

General Catalog of **YSS** TOOL STEELS





Cold Work Tool Steels



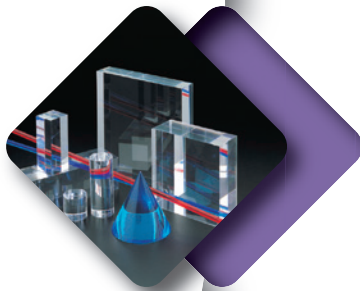
Cold Work Tool Steel SLD-MAGIC



Hot Work Tool Steels



Die Steels For Die Casting DAC Series



Plastic Mold Steels HI-PM Series



Plastic Mold Steel CENA1



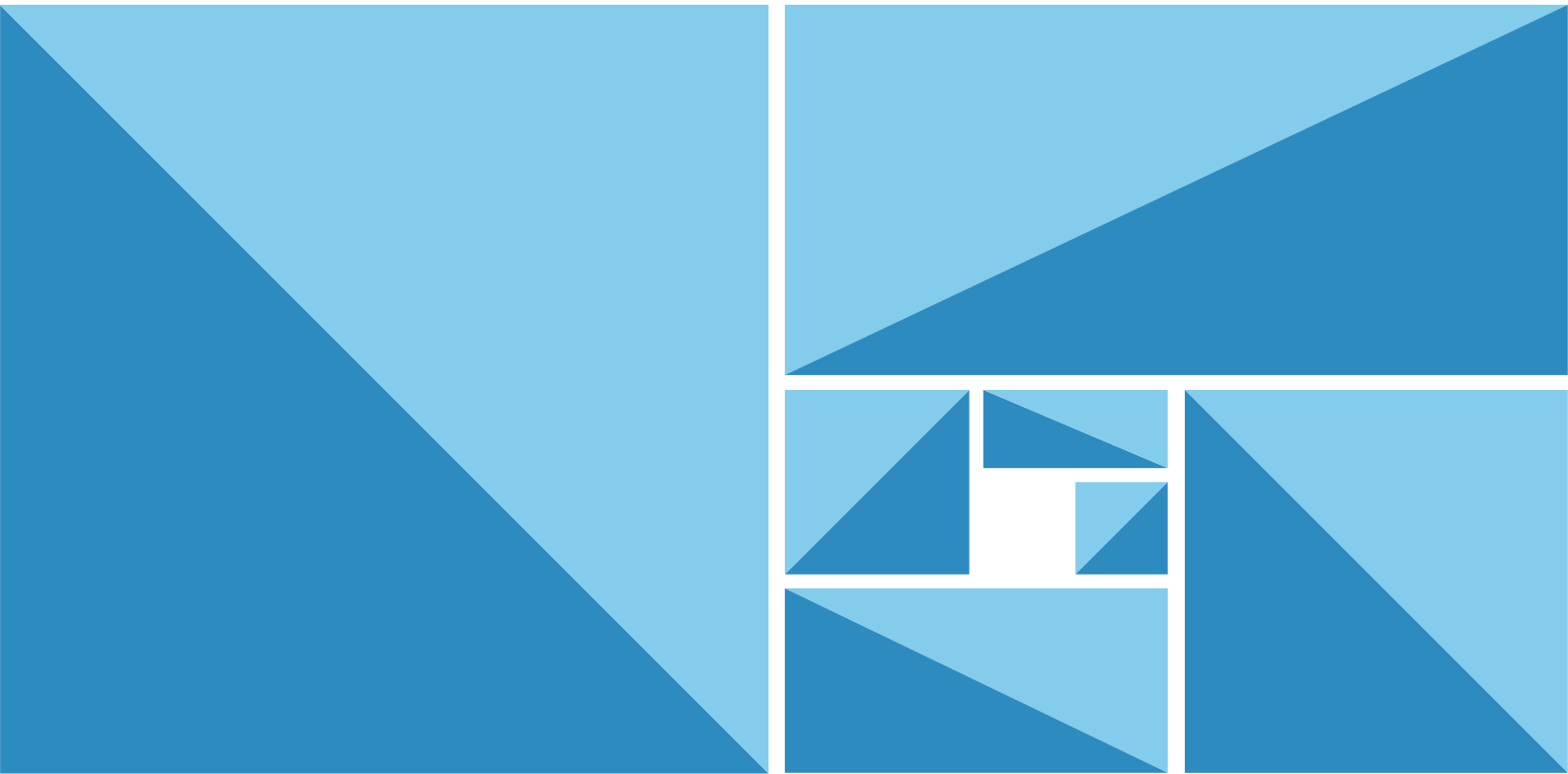
High Speed Tool Steels

CONTENTS



YSS

Cold Work Tool Steels



Types of YSS cold work tool steels

Grade					Chemical composition (%)								
YSS	Color	JIS equivalent	AISI	DIN WNr.	C	Si	Mn	Cr	W	Mo	V	Co	Others
Cold work tool steels	SLD-MAGIC	Original steel			High-performance cold work tool steel								Free-cutting elements added
	SLD	SKD11	D2	1.2379	1.5	0.3	0.4	12.0	—	0.9	0.3	—	
	SLD10	8% Cr steel			1.0	1.0	0.4	7.5	—	2.8	0.4	—	
	ARK1	Original steel			0.7	0.3	0.4	7.5	—	1.0	0.3	—	S : 0.05
	SGT	SKS3	O1	1.2510	1.0	0.3	1.0	0.7	0.7	—	—	—	
	YCS3	SKS93	W5		1.0	0.4	0.9	0.4	—	—	—	—	
	ACD37	Original steel	A4		0.9	0.3	2.0	1.1	—	1.3	—	—	
	HMD5	Original steel			0.7	1.0	1.0	1.2	—	0.2	—	—	
	HI-PM MAGIC	Original steel			40HRC pre-hardened steel								
High speed tool steels	YXM1	SKH51	M2	1.3343	0.9	0.3	0.4	4.2	6.5	5.0	2.0	—	
	YXM4	SKH55		1.3243	0.9	0.3	0.3	4.2	6.5	5.3	1.9	5.0	
	YXR7	Matrix high speed steel			0.8	0.8	0.3	4.7	1.3	5.5	1.3	—	
	YXR3				0.6	1.5	0.4	4.3	—	2.9	1.8	—	
