FUJILLOY

Cemented Carbide

INTRODUCTION

Company Profile of Fuji die Co., Ltd.

Founded : June 6,1949
Business Fiels : Manufacture of cemented carbide tools (Specialized in wear-resistant tools)
Paid-in Capital : 164 million yen
The founder : Takayoshi Shinjo
President : Morio Nishijima
Employee : 1000

Fuji Die Co., Ltd. is the manufacturer expert of wear-resistance & impact-resistance tools made from cemented carbide, and we have developed a wide variety of investigation in response to usage.

Fuji Die Co., Ltd. recognizes it our duty to offer industrial world the supreme cemented carbide tools. Let us introduce you the FUJILLOY™ products.

Defintion of Cemented Carbide

Cemented carbide is a general term for 9 sorts (W, Mo, Cr, Ti, Zr, Hf, V, Nb, or Ta) of carbides combined with Fe Group (Fe, Co, or Ni), and the most popular one is WC-Co alloy.

Superiority of Cemented Carbide

- Improve the detailed and precise level of tool dimensions.
- Improve the surface conditions of tools and it affects good outlook of the products.
- Improve wear-resistance of tools and reduce wear-dust mingled into the products.
- Improve machinery operation ratio and minimize frequency maintenance through prolong tool life.
- Above all superiorities contribute the environment.

Characteristic Comparison of Tool Material Variety

Table 1 shows properties of various tool materials. Cemented carbide of FUJILLOY™ possesses, in particular, high scores for Young's modulus of elasticity and thermal conductivity compared with SKD, SKH and ceramics. FUJILLOY™ cemented carbide shows the hardness & compressive strength covering properties from SKD11 to ceramics. FUJILLOY™ cemented carbide, of which Young's modulus of elasticity shows the highest score among tool materials, proves FUJILLOY™ the best selection for the plastic working tool material.

Table 1 Properties of various tool materials

Properties		SKD11	SKD61	HSS	KF2 alloy	FUJILLOY™ WC grain size 0.2~6.0μm	Ceramics			
							SiC	Si_3N_4	ZrO_2	Al_2O_3
Hardness	HV	650~740	440~510,550	~900	900~1200	660~2400	~2100	~1360	890~1270	~1850
	HRC	58~62	45~49,52	62~68	68~72	58~(85.5)	–	–	–	–
Fraucture Toughness (K_{IC})	$MPam^{\frac{1}{2}}$	–	–	–	6.6~(26)	2.1~(55)	(3.5)	5	7~12	3.1
Transeverse Rupture Strength (TRS)	GPa	3.43	2.16	2.06~3.92	1.96~2.74	1.32~4.41	0.34	0.79	0.54	0.44
Compressive Strength (02% Proof Stress)	GPa	4.21(2.26)	2.94	4.90~5.39 (2.75~2.84)	3.38~3.92 (3.33~3.83)	1.86~6.88	3.5	2.94	1.4~3.7	2
Young's Modulus of Elasticity	GPa	206	206	217~230	219~234	420~680	300~400	220~300	180~200	363
Mean Thermal Expansion Coefficient RT-600℃	MK^{-1}	12.9	13.8	10.8~11.8	9.7~9.9	4.8~7.6	3.7	2.1	8~11	7.7
Thermal Conductivity	Wm/K	29	31	25~27	20~21	25~120	48	15	1.7~4.6	30
Thermal Shock Resistant Temperature	ΔT℃	–	–	–	650	400~1200≦	(400)	600	250	200

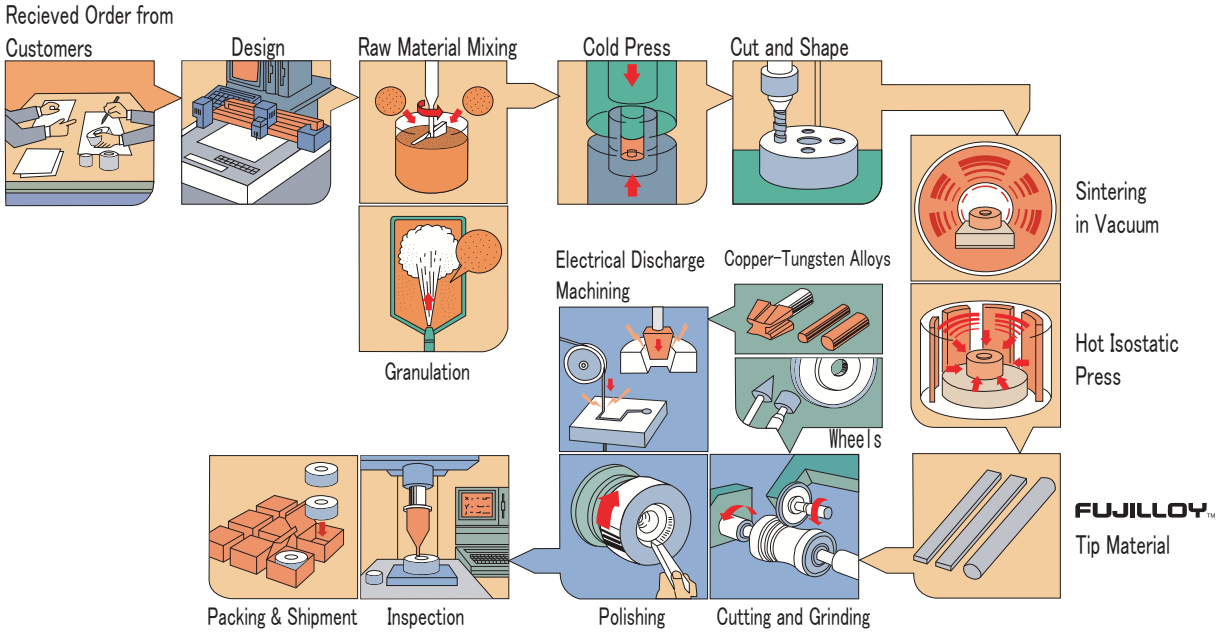
SKD11: ASTM D2 SKD61: ASTM H13 HSS: High Speed Steel KF2 alloy: Sintered High Speed Steel
This document does not show standard value, and shows our test data.

Manufacturing Process of FUJILLOY™

Fuji Die Co., Ltd. offers the most favorite cemented carbide products serve customers' satisfaction in accordance with FDS (Fuji Die Standards), which is specified based on ISO9001.

Fuji Die Co., Ltd. furnishes customers with the precious & precise cemented carbide well controlled technical products.

Fuji Die Co., Ltd. operates integrated process from the drawing in conformity with plasticity engineering, powder mixing and granulation, sintering, mechanical work to the precise final inspection.



Service Network for ASEAN & China; Worldwide Market

Fuji Die Co., Ltd. established in 1949 and work all the way through in pursuit of customers satisfaction serving super hard wear resistant tools with sincere. Fuji Die Co., Ltd. has overseas bases in ASEAN & China, let alone in Japan, and seeks after delivery & other services in short term with punctual.

High Technology & Capacity

Fuji Die Co., Ltd is proud of the most excellent techniques and the capacity in wear-resistance tool industry, Japan and also international.

3 sintering plants strategicaly located throughout Japan and equipped with 4 HIP units and 40 furnaces.

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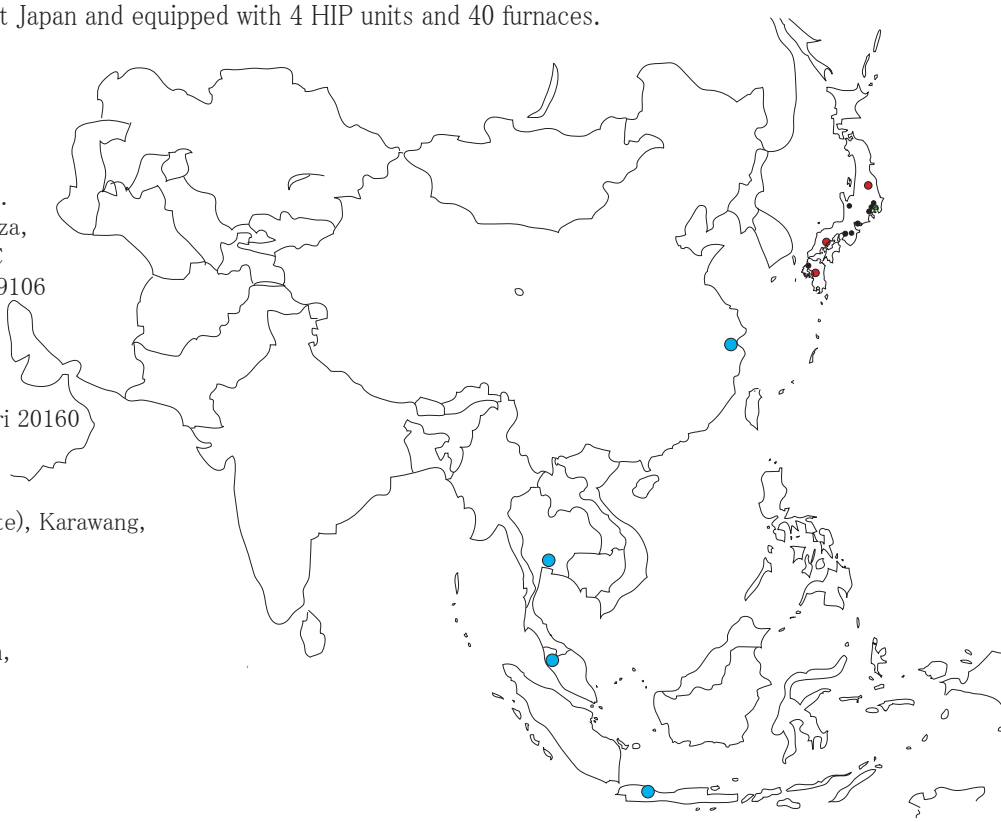


