7020		LN10 CX50	T15 C7X	CM CMP	TTI25	IC30N
	M20	**NS730 NS530**	NX2525 NX3035 AP25N	T1200A T2000Z	CT530	TN90 TN100M TN6020 PV90 PV7020	MZ1000 CH550 MZ2000 CM7030	CX50 CX75	C45 C7X	C15M	KT530M HT7 KT605M	IC30N
	M30	**NS740 NS540**	NX4545	T3000Z T250A			MZ3000 CM7035	CX90 CX99	N40			
K Cast irons	K01	**GT720 NS520 AT520 GT520**	NX2525 AP25N	T110A T2000Z		TN30 PV30		LN10	T3N T15			
	K10	**GT730 NS730 NS530 GT530**	NX2525 AP25N	T1200A T2000Z		TN60 TN6020 PV60 PV7020		LN10	T15 C7X		KT325 KT6215 TTI25	
	K20		NX2525 AP25N	T3000Z				CX75			KT530M HT7	

●Ceramics Grades

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Sandvik	Kyocera	Hitachi Tool	Dijet	NTK	Seco Tool	Kennametal	Iscar
P Steels	P01	**LX11 LX21**		NB90S NB100C		A66N		HC1 HC4 HC7 ZC7				
	P10			WX120				WA1	Whiskal			
	P20											
M Stainless steel	M01											
	M10			WX120				WA1	Whiskal		KY1540	
	M20											
K Cast irons	K01	**LX11 LX21**		NB90S NB90M	CC620 CC650	KA30		HC1 HW2 HC2 HC6 HC7	NPC-H2 NPC-A2 Win		KY1615 KY1310	
	K10	**CXC73**		NS260C NS260 WX120	CC6090 CC1690	A65 A66N KS500		WA1 SX1 SP2 SX9	NX NXA Whiskal		KY3500 KY4300	
	K20	**FX105 CX710**		NS260C NS260		KS500 KS6000		SX8 SP2 SX1	NX NXA			
S Super alloys	S01								NPC-H2 NPC-A2			
	S10			WX120	CC670 CC6080			WA1	Whiskal Win		KY4300 KY1540	
	S20											
H Hard materials	H01	**LX11**		NB100C	GC6050 CC650 CC670	A65 A66N		HC4 HC7 ZC7	NPC-A2			
	H10					A65 A66N		WA1	NPC-A2 Win		KY4300 KY1615	
	H20											

Note: The above charts are based on published data and not authorized by each manufacturer.

● PCBN + PCD

Application code			Tungaloy	Mitsubishi Material	Sumitomo Electric Hartmetall	Sandvik	Kyocera	Hitachi Tool	Dijet	NTK	Nippon	Seco Tool	Kennametal	Iscar
PCBN	K Cast irons	K01	**BX930**	MB710	BN500	CB50 CB7050	KBN900 KBN65B		JBN795	B20 B22 B16	NBN10 NBN20 NBN30		KD120 PB100	IB85 IB90A
		K10	**BX470 BX480 BX950**	MB710 MB730	BN700		KBN900	BH200	JBN330	B20 B22 B16	NBN10 NBN20 NBN30	CBN200 CBN300 CBN300P	KB9610	IB90 IB90A
		K20	**BX950 BX90S BXC90**	MB730 MBS140	BN700 BNS800			BH250				CBN200 CBN300 CBN300P		
		K30	**BXC90 BX90S**	MBS140	BNS800							CBN350	KB9640	
	S Super alloys	S01	**BX950 BX450 BX480**	MB730	BN700									IB85
		S10											KD120 PB100	
		S20												
		S30												
	H Hard materials	H01	**BXC30 BX310**	MBC010 MB810	BNX10 BNC150 BNC80		KBN510 KBN10B KBN10N KBN25N			B20 B24	NBN10	CBN10 CBN100 CBN100P CBN050	PB250	
		H10	**BXC50 BXC30 BX330**	MB820 MB8025 MBC020	BNC150 BNC200 BN250	CB7015 CB7020 CB20	KBN25N KBN900 KBN525	BH200	JBN300	B20 B24	NBN10	CBN100 CBN100P CBN300 CBN300P CBN200	KD050 KD120 KB9610	IB50
		H20	**BXC50 BX360**	MB825 MB8025 MBC020	BNC200 BNX20	CB50 CB7050		BH250	JBN245	B26		CBN150 CBN300 CBN300P CBN350 CBN200	KB5625	IB55
		H30	**BXC50 BX380**	MB8025 MB835 MBC020	BNC300 BN350 BNX25					B36		CBN350	KB9640	IB85
PCD	N Nonferrous metals	N01	**DX180 DX160**	MD205	DA90	CD10	KPD001		JDA30 JDA735	PD1	NPD		PD100 KD1405	
		N10	**DX140**	MD205 MD220	DA150 DA2200		KPD001 KPD010		JDA40 JDA745			PCD10	KD100 KD1410 KD1415	ID5
		N20	**DX120**	MD220 MD230	DA2200				JDA10 JDA715			PCD20		
		N30	**DX120**	MD230	DA2200							PCD30		