	YXR33				0.5	0.2	0.5	4.2	1.6	2.0	1.2	—	
P/M High speed tool steels	HAP5R	P/M high speed steel			0.9	0.8	0.3	4.3	2.0	3.0	3.0	—	
	HAP10		M3 : 2		1.4	0.6	0.3	5.0	3.0	6.0	3.8	—	
	HAP40	SKH40		1.3244	1.3	0.3	0.4	4.2	6.0	5.0	3.1	8.0	
	HAP72	P/M high speed steel			2.1	0.4	0.3	4.2	9.5	8.3	5.0	9.5	

Applications in cold work dies

Application		Standard hardness (HRC)	Recommended YSS steel			
			For general use	For mass production use		
				For abrasion resistance	For impact resistance	
Cold press die	Blanking dies (small, progressive)	58-62	SLD, SLD-MAGIC, ARK1	HAP10, HAP40	YXM1, YXR7, HAP5R	
	Blanking dies	For general sheet use	55-60	HMD5	SLD, SLD-MAGIC	ARK1
		For general heavy plate use	58-62	SLD, SLD-MAGIC, ARK1	HAP10, HAP40	YXM1, YXR7, HAP5R
	Bending and Swaging dies	For general sheet use	58-62	SLD	SLD-MAGIC	ARK1
For general heavy plate use		58-62	SLD, SLD-MAGIC	HAP40	YXM1	
Cold forging dies	Forging dies	Male die	58-63	SLD, SLD-MAGIC	YXM1, HAP40, YXM4	YXR7, YXR3, HAP10
		Female die	55-60	SLD, SLD-MAGIC, ARK1	YXM1, HAP10	YXR7, YXR3, HAP5R
	Heading dies	Male die	58-62	SLD, SLD-MAGIC	HAP40, YXM4	YXM1, YXR7, YXR3
		Female die	55-60	YSM	SLD, SLD-MAGIC	YXM1, YXR7, YXR3
Thread forming dies		58-64	SLD	YXR7, YXM1, SLD10		
Cold working rolls		≥80HS	SLD, SLD-MAGIC	YXM1, HAP40		