LINE UP

FUJILLOY™ Line Up

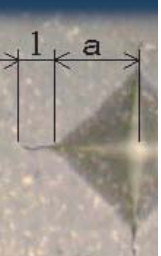
◎ is stock, ○ is available, △ is now testing.

Grade Type		Grade	HIP	For Pre-form	For Plate	Density	Hard-ness (HRA)	TRS (MPa)	Tensile Strength (MPa)	Compressive Strength (MPa)	K_{IC} *1 (MPa·m$^{\frac{1}{2}}$)	Young's Modulus of Elasticity (GPa)
Nano Grade	Suitable Grade for W-EDM Process (Corrosion Resistance)	TFS06	●		◎	14.55	95.0	4200	2220	6880	4.9	575
Super & Ultra Fine Grade		TF05	●			14.60	95.1	1470	810	6660	3.3	610
		F08	●	○	◎	14.30	93.5	3920	2140	6280	5.2	560
		F09	●		◎	14.00	93.0	4410	2450	6080	6.5	540
	The first popularity	F10	●	○	◎	14.40	92.5	3820	2110	5880	5.4	560
		F20	●	○	◎	13.90	91.0	3480	1910	5390	6.5	520
Fine Grade		N05	●			14.95	93.5	2700	1480	5880	6.0	620
		N10	●	○	○	14.95	92.5	3240	1770	5690	5.1	620
Medium Grade		D10	●	○	○	15.20	92.0	2940	1620	5690	4.5	640
		D20		○	○	14.95	91.5	2890	1570	5400	6.7	620
		D40		○	◎	14.55	90.0	3290	1810	4900	8.9	560
		D50		○	○	14.35	89.0	3330	1810	4610	11	540
		D60		○	◎	14.05	88.0	3430	1860	4310	(15)	520
Medium Coarse Grade		G55		○	○	14.50	88.5	3140	1720	4610	12	560
		G65		○	○	14.05	86.5	3040	1670	3920	(18)	520
		G70		○	○	13.70	85.0	2940	1620	3530	(24)	490
		G85		○	○	13.35	84.0	3090	1720	3330	(33)	460
Coarse Grade		C50		○	○	14.85	88.5	2600	1420	4610	10	590
		C60		○	○	14.45	87.0	2840	1570	4210	(18)	550
		C70		○	○	14.00	85.5	2750	1520	3730	(22)	520
		TC79				13.60	84.0	2550	1470	3330	(25)	490
		C89				13.30	82.5	2550	1470	3140	(40)	470
		C95				13.00	81.5	2500	1370	2940	(52)	420
Super Coarse Grade for Rolls for Hot Rolling Mill		TUC72	●			14.15	86.0	2500	1180	3530	(25)	560
		UC73	●			14.25	85.5	2450	1370	3430	(26)	560
		U61	●			14.40	85.5	2060	1130	3430	(19)	580
		U77	●			14.00	83.0	2110	1180	2550	(30)	530
		U83	●			13.80	82.0	2260	1230	2260	(35)	510
		U89	●			13.40	80.5	2260	1230	1860	(55)	480
Nonmagnetic Nickel Binder Grade	Ultra Fine	MF10	●			14.25	92.5	3240	1770	4510	5.0	510
	Fine	MN10	●	△	○	14.35	91.5	3240	1770	4120	5.3	510
	Medium	M45	●	△	○	14.40	89.5	3240	1770	3330	7.6	500
		M70	●	○	○	13.80	88.0	3430	1860	2940	12	470
	Mediun course	MG85	●	○	○	13.45	83.5	2650	1570	3140	(42)	480
Suitable Grade for W-EDM Process (Improved Toughness and Corrosion Resistance)	Ultra Fine	VF12	●	○	◎	14.45	91.5	3600	1960	5390	7.6	560
	Medium	VD15	●			14.90	92.0	3230	1720	5490	6.4	620
		VD45	▲	○	◎	14.20	90.0	3530	2160	4900	9.7	540
		TVD55	▲	○	○	13.80	89.0	3950	2300	4610	15	500
	Mediun course	VG60	▲	○	○	13.85	88.0	3400	1860	4410	(18)	520
		VG86	●	○	○	13.25	85.0	2940	1670	3530	(28)	460
Special Grade	Medium	T15	●			7.05	91.0	2010	1080	3140	4.1	410
		BD20				12.50	91.5	1960	1080	4120	4.9	510
	Fine	UN45	●			13.70	90.0	3240	1770	4000	9.1	490
	Ultra Fine	JF03	●			15.40	(2400HV)	2000	800	4000	2.4	680
	Medium	J05	●			14.65	93.5	1320	740	3830	2.1	650

*1 Vickers indentation methode : our empirical formula based on Niihara's formula.

$K_{IC}=0.02576\times a\times l^{-1/2}\times E^{2/5}\times \sigma mb^{3/5}$ (MPa·m$^{1/2}$)

a=Half length of Vickers indentation's diagonal line (m). l=length of crack (m). E=Young's model of elasticity (MPa) . σmb=TRS (MPa)



We might not produce due to form and dimension. We would appreciate that you would ask the inquiry every time. And about the grade whose name starts from T, we would need to discuss with you about the delivery date and etc. before acceptance of orders. Up to 11/1/2016. This document does not show standard values, but shows representative exsamples. The data may change without prior notice.