●Ultra-fine Grain Cemented Carbide Grades

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hartmetall	Sandvik	Kyocera	Hitachi Tool	Dijet	NTK	Nippon	Seco Tool	Kennametal	Iscar
P Steels	P01									SN03			
	P10	**TX10S**		ST10P	S1P		WS10	SRT		SN10		P10	IC70
	P20	**TX20 TX25**	UTi20T	ST20E	SMA		EX35	SRT DX30		SN20 FL37S		K125M TTM	IC70 IC50M
	P30	**TX30 UX30**	UTi20T	A30 A30N	SM30	PW30	EX35 EX40	SR30 DX35		SN30		GK K600 TTR	IC50M IC54
	P40	**TX40**		ST40E	S6		EX45	SR30 DX35		SN40		G13	IC54

Note: The above charts are based on published data and not authorized by each manufacturer.

●Ultra-fine Grain Cemented Carbide Grades

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hartmetall	Sandvik	Kyocera	Hitachi Tool	Dijet	NTK	Nippon	Seco Tool	Kennametal	Iscar
M Stainless steel	M01									UN10			
	M10	TU10		EH510 U10E	H10A		WA10B	UMN	MT1	UN20	890	K313	
	M20	TU20	UTi20T	EH520 U2	H13A		EX35	DX25 UMS	KM1	UN30	HX 883	K68 KMF K125M TTM	IC07 IC08
	M30	UX30	UTi20T	A30 A30N	H10F SM30		EX40 EX45	DX25 UMS	KM3	UN40		K600 TTR	IC28
	M40	TU40			S6		EX45	UM40				G13	IC28
K Cast irons	K01	TH03	HTi05T	H1 H2	H1P		WH05	KG03		HN05		K605	
	K10	G1F TH10	HTi10	EH10 EH510	H1P H10 HM	KW10	WH10	KG10 KT09		HN10 G1	890	K10 K313 KF1 KM1 K110M THM THM-U	IC20
	K20	G2F G2 KS20	UTi20T	G10E EH20 EH520	H13A	GW10	WH20	CR1 KG20	KM1	G2	890 HX 883	K715 KMF K600	IC20 IC10
	K30	G3	UTi20T	G10E				KG30	KM3	G3	883	THR	IC10 IC28
	K40											G13	IC28
N Nonferrous metals	N01			H1 H2	H10 H13A			KG03				K605	
	N10	TH10 H10T KS05F	HTi10	EH10 EH510				KG10 KT9		HN05	890 H15	K10 K313 KF1 KM1 K110M THM THM-U	IC08 IC20
	N20			G10E EH20 EH520				CR1 KG20	KM1		HX KX 883 H15 H25	K715 KMF K600	IC28 IC20
	N30							KG30	KM3		H25	G13 THR	
S Super alloys	S01		RT9005					KG03					
	S10	TH10	RT9005 RT9010	EH10 EH510	H10 H10A H10F H13A			FZ05 KG10		HN05 HN10	890	K10 K313 THM	IC20
	S20	KS20	RT9010 TF15	EH20 EH520				FZ15 KG20			890 883 HX H25	K715 KMF	IC20
	S30		TF15					KG30				G13 K600 THR	IC28
H Hard materials	H01	TH03		H1				KG03		HN05			
	H10	TH10						FZ05 KG10		HN10			
	H20							FZ15 KG20			890 HX 883		

Note: The above chart is based on published data and not authorized by each manufacturer.