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Types of YSS cold work tool steels

Grade	Characteristics	Main Application	
YSS			
Cold work tool steels	SLD-MAGIC	High-performance cold work tool steel attaining both extended die life and easy die fabrication.	Cold work dies for high-tensile steels, SUS, mass production, and general use.
	SLD	Cold work die steel with high abrasion resistance for general use, excellent harden-ability and minimal quench stress.	Cold work dies for general use, forming roll, shear blade.
	SLD10	Extremely high hardness with excellent toughness in die steels, 62-64HRC.	Rolling dies.
	ARK1	Cold work die steel with high toughness and improved machinability.	Dies for printed circuit board, die plates, stripper plates.
	SGT	Cold work die steel with superior machinability for general use; Special care is required for quenching large-size dies or wire electric discharge machining.	Dies for deep drawing, gauges.
	YCS3	Carbon tool steel for small production to be quenched in oil. Improved SK105 grade for its hardenability.	Press forming dies, jigs and tools, gauges.
	ACD37	Vacuum quenched and air quenched steel. Improved SGT grade for its hardenability and wire electric discharge machining.	Dies for deep drawing, gauges.
	HMD5	Steel for flame hardening, resulting in high hardness and small strain even with air quenched; good weldability.	Dies for deep drawing.
	HI-PM MAGIC	40HRC pre-hardened steel.	Press forming dies for small production, jigs and tools.
High speed tool steels	YXM1	High speed steel with high abrasion resistance and toughness for general use.	Cold forging dies, cold heading dies, slitter.
	YXM4	High speed steel to prevent from abrasion, seizure and deformation under high pressure	Cold forging dies, drawing dies.
	YXR7	Matrix high speed steel, extremely highest toughness in 62-65HRC. Available for vacuum quenching.	Rolling dies, cold forging dies, roll, cold forging punches, blanking punches.
	YXR3	Matrix high speed steel for general use, extremely highest toughness in 58-61HRC.	Dies to be used for cracking or chipping resistance.
	YXR33	Matrix high speed steel highest toughness in high speed steels. Standard hardness 54-58HRC.	Cold forging dies, warm forging dies.
P/M High speed tool steels	HAP5R	Extremely tough Powder Metallurgy process high speed steel.	Cold forging dies, fine blanking dies.
	HAP10	Extremely tough Powder Metallurgy process high speed steel.	Cold forging dies, fine blanking dies.
	HAP40	P/M high speed steel with high abrasion resistance and toughness for general use.	Press forming dies for mass production, roll.
	HAP72	P/M high speed steel with high hardness and highest abrasion resistance.	Cold plastic working dies of long life, high performed IC molds.