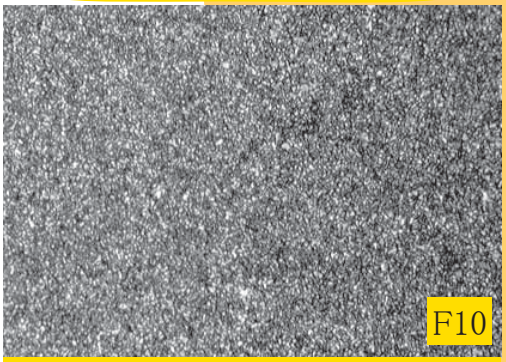
Poisson's Ratio	Thermal Conductivity (W/m·K)	Mean Thermal Expansion Coefficient $MK^{-1}(\times 10^{-6}/°C)$ RT–400°C	RT–600°C	RT–800°C	Wear*2 Resistance ($\times 10^{-5}$ cm^3/rev)	Rcorr*3 24hr (Ω/m^2)	CIS Coad (Japanese Standared) C.C. society	Application: Wear Surface	Impact	Wear at Elevated Temperatures	Non-Magnetic and/or Resistance to Chemical Reactions	Main Examples of Tools *4～*6, Refer to Underlines Tools
0.20	42	5.3	5.6	5.9	0.1	1.0	VF-10	Medium	Medium			Precision Component.
0.21	25	5.0	5.2	5.5	0.04	6.8	VF-10	Light	Light			Drawing Die & Plug, Nozzle, Plunger, Slitter, Reducing Dies, Punch & Die, Bush, Gauge, Epoxy & Glass Mold with Light Shock.
0.22	29	5.5	5.7	6.0	1.1	2.6	VF-10	↕	↕			
0.22	42	5.7	6.1	6.4	2.1	1.0	VF-10					
0.22	42	5.1	5.5	5.8	2.6	0.8	VF-20					
0.23	42	5.8	6.2	6.6	6.1	1.1	VF-30	Medium	Medium			Above Same Tools with Medium Shock.
0.21	50	4.6	4.9	5.2	0.2	89	VM-10	Light				Punching Mold, Forming Die.
0.22	80	4.6	5.1	5.3	1.5	0.3	VM-20	↕				Pressing Mold, Punch, Powder, Compacting Mold, Reducing Die. Slitter, Punching Mold, Guide*4 with Light Shock. Slitting Knife Rotary Knife, Drawing Dies Plug, Nozzles, Reducing Die, Punch & Die, Bush, Gauge, with Medium Shock. Anvil, Center.
0.21	97	4.6	4.9	5.1	1.6	0.8	VM-20		Light			
0.21	95	4.7	5.0	5.2	2.4	1.3	VM-30		↕			
0.22	90	5.1	5.5	5.8	5.8	0.5	VM-40					
0.22	88	5.4	5.8	6.1	7.8	0.6	VM-40					
0.23	82	5.7	6.1	6.5	14	1.1	VM-50					*4 and Rotary Knife with Medium Shock.
0.22	105	5.1	5.5	5.8	12	0.6	VC-50	↕				*4 with Semi Heavy Shock. Heading Die, Forming Dies Forging Die*5 with Light Shock.
0.23	97	5.7	6.1	6.5	18	1.8	VC-60					
0.23	94	6.0	6.5	6.9	21	0.9	VC-60	Heavy				
0.24	87	6.5	7.0	7.4	23	0.3	VC-70		↕			*5 with Medium Shock
0.21	120	4.8	5.2	5.4	5.1	0.6	VC-50					*4 with Heavy Shock. *5 with Semi Medium Shock.
0.22	109	5.3	5.7	6.0	13	2.5	VC-50					
0.23	103	5.7	6.1	6.5	20	1.0	VC-60					
0.23	96	6.2	6.7	7.2	24	0.3	VC-70					Pressing Mold, Punch, Powder Compacting Mold with Super Heavy Shock. *5 with Medium Shock.
0.24	90	6.6	7.0	7.6	28	0.4	VC-70					
0.24	78	7.2	7.6	8.1	27	0.4	VC-80		Heavy			
0.22	96	5.6	5.9	6.4	15	7.1	RC-60			Light		Hot Rolling Mill with Light Shock. Hot Forging Die with Heavy Shock.
0.22	96	5.7	6.1	6.4	10	1.6	RC-60			↕		
0.22	105	5.4	5.8	6.1	12	5.9	RU-60					
0.23	96	5.9	6.4	6.8	16	9.2	RU-70					Hot Rolling Mill with Medium Shock. Hot Forging Die with Super Heavy Shock.
0.23	88	6.2	6.7	7.1	17	1.6	RU-70					
0.24	71	6.7	7.2	7.7	19	2.9	RU-80			Heavy		
0.22	29	5.7	6.1	6.5	2.9	95	NF-20				Light	*6 with Light Shock (Refer to *6)
0.22	54	5.3	5.7	6.1	4.1	62	NF-30				↕	*6 with Light Medium Shock
0.22	59	5.5	5.9	6.2	6.4	36	NM-40					Nonmagnetic Mold, Sealing Rings, Nozzle, Corrosion Resistance Mold*6 with Medium Shock.
0.23	59	6.3	6.6	7.1	13	188	NM-50					
0.23	59	5.9	6.3	6.8	24	154	NC-70				Heavy	Nonmagnetic Mold with Heavy Shock.
0.22	72	5.4	5.6	5.9	4.3	1.6	VF-30	Light	Light			This is More Excellent about Wear Resisitance and Toughness than Same Hardness of Other Grade. And it Improves Corrosion and Progression of Tiny Crack for EDM Process.
0.21	89	4.7	5.0	5.3	1.9	1.2	VM-20	↕	↕			
0.22	78	5.5	5.8	6.2	6.4	0.7	VM-40					
0.20	77	6.2	6.4	6.7	13	3.6	VM-40					
0.23	90	5.9	6.2	6.6	16	1.6	VC-50					
0.23	84	6.5	7.1	7.5	21	1.2	VC-60	Heavy	Heavy			
0.21	8	7.6	8.2	8.6	11	0.8	(P10)					Plug for Hypodermic Needle.
0.22	34	5.7	6.2	6.5	5.2	0.7	(P20)					Shaving Die
0.23	42	6.2	6.7	7.0	6.4	202						Corrossion Resistant Mold with Magnetic
0.17	62	4.2	4.5	4.7	1.4	169	VF-10				Light	Glass Mold
0.20	63	4.6	4.8	5.1	3.4	148	VM-10				Light	Seal Ring, Glass Mold

*2 Wear resistance testing by ASTM B611-76. Load 10kg, Wheel FC20, Aluminum oxide slurry.

*3 Corrosion resistance. As for the usual solution test, Cl^- is 3000ppm, PH3 with sodium citride solution (24hr).

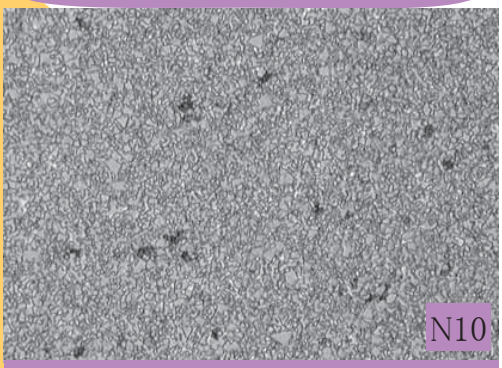
FUJILLOY™ Cemented Carbide Microstructures & Characteristics-1

Super & Ultra Fine Grade F series



High Hardness and High TRS

Fine Grade N series



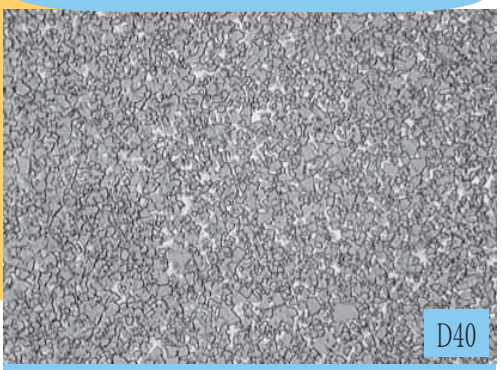
Excellent Performance for Plastic Working

HARDNESS IMPROVEMENT

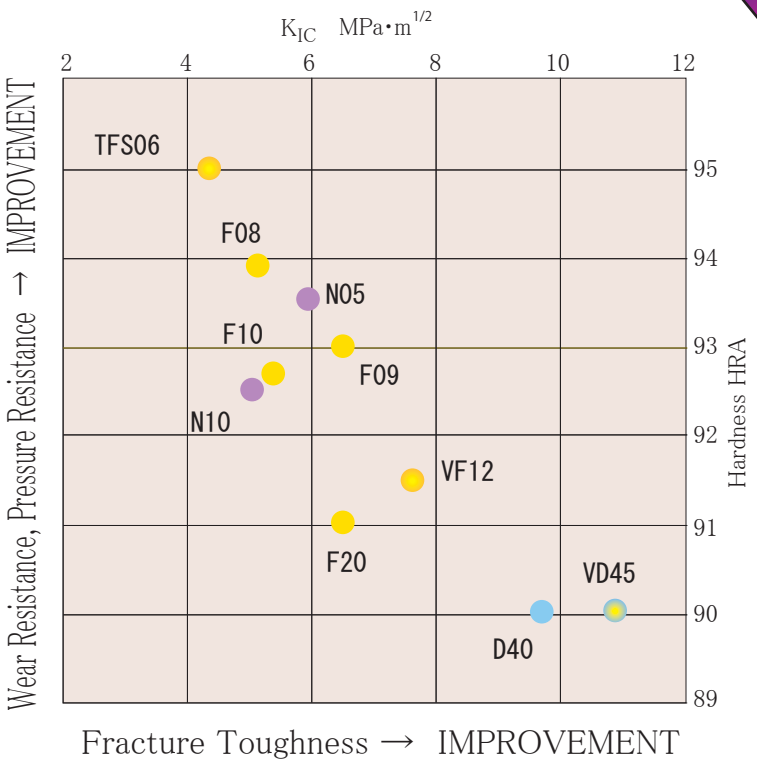
WEAR SURFACE DECREASE

TRS IMPROVEMENT

Medium Grade D series



High General Versatility



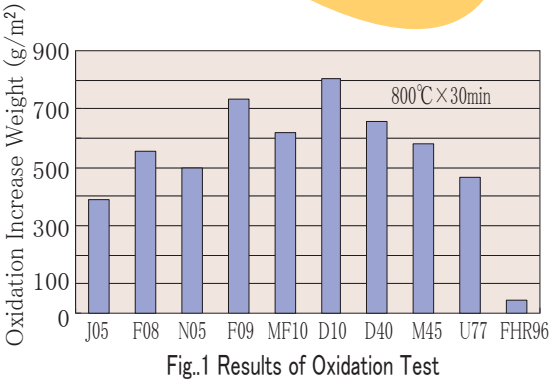


Fig..1 Results of Oxidation Test

In general, it is said cemented carbide is weak for oxidation, but FUJILLOY™ achieved to improve it, especially tungsten based heavy alloy FHR96 shows comparative superior characteristic to oxidation (refer to 14 page).