Chipbreaker Comparison Charts

●Negative inserts

Application code		Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Kyocera	Sandvik	Hitachi Tool	Kennametal	Dijet	Iscar
P Steels	Precision finishing	**TF, 01**	PK	FA, FL	DP, XP CF			FF	PF	SF
	Finishing and light cutting	**TS, TSF ZF 11, 17, NS AS AFW, ASW 27, NM CB C**	FH, SY, FY FS, C SH SW, MW SA R/L-1G, R/L-K R/L-F, R/L-FS	FP LU, SU, SK LUW, GUW SP ST, C	HQ, PS, GP VF XQ CJ WQ CQ	PF QF MF WF, WM, WR	BCT FE CE BE	FN	UA, FT UR, UT	NF No sign WG C, RF
	Medium cutting	**TM DM 32Y ZM, 37, 38 33, All round**	MV, MZ, MA MH All round	UG, UU GUW, UX, GU UA UM, UZ, MC	GS, HS CS, PT HK, XS GC, All round	PM, QM SM R/L-K	AE , AY AH Y, V	P MN	PG, UB, GN GNP	TF, PP, LF
	Medium to heavy cutting	**TH**	GH	MU, MX UZ	GT, HT	PR(P) MR	RE AR	RN, RP MG	GG, UD	TNM, NR
	Heavy cutting	**TU 57 65**	HZ, HX, HV, HA HAS, HBS, HCS HDS, HXD	MP, HG, HP	HX	PR MR 31, HR, QR	TE, UE H HX, HE	RM RH	UC	NM Without chipbreaker
M Stainless steel	Finishing and light cutting	**SS**	MS	SU	GU	MF 23	SE	FP	SF	
	Medium cutting	**S SM**	ES, 2G MA	EX, UP, UG MU, MM, GU	ST HU, SU	 MM, QM	DE	MP , P	SG	TF, PP
	Heavy cutting	**TH TU**		MP, HG, HP		MR QR, HR		RM RH		
K Cast irons	Finishing	**CF Without chipbreaker**	SH	FX, FY	All round, C	KF Without chipbreaker	Y , V Without chipbreaker	FN	Without chipbreaker	
	Medium cutting	**CM, All round 33**	All round	UM, UX	ZS	KM QM	AE	UM, P		
	Heavy cutting	**CH**	Without chipbreaker	MU, UZ, MM	GC Without chipbreaker	KR MR QR	RE	RP, MG RN	GG	GN
N Nonferrous metals	Cutting of nonferrous metals	**P**		UP, FY, GX	A3 AH	23	R/L	MS, MP RP, MG		PP
S Super alloys	Cutting of heat resisting alloy	**SA SM**	MS ES FJ, MJ, GJ	FY, FX, SU EX, UP MU	SU	23 SR, NGP SM(NMX)		FS, LF K, GP, P MG-MS		PP

Note: The above chart is based on published data and not authorized by each manufacturer.

●Positive inserts

	Application code	Tungaloy	Mitsubishi Material	Sumitomo Electric Hard Metal	Kyocera	Sandvik	Hitachi Tool	Kennametal	Dijet	Iscar
P Steels	Precision finishing	01		FW	CF		No sign	UF		SF
	Finishing and light cutting	PF	FV , SQ	FP, FZ, LU	XP, GP, DP	UF, PF	JQ	11, GM	FT	PF
		PS	SV	FK, SS, SC SU, SK, SF US	HQ, XQ , VF GP	PF(MF) PM(MM) UF, UM	JE	LF		SM, 14, 17 19, XL
		W08~20	R/L, R/L-FD R/L-FS, R/L-MV R/L-F, R/L-L	W, SD FX, FY	R/L A, B, C, H, Y	R/L-K				R/L RF, LF No sign
	Medium cutting	PM	MV No sign RR, RBS	SU, MU	HQ	PM, PR UM, UR	J	MF		DT, HQ
		23		UJ	GP, DP	53				
		24		SC (except for G-class inserts)	All round (No sign) G	No mark	JE			
		All round					All round			
		RS	No sign	RP		No mark	RG		GG	
	High-feed, small depth of cut cutting	61	No sign			No mark	WE			No sign 14
	Turning on small lathes	J08~10	R/L-SR, R/L-SN R/L-SS		F, J, U, CK FSF, USF, JSF	R/L-F			MF, MM ALU, MM1 ASF FT, ACB	
M Stainless steel	Finishing	SS	FV			MF MM, UM MR		GM, LF MF		
K Cast irons	Cutting of cast irons	Without chipbreaker	Without chipbreaker No sign	Without chipbreaker	Without chipbreaker	KF, R/L-K, KM Without chipbreaker UM, KR	Without chipbreaker	Without chipbreaker	Without chipbreaker	19
N Nonferrous metals	Cutting of nonferrous metals	AL	MJ, FJ	AG, AW	AH	AL		GT-HP		AS
		Read-type	R/L-F R/L	FY	A3					

Note: The above chart is based on published data and not authorized by each manufacturer.