Applications in cold work dies

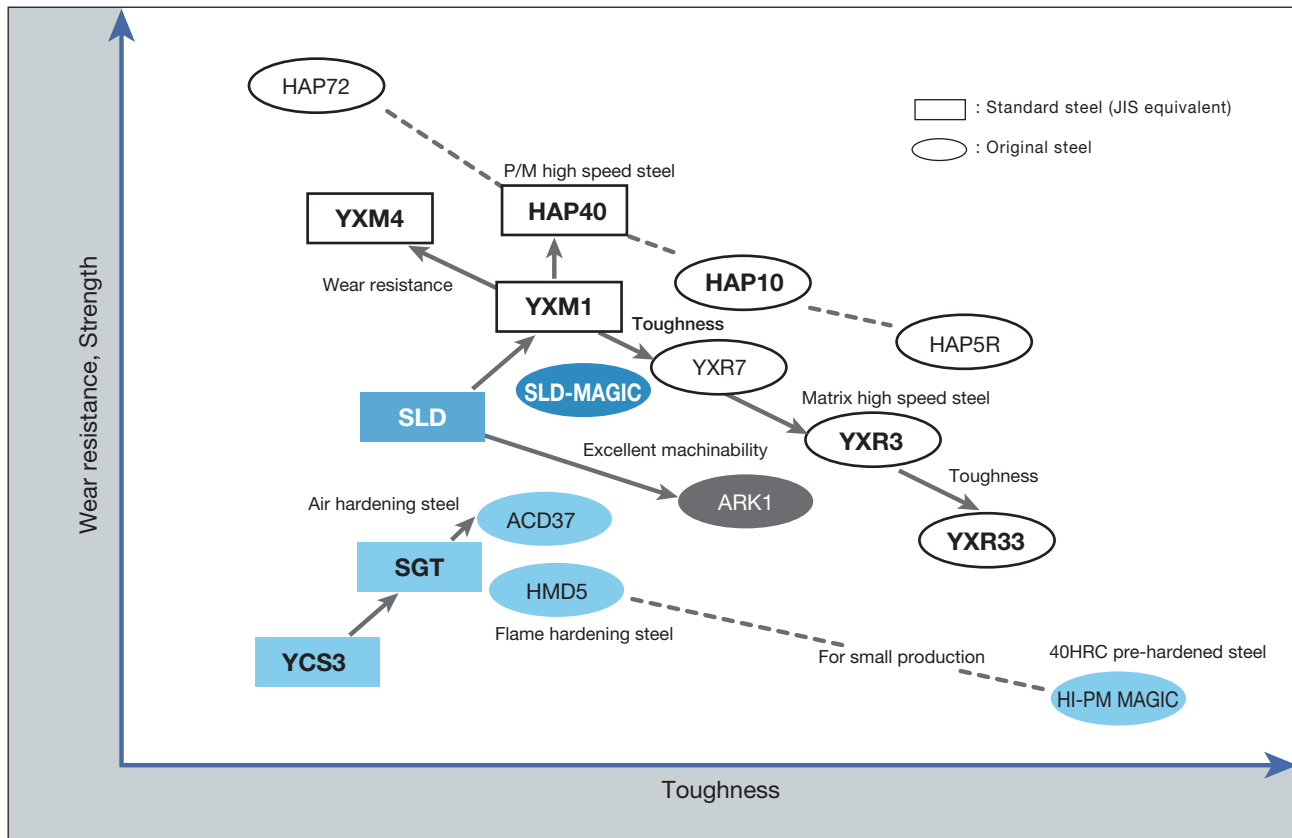
Application			Standard hardness (HRC)	For general use	Recommended YSS steel	
					For mass production use	
					For abrasion resistance	For impact resistance
For plastic forming	Trimming dies	For sheet use	55-60	SLD, SLD-MAGIC, ARK1	YXM1, HAP40	YXR3, YXR7
		For heavy plate use	50-55	DAC, DM		
	Cold hobbing dies	55-60	SLD, SLD-MAGIC	YXM1		
	Drawing dies	57-62	SLD, YXM1	HAP40		
Machine cutter	Shearing blade (straight tooth)	For sheet service	55-60	SLD, SLD-MAGIC, ARK1	YXM1, YXR7	YXR3
		For medium plate	53-58	SLD, SLD-MAGIC, ARK1, ACD8		YXR33
		For heavy plate	48-53	DM, ACD8		
	Rotary shear slitters	54-60	SLD, SLD-MAGIC, ARK1	YXM1, HAP40		
	Billet shear	Thicknesses 50mm and under	50-55	DM, ACD8		
		Thicknesses over 50mm	48-53	DAC, DM, ACD8		
Gauges		60-64	SGT, ACD37, YCS3			



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Characteristics of YSS cold work tool steels