Hardness of cemented carbide varies by WC grain size and Co content.
The grain size finer and Co content lower, alloy shows harder feature.
FUJILLOY™ ultra fine grained cemented carbide show less defect and rather higher figure of TRS because almost of them cemented carbides passed through HIP treatment.

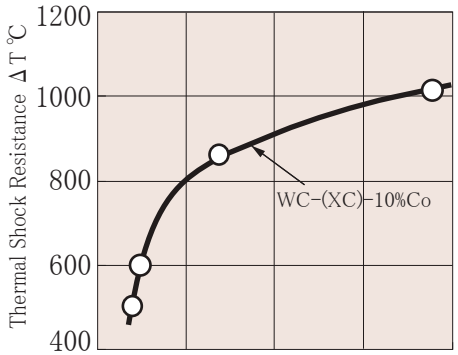


Fig.2 Relationship between thermal shook resistant temperature (△T) and WC grain size of FUJILLOY™

WC grain size becomes smaller, △T becomes lower.
It is necessary to beware of this point for tools used in the high temperature atmosphere.

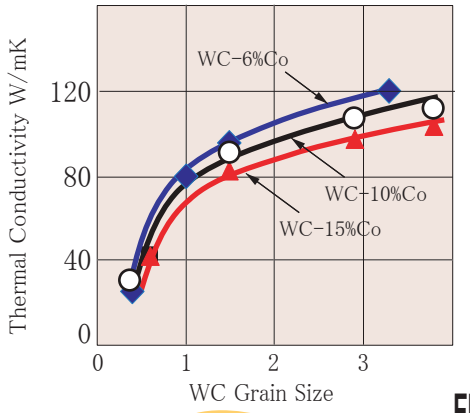


Fig.3 Relationship between thermal conductivity and WC grain size of FUJILLOY™

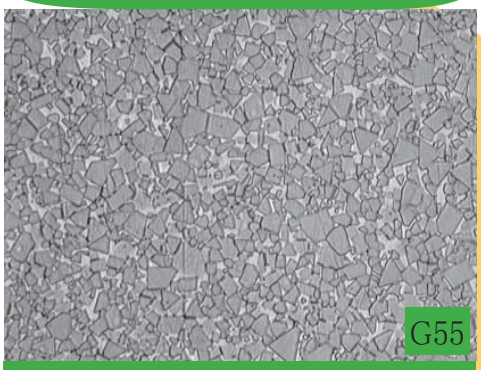
Co content becomes lower and grain size becomes bigger, thermal conductivity shows higher feature. In case of easy seizing occurred risk forecasted, it is necessary to consider thermal conductivity at material selection.

FRACTURE TOUGHNESS IMPROVEMENT

THERMAL CONDUCTIVITY INCREASE

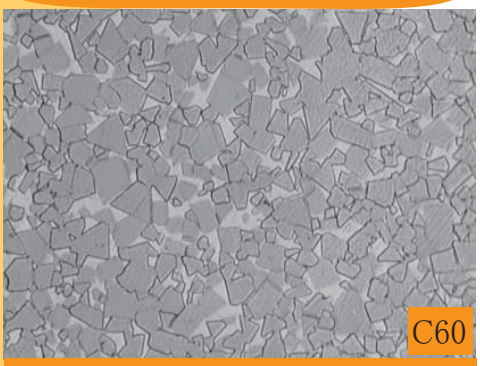
HEAT RESISTANCE INCREASE

Semi Coarse Grade G series

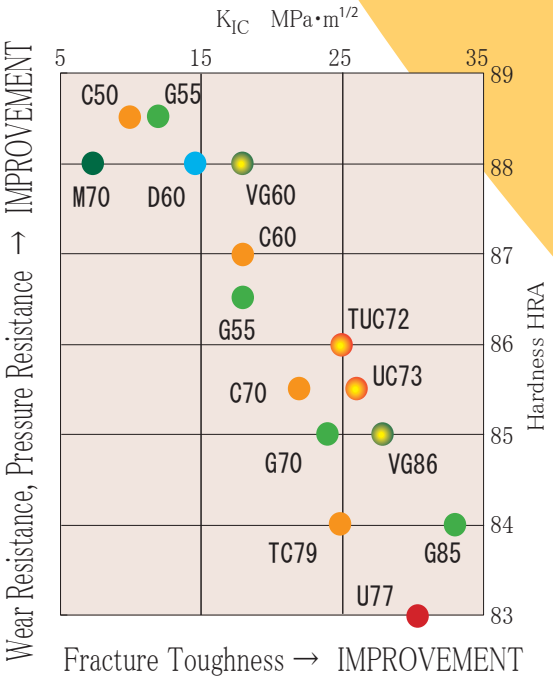


Suitable for Tools Requiring Toughness

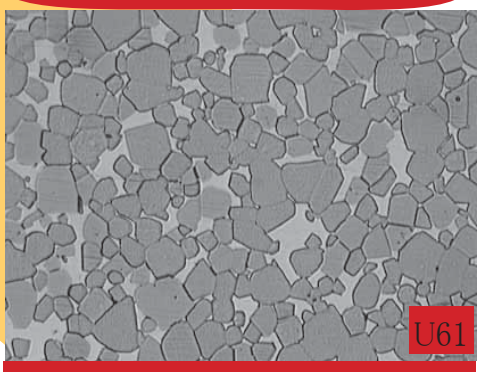
Coarse Grade C series



Suitable for Tools Requiring More Toughness



Super Coarse Grade U series



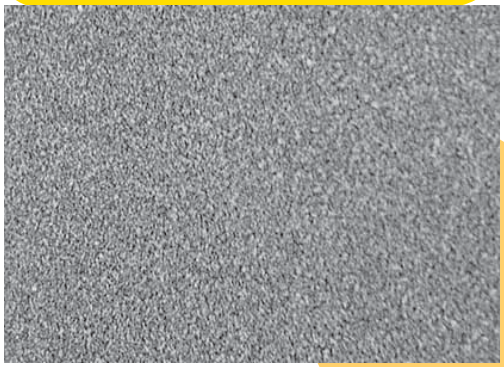
Suitable for Hot Rolling Mill

10 μm

FUJILLOY™ Cemented Carbide Microstructures & Characteristics-2

M series

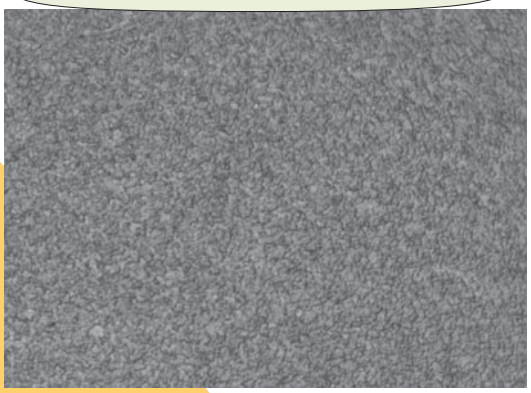
Ultra Fine Grade MF10



FUJILLOY™ is the pioneer of micro grain cemented carbide with WC-Ni called MF10 brand, which is remarkable fruit from FUJILLOY™ , meets with public approval. Non-magnetic and also satisfactory corrosion resistance

NEW

Fine Grade MN10



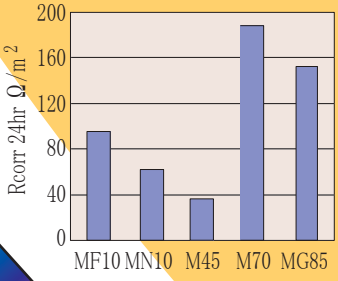
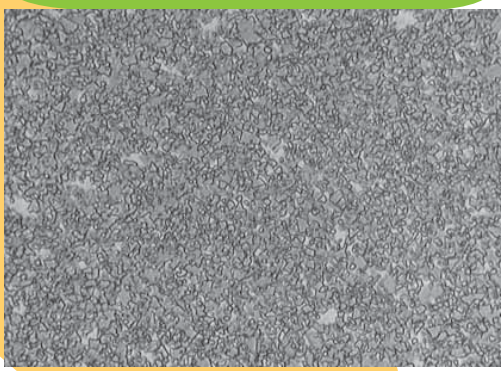


Fig.4 Corrosion Resistance of M series ＊Refer to Line up Table

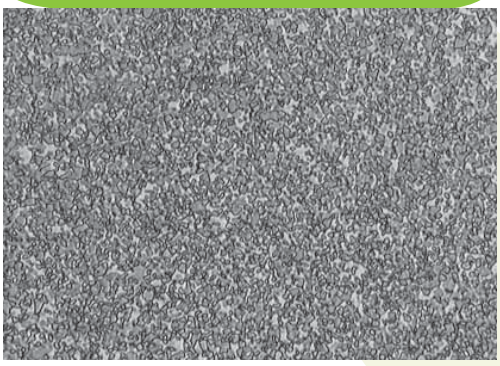
HARDNESS IMPROVEMENT

WEAR SURFACE DECREASE

Medium Grade M45



Medium Grade M70



10 μm

FRACTURE TOUGHNESS IMPROVEMENT

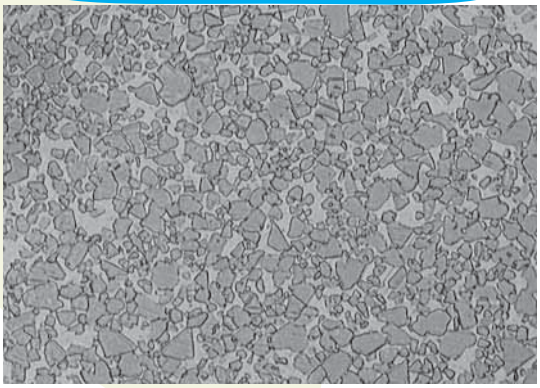
Table 2 Magnetic permeability of M series *1

Grade	Magnetic Permeability (Oe)		
	250	1000	10000
MF10	1.0003	1.0001	1.0000
MN10	1.0004	1.0001	1.0000
M45	1.0006	1.0002	1.0000
M70	1.0005	1.0001	1.0000
MG85	1.0006	1.0002	1.0000

*1 May, 2016 measurement data.

Magnetic permeability of M series is less than 1.01 and gets no-magnetism even passed through strong magnetic field.

Semi Coarse Grade MG85

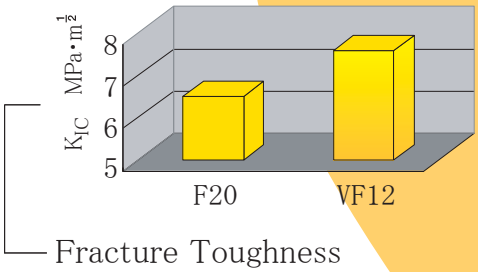


MG85 with WC-Ni shows high toughness characteristic.

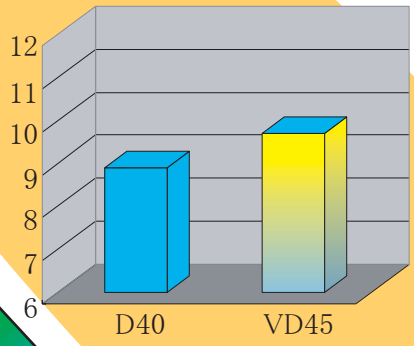
V series

FUJILLOY™ V series show superior performance in electric discharge machining.

Among similar hardness range of FUJILLOY™, V series show better figures of fracture toughness and corrosion resistance. V series gets few microcracks in electric discharge machining, and show strong corrosion resistance.



Fracture Toughness Comparison



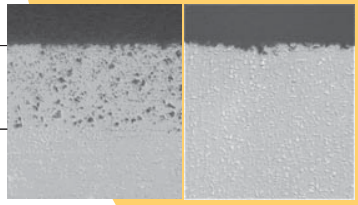
JCTMA 2007-034
ECO PRODUCT

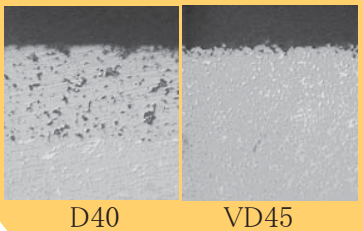
The V series made in Okayama factory is the eco-product which JCTMA* accepted.

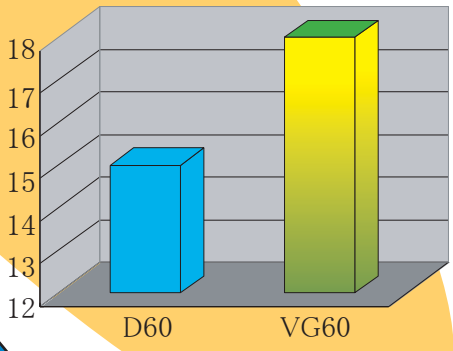
* JAPAN CEMENTED CARBIDE TOOL MANUFACTURERS' ASSOCIATION

HARDNESS IMPROVEMENT

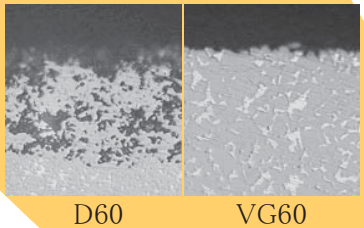
Corroded Area by Electric Discharge Machining







Corroded Area by Electric Discharge Machining



FRACTURE TOUGHNESS IMPROVEMENT

Table 3 Comparison with variety of V series and other FUJILLOY™ grades showing similar hardness value

Grade		Density	Hardness (HRA)	TRS (MPa)	K_{IC} (MPa·m$^{\frac{1}{2}}$)
Ultra-Fine	F20	13.9	91.0	3430	6.5
	VF12	14.5	91.5	3600	7.6
Medium	D40	14.6	90.0	3290	8.9
	VD45	14.2	90.0	3530	9.7
	D60	14.1	88.0	3430	15
Semi Coarse	VG60	13.9	88.0	3400	18

These photographs shows typical feature through anti-corrosion test under the rather corrosive circumstance.

FUJILLOY™ Cemented Carbide Main Products Lines

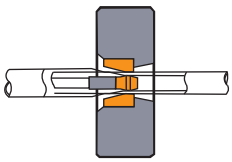
① Drawing Dies & Plugs
② Various Rolls
③ Super Precious Measuring Equipment and Gauge
④ Compacting Molds
⑤ Can Manufacturing Tools
⑥ Resign and/or Ceramics Extrusive Screw Mold
⑦ Forming Mould for Electronic Parts
⑧ Tools for Semiconductor Equipment
⑨ Tools for Glass Lens Compacting Mold
⑩ High Pressure Components

Recommendation of FUJILLOY™ Grade

Green Grade is Special Grade. Please contact us.

Die and Plug

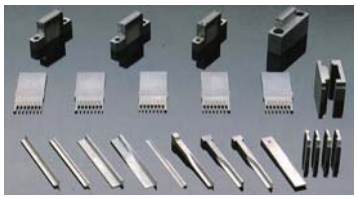
N10
F10
D20
D40
VD15



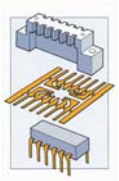
Mold (for Powder)

M45 G55
M70 G70
D40 G85
D60
VD45
VG60

Die and Punch for Electronic Parts



TFS06 VD15
F08 VD45
F10 TVD55
VF12 VG60
F20 C50



Die and Punch for Epoxy Molding Compound

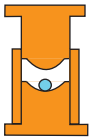
F08
F20
D60
C70

Can Manufacturing Tools

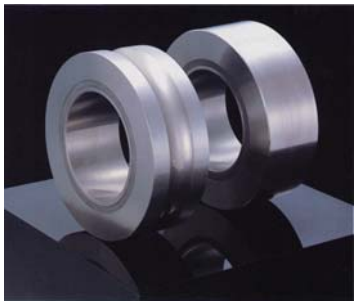
N05
VD15
TUN27
D20
VD45
VG60
UN45
M45
M70

Die and Punch for Lens Mold

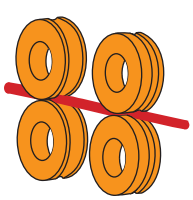
TJS01
TJS02
JF03
J05
MF10
F09
M45



Roll for Morgan Block Mill



U61
TUC72
UC73
U77
U83
U89
TU78



Anvil and Cylinder for Ultra-High Pressure Mold

ϕ 70mm

ϕ ～470mm

VD15 VD45
D20 C60
TF05 AG54
TF06 MF12
F10 TMS05

FUJILLOY™ Tip Sinetering Technique

We can deliver highly reliable precision cemented carbide FUJILLOY™ tips, for any purpose.
We also supply pre-form products based on top technology of industry leader in Japan.