Characteristics of steels



Comparison of characteristics

Grade	Wear resistance	Pressure resistance	Toughness	Hardenability	Distortion by heat treatment	Machinability	Weldability	Standard hardness (HRC)
SLD-MAGIC	A	A	A ⁻	A ⁺	A ⁺	A ⁻	B	58-62
SLD	A	A	B	A ⁺	A ⁺	B	C	57-63
SLD10	A ⁻	A	A ⁻	A ⁺	A	B ⁻	C	59-65
ARK1	B ⁺	A	A	A ⁺	A	A ⁻	B	58-60
SGT	C	B ⁺	B	C	D	A	B	57-63
YCS3	D	C	C	D	D	A ⁺	B	57-63
ACD37	B	A ⁻	B	A ⁺	A	A	B	55-60
HMD5	C	B	B	—	—	A	A	55-60
HI-PM MAGIC	D ⁻	D	A ⁺⁺	—	—	A ⁻	A ⁺	40
YXM1	A	A ⁺	A ⁻	B	B	B	C	58-64
YXM4	A ⁺⁺	A ⁺	B	B	B	B ⁻	C	62-66
YXR7	A	A ⁺	A	A	B	B	C	61-65
YXR3	A ⁻	A	A ⁺	B	B	B ⁺	C ⁺	58-61
YXR33	B	B ⁺	A ⁺⁺	A	B	B ⁺	C ⁺	54-58
HAP5R	A	A	A ⁺	A	A	B	C	58-62
HAP10	A ⁺	A ⁺	A	A	A	B ⁻	C	62-65
HAP40	A ⁺⁺	A ⁺⁺	A ⁻	B	A	C ⁺	C	64-67
HAP72	A ⁺⁺⁺	A ⁺⁺⁺	C	A ⁻	A	C ⁻	D	68-71

(A is the uppermost level and + indicates higher performance)



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Characteristics of YSS cold work tool steels

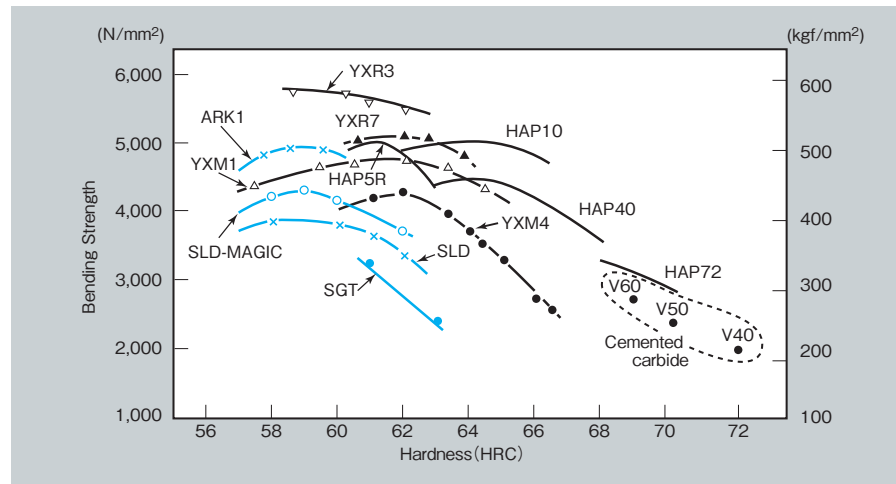
Wear resistance

Grade	Hardness (HRC)	Specific abrasion volume (mm ³ /mm ² · mm) × 10 ⁻⁷			
		0.5	1.0	1.5	2.0
SLD-MAGIC	62.0	~0.4	~0.5	~0.6	~0.7
SLD	60.0	~0.5	~0.6	~0.7	~0.8
ARK1	59.0	~0.6	~0.7	~0.8	~0.9
SGT	60.0	~0.7	~0.8	~0.9	~1.0
YCS3	60.0	~0.8	~0.9	~1.0	~1.1
ACD37	60.0	~0.9	~1.0	~1.1	~1.2
YXM1	65.5	~0.4	~0.5	~0.6	~0.7
YXM4	66.0	~0.4	~0.5	~0.6	~0.7
YXR7	65.0	~0.5	~0.6	~0.7	~0.8
YXR3	59.0	~0.6	~0.7	~0.8	~0.9
YXR33	58.0	~0.7	~0.8	~0.9	~1.0
HAP5R	60.0	~0.5	~0.6	~0.7	~0.8
HAP10	64.0	~0.4	~0.5	~0.6	~0.7
HAP40	67.0	~0.4	~0.5	~0.6	~0.7
HAP72	70.0	~0.4	~0.5	~0.6	~0.7

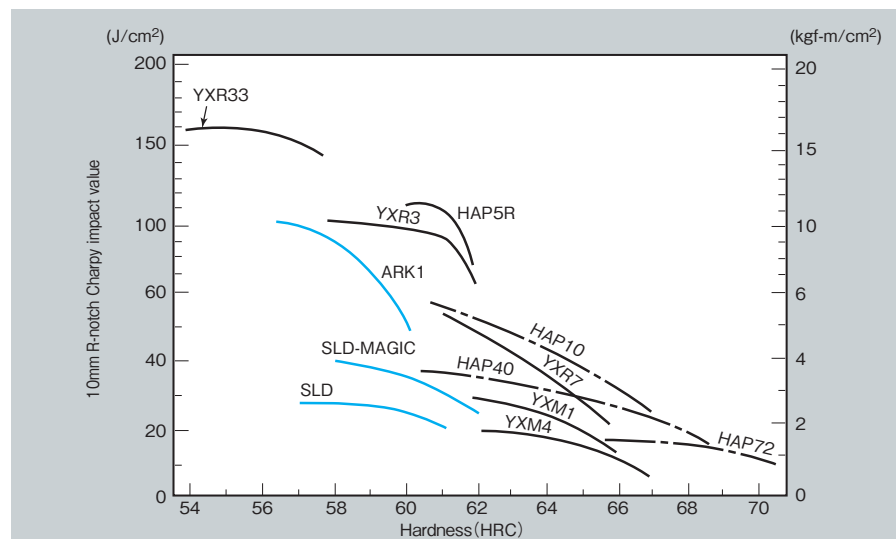
Ongoshi-method wear test
 Work material : SCM415
 Friction distance : 400m
 Friction speed : 0.76m/s
 Load : 67N