Features

1. Utilizes pre-form tip material and thus contributes to cost reduction and shortened delivery times to the processing industry.
2. 3 sintering plants strategically located throughout Japan and equipped with 4 HIP units and 40 furnaces.
3. Technology and supplying capacity are verified by production of 1 million items per year.
4. We also offer HIP treatment of various materials on consignment basis.

Typical Dimensions of FUJILLOY™ Cemented carbide Material (mm)

(The Example of the Manufacture Maximum Size of General Grade Tips)

Rod stick	φ100×800	Above 6mass%Co, Ni, However, exclusion MF10, M45
Ring	φ530×φ480×200	D, G, C, U series
Disk	φ440×3～70	D, G, C series
Plate	360×450×3～100	D, G, C series
Large	φ455×155 (310kg), φ468×φ110×280 (615kg)	D series

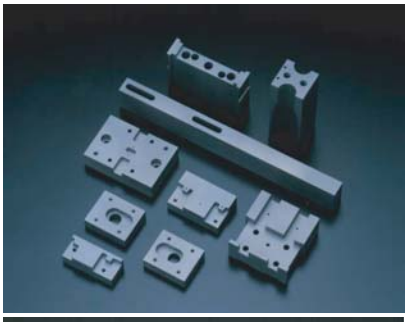
We might not produce due to form and dimension.
We would need to discuss with you about the delivery date and etc.

Cemented Carbide Tip with Screw Thread [Hard Tap]

1. C70、M12 Test Deta. Internal Threads with High Toughness.

Torque N·m	117	147	176	206	235	Bolt breakage point torque
Steel Bolt	○	○	○	○	△	257
Stainless Steel Bolt	○	○	△	—	—	191

○:Toruqe limit prior to breakage
△:Toruqe at point of bolt breakage
(No damage to ultra hard hard-tap product)



2. Hard Taps with High Accuracy. (mm)

	Length	Accuracy
Accuracy of Pitches	100L	±0.15
	50L	±0.10
	25L	±0.05
Accuracy of Screw	Comparable as electric discharge finish	
Toughness	Generally, breakage of a bolt occurs before breakage of a hard tap part.	
Screw Size	M3～M12 (Metric Thread)	

3.″Cracks, slips and chips″ and distortion which sometimes occur the tips brazed or EDM are eliminated.
4. Possible to machine the internal threads in thin tips, complex formed tips and special cemented carbide tips.
5. Usable for hot using tools, for which brazed tips can't be used.

Standard Plates Tip (mm)

Size	100×60×t, 105×105×t t=1.0～9.5
Grade	F08 F09 F10 F20 (TFS06)

FUJILLOY™ Grinding Technique

The hardest grade among FUJILLOY™ cemented carbide, such as ultra fine grained requires severe grinding condition control. Resin bonded diamond wheel with cocentration ratio 75-90 (3.3-3.96 ct/cc) is suitable for cemented carbide which hardness is over than 90HRA. Table 4 shows typical case of grinding conditions used FUJILLOY™ standard type resin bonded diamond wheel. Careful treatment to rough grinding work is required for fine grained type and the hardest type because they are easy to get chipping. At the finishing work, those types of material appear another trend. Photo 1 & 2 show the ground face and edge of a test piece treated in accordance with the finishing grinding condition mentioned in Table 4. Each photo appears WC grain size and Co content ratio efficiency.

These photos appeal that grain size become finer, surface roughness and chip defect on edges become smaller.

And effected by the certain level of Co content prevent surface roughness and chip defect of edges.

Those phenomena are recognized as related to fracture toughness and tensile strength.

It means that ultra fine grained cemented carbide with high tensile strength, and which alloy was ground as finishing condition, is suite for the blanking punch tools to which sharp edges are required.

Table 4 Typical grinding condition

Item	Unit	Surface Grinding		Cylindrical Grinding
		Rough	Finish	Rough
Work Size	mm	100×60×5	24×8×5	φ50
Wheel Size	mm	355	205	355
Grain Size	#	140	1000	140
Concentration Ratio		75～120	90	75～90
Wheel Speed	m/min	1100～1900	1100～1900	1300
Traverse Feed	m/min	0.9	0.3	-
Cross Feed	m/min	18	15	0.3～0.4
Work Revolution	m/min	-		
Fluid Grade	-	Limited to Cemented Carbide		
Fluid Flow	ℓ/min	2～3		
Depth of Cut	mm/pass	0.01	0.001～0.002	0.008

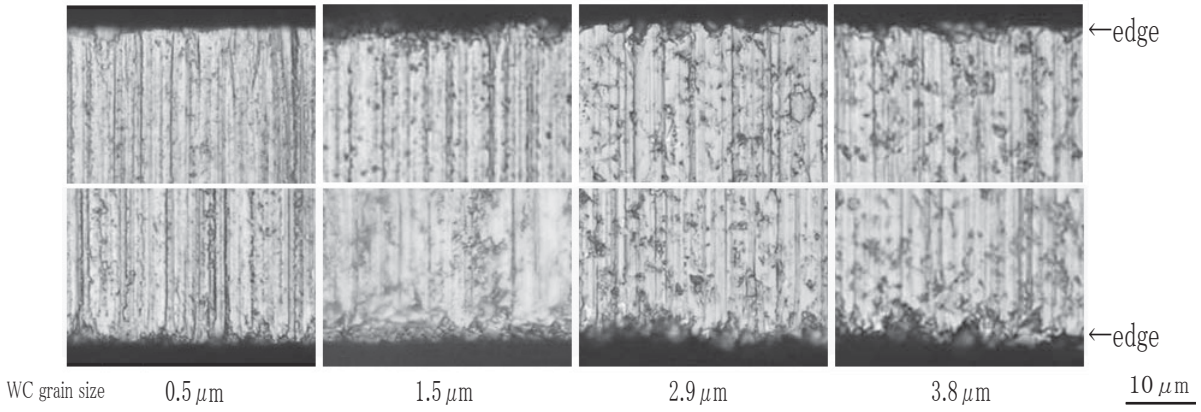


Photo.1 Both edge condition with WC grain size of WC-(XC)-10%Co alloy after grinding

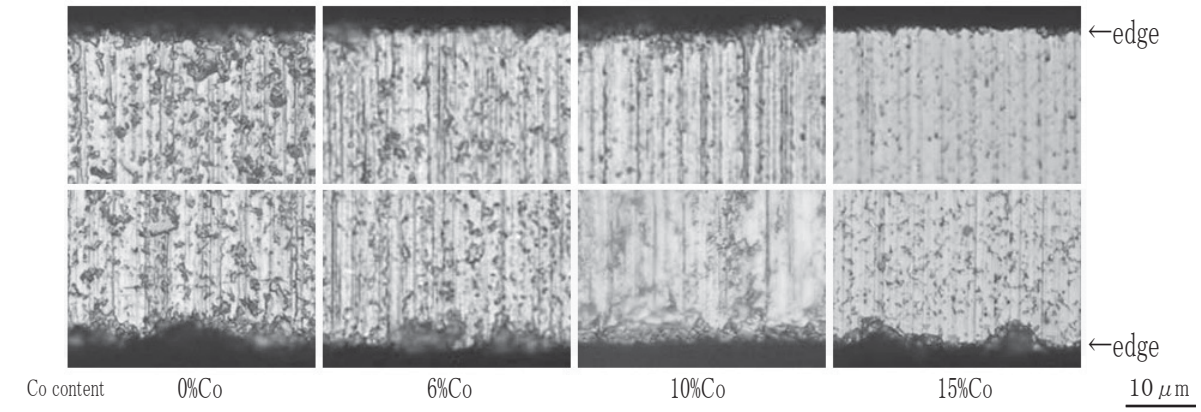


Photo.2 Both edge condition with Co content of WC-(XC)-Co alloy(WC grain size 1.5 μm)after grinding

It is necessary to minimize microscopic cracks mentioned as bellows.

1) Lower electric current value, and control fabrication speed slower 50% than standard method.

2) Use diameter less than 0.2 wire electrodes and restrain fabrication power. Above condition showed in Table 5.

Fig.5 shows TRS (transverse rupture strength) comparison data in related with grain size and Co content when material is fabricated by grinding method and 3 types of wire cut electric discharge machining (W-EDM) method in Table 6.

FUJILLOY™ cemented carbide property; in case of grinding method, WC grain sizes become finer TRS become bigger. Incase of W-EDM method, WC grain sizes become finer TRS become smaller in any type of 3 methods. Particularly WC grain size 0.5 μm range, it shows obvious lower figures of TRS. Finer grain alloy is easier to get fine cracks pointed by arrow in Photo 3(a). Bigger grain alloy also get them but limited to degenerate stratum showed by arrow in Photo.3(b).

Above should be considered for selection of tools strength.

TRS shall be recovered to original value by taken off degenerate stratum, which was caused by electric discharge machining, through grinding process.

Table 5 W-EDM typical operation method

Condition	Unit	Setting
Wire Diameter	mm	0.15
Wire Material	–	Brass
Water Electric Resistance	$\times 10^4 \Omega \cdot cm$	10
Water Flow	ℓ/min	3～6

Table 6 Surface roughness after W-EDM process

Condition	Type	Ra μm
Rough Cut	W-EDM A	1.1～1.6
Pre-Forming	W-EDM B	0.22～0.32
Finishing	W-EDM C	0.11～0.16

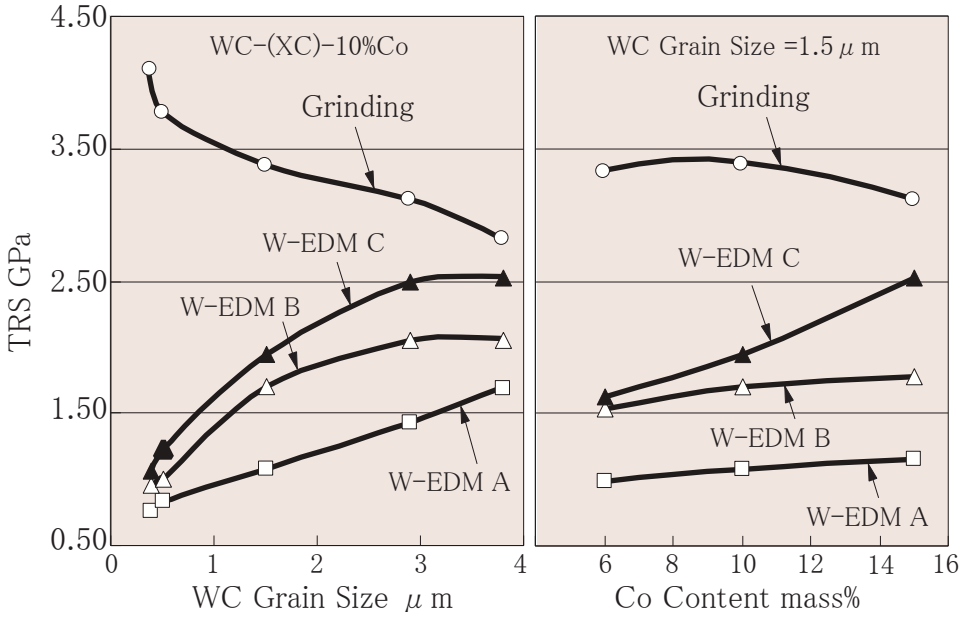
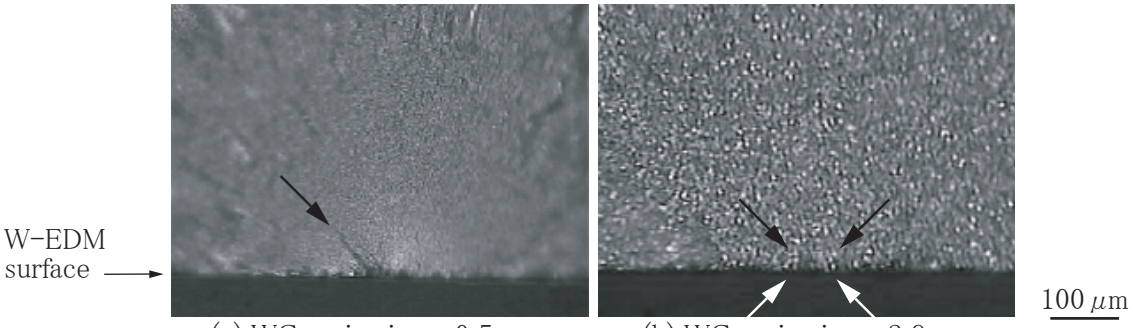


Fig.5 TRS variation by surface processing method related with WC grain size and Co content



(a) WC grain size = 0.5 μm (b) WC grain size = 2.9 μm

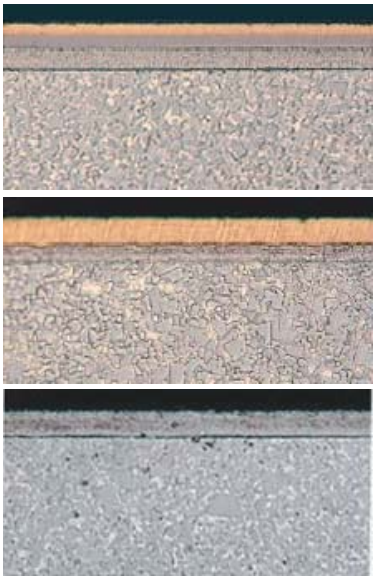
Photo.3 Fracture source of WC-(XC)-10%Co cemented carbide after W-EDM process

It is also required to take care of corrosion in electric discharge machining process. FUJILLOY™ prepares appropriate material for it as V series, such as VF12, VD45, VG60 and others. V series material shows less cracks and corrosion compared with other type material which hardness is similar to V series.

FUJILLOY™ Coating Technique

CVD

CVD(Chemical Vapor Deposition) coating means making 4-8μm film on the material at 800-1000℃ atmosphere .
FUJILLOY™ has 3 categories of film coat stuff [TiC (Titanium Carbide), Ti(C,N) (Titanium Carbonitride), TiN (Titanium Nitride)] and 3 types of coating method [single, double, triple].
FUJILLOY™ casts about process control of CVD and succeeded to find out a strong adherent film in minute density method.



TiC+Ti(C,N)+TiN 2+3+2μm 2400HV
High resistance against diffusion
High wear resistance
Good abrasion resistance
Golden top layer

TiC+TiN 3+4μm 2000HV
High resistance against diffusion
Golden top layer

TiC 4μm 3500HV
High abrasion and wear resistance
Good abrasion resistance

10 μm

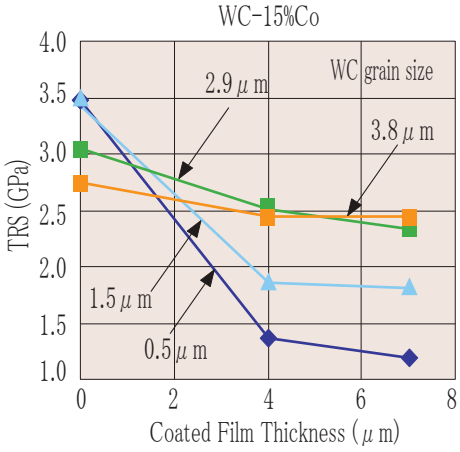


Fig.6 TRS vs CVD coated film thickness

Cemented carbide can increase a wear resistance peculiarity with CVD coating, but decreases TRS. Fig.6 shows that, stratum becomes thicker, TRS becomes lower. And also the grain size becomes finer, TRS becomes lower. It is necessary to consider above points when making up tools idea.
Surface of CVD coating is hard to polish, and it is said, in general, that CVD coating surface roughness is inferior to that of cemented carbide.
Available size range; φ256×500mm

PVD

FUJILLOY™ DLC (Diamond Like Carbon) coating shows less friction and less seizing and adopted FUJILLOY™ own brand tools. There are 2 types of DLC method. DLC-I for high excoriation resistance and DLC-R for less friction usage.
PVD coating (CrN, TiN, Ti(C,N)) by AIP (Arc Ion Plating) method also adopted FUJILLOY™ own brand tools. AIP method is to produce the film through flying off ion in vapor by electric arc spark from evaporating metal source as the cathode in a vacuum and that operation does not require difficult handlings. Material attachment and other preparation are easy.

Table 7 Typical characteristics of FUJILLOY™ PVD coated film

	Unit	DLC	CrN	TiN	Ti(C,N)
Coating Method	-	Ionization Vapor Deposition	Arc Ion Plating		
Standard Thickness	μm	～1	～2		
Frictional Coefficient	-	0.1～0.15	～0.4	～0.5	～0.4
Film Hardness	HV	2500～3000	～1800	～2500	～2800
Film Adherence	N	70	100	100	100
Color	-				
Surface Roughness	-	Excellent	Good		
Available Size Range	mm	Outside Diameter Max φ200×250H / Inner diameter upper φ80	180×180×100		

Table 8 Caution about PVD coating

		DLC	CrN TiN Ti(C,N)
1	Substrate Material	No deformation, no shrinkage, no degeneration, no gassing risk in 150℃ temperature neighborhood and well brazed material only.(Not allowed Zn, Cd content in brazes)	No deformation, no shrinkage, no degeneration, no gassing risk in 300℃ temperature neighborhood and well brazed material only.(Not allowed Zn, Cd contents in brazes)
2	Substrate Material Surface Condition	No rust, no oxidize, no sintered surface, no degenerative stratum and no surface treatment such as plating, nitride, other coating. Surface condition is flatter and roughness is smaller, surface can obtain better coating film.	
3	Substrate Shape	Aperture and inside of groove treatment is limited. Dimension and structural stability should be confirmed in advance.	Aperture and inside of groove treatment is limited. Outside diameter Max.180mm X Depth Max.100mm, inside diameter Min.5mm
4	Composition, Shrinkage Fit	Segment built-up is available by requirement in advance notice. Shrinkage fit process should be done after gas extraction treatment which takes around 12 hours.	
5	Masking	In case of needless area from coating treatment exists, informing us in advance.	

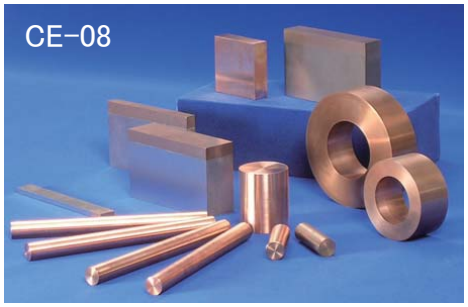
FUJILLOY™ Other Material

Cu-W Alloy, Ceramic, Heavy Alloy, KF2 Alloy

FUJILLOY™ Other Material		Grade	HIP	Dencity	Hardness		TRS (MPa)	Tensile Strength (MPa)	Compressive Strength (MPa)	K_{IC} ($MPa \cdot m^{\frac{1}{2}}$)	Young's Modulus of Elasticity (GPa)	Poisson ratio	Thermal Conductivity (W/m·K)	Mean thermal Expansion Coefficient (MK^{-1})($\times 10^{-6}$/℃) RT-400℃	RT-600℃	RT-800℃	Rcorr 24hr (Ω/m²)
Cu-W Alloy		CE-08		14.0	93.5	HRB	1225	588			224	0.30	180	9.0	9.8	10.1	
Cera-mic	Al_2O_3	FCA10		3.93	1850	HV	440		2060	3.1	363	0.23	30	7.2	7.7	8.1	
	ZrO_2-Al_2O_3	FCY40A	HIP	5.00	1560	HV	1670		3630	5.3	294	0.28	8.4	8.7	9.1	9.4	
	ZrO_2-Al_2O_3	FCY20A	HIP	5.48	1410	HV	1860		4120	6.2	248	0.29	5.0	9.7	10.0	10.2	
	Y-TZP	FCY0M		6.07	1270	HV	880		3730	7.1	200	0.31	4.6	10.7	11.1	11.3	
	Mg-PSZ	FCZ10		5.72	890	HV	540		1370	12	180	0.33	1.7	8.8	8.4	8.3	
	Si_3N_4	FCS60		3.20	1380	HV	880		2630	5.0	291	0.27	15	2.4	2.7	2.95	
Heavy Alloy		FHR96		17.6	34.5	HRC	1500	880	2400		350	0.28	54	5.4	5.5	5.7	80
KF2-Alloy	SKH57+VC	KF235ME	HIP	7.8	68	HRC	2740	1770	3680	(26)	215	0.24	18	9.0	9.7	—	
	SKH57+VC,TiN	KF261ME	HIP	7.6	70	HRC	2260	1670	3920	(19)	222	0.24	19	9.4	9.9	—	
	SKH57+VC,TiN	KF263ME	HIP	7.3	72	HRC	1960	1570	3380	(6.6)	230	0.23	20	8.8	9.4	—	

Copper-Tungsten Alloys "CE-08"

On the basis of own powder metallurgy technology, we have been able to manufacture and market copper-tungsten alloys as materials for electric discharge machining.
These alloys are known for superior conductivity and wear-resistance, and can improve significantly the efficiency of electric discharge machining.



Advanced Ceramics

Main Examples of Tools

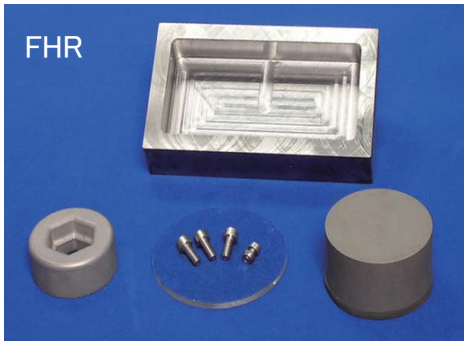
FCA10 (Al_2O_3)	Guard Block, Die for Chemical material
FCY40A FCY20A (ZrO_2-Al_2O_3)	Nib, Die and Punch for Cupper, Guide, Pinch Roll for Cupper
FCY0M (Y-TZP)	Guide, Slitter, Guide Roll for Nonferrous
FCZ10 (Mg-PSZ)	Heat Insulator, Die for Cupper alloy
FCS60 (Si_3N_4)	Nozzle, Squeeze Roll, Collet

Heavy Alloy "FHR96"

Heavy alloys are tungsten based alloys, generally containing W 90 mass%, and small amounts of Ni etc. The specific gravity is about 17.6.
They are superior in mechanical properties at high temperature.
They are made by powder metallurgy similar to cemented carbides.
Grinding, cutting and electric discharge machining can process them.

Main Examples of Tools

FHR96	Parts of Molds for Optical Lenses
	Parts of Mold for the Aluminum Alloy which Melted



KF2 Alloy

KF2 Alloys are sintered high speed steel (HSS).

Main Examples of Tools

KF235ME	Cold Forging Die (Substitution of HSS) Roll for Cold Rolling Mill (Substitution of HSS)
KF261ME	Kneader Screw (For Epoxy Molding Compound)
KF263ME	Wear Plate (For Epoxy Molding Compound) Hot Extrution Die (For Aluminum Alloy)

Product Inspection

Using the world advanced equipment, including surface texture measuring machines high magnifications of 2,000,000 times, FUJILLOY™ supports cutomers' advanced requests.

Measuring instrement	Manufacture Name	Machine Type	Specification*
Laser Interferometers	ZYGO	GPI-XP HR	λ /40 (Sphere: λ /20)
Surface Texture Measuring Instrument	TAYLOR HOBSON	TALYSTEP	1Å 2,000,000times
Poundness and Cylindrical Profile Measuring Instrument	TAYLOR HOBSON	TALYROND 400	±0.05μm
Surface Finish and Form Measuring Instrument	TAYLOR HOBSON	FORM TALYSURF PGI 1240	0.8nm
Length Measuring Instrument	SIP	305M	±0.2μm
Angle Jig Grinding Attachment	MOORE	1440 Index	±0.1″
Auto-Collimator	Hillger Wat	TA-80	±0.2μm
Precision Granite Surface Plate	RAHN	900×1800	AAA
Step Gauge	MOORE	the standard for measures(450mm)	±0.25μm
Master Straight Edge	MOORE	the standard for straightness(610mm)	0.254μm
Calibration Cylinder	TAYLOR HOBSON	the standard for straightness(500mm)	0.3μm
Calibration Cylinder	TAYLOR HOBSON	the standard for straightness(1000mm)	1μm
Gauge Blocks	Johansson	112	000
NPL Angle Gauge	Hillger Wat		±1″
CNC Video Measuring System	Nikon	NEXIV VMH-300N	(0.9+0.8L/300)μm
Ultra High Accuracy CNC coordinate measuring machine	Mitutoyo	LEGEX 774	(0.35+1000L/1000)μm)
Non-Contact CNC coordinate measuring machine	Mitaka Kohki	NH-3SP	(0.1+0.3L/1000)μm
Ultra Accuracy 3-D Profrilometer	Matsushita Electric Industrial	UA3P-5	0.01μm
CNC Gear Measuring Machine	OSAKA SEIMITU KIKAI	CLP-35	1μm
3-D Optical Profiling System	ZYGO	NEW VIEW 6300	0.1nm
Ultra-high Resolution Scanning Electron Microscope	Hitach High-Technologies	S-4800	1.0nm

* Resolution, output units and and assured accuracy (Extracted from manufactures' catalogs)
** λ=633nm
We also have many other types of measuring equipment.

Information for Better Selection of FUJILLOY™ Grade

＊Passive material data manufactured by the tool
-material composition -shape - surface condition -mechanical characteristics

＊Manufacture method for passive material
-working stress (specification of equipment)
-lubricant material if there is
(specification & quantity)
-temperature -forming speed
-cooling system if there is
(specification & quantity)
-operation frequency
-maintenance method

＊Conventional tools
-sort of tools
-life time
(caused working condition)
-preciseness
-productivity

＊Others
-related information

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