Toughness

Bending strength



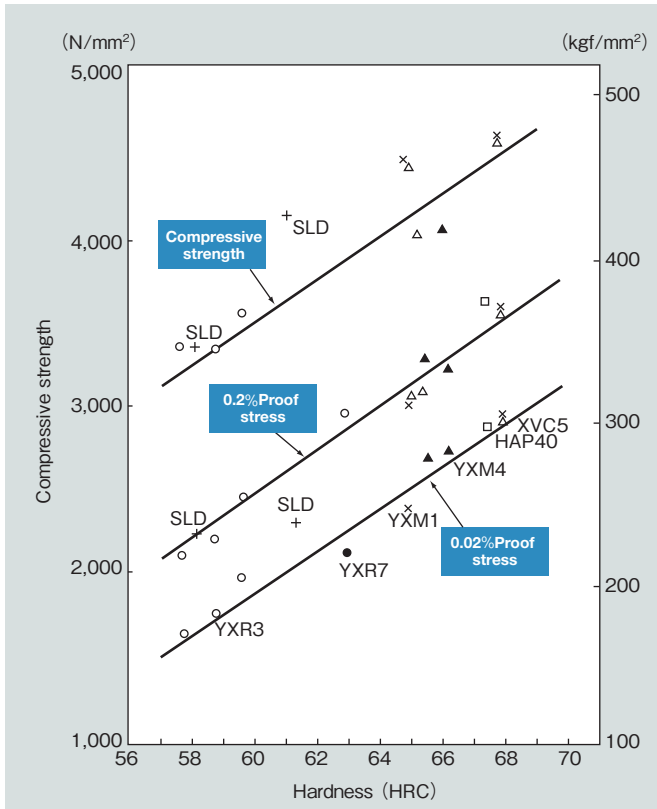
Charpy impact value



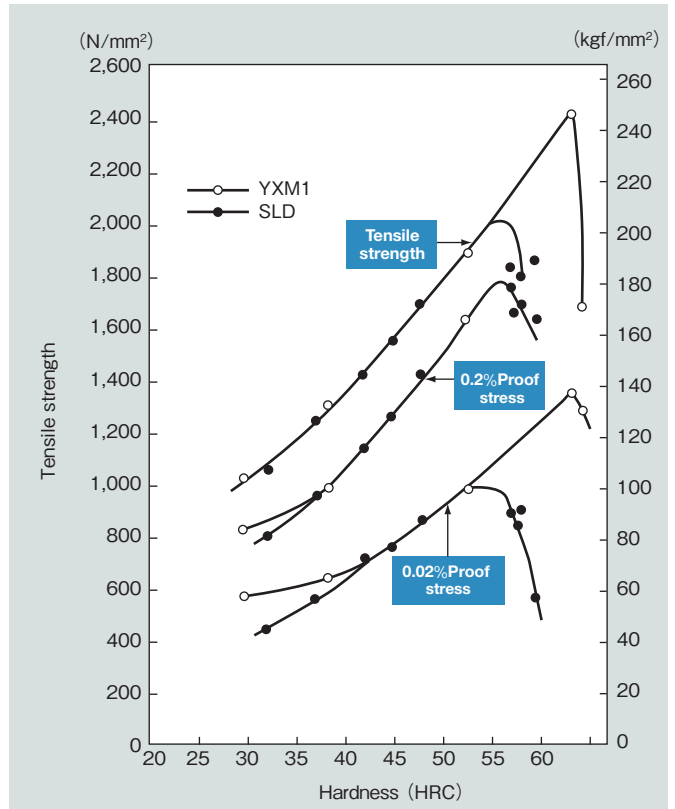
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Characteristics of YSS cold work tool steels

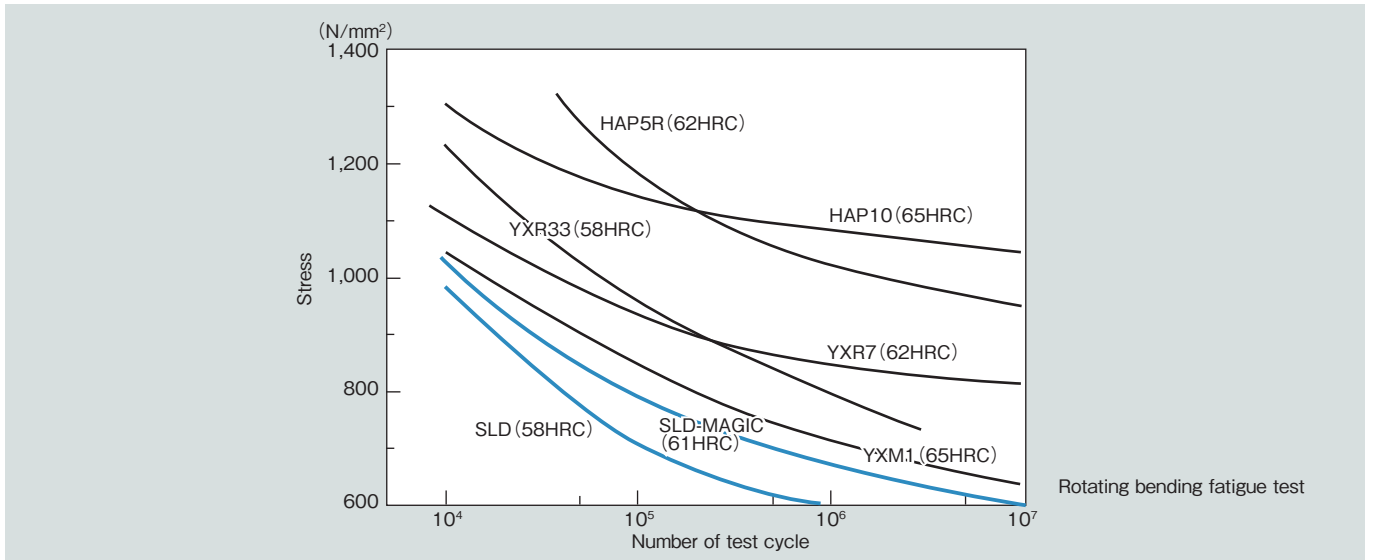
Compressive strength



Tensile strength



Fatigue strength



Physical properties

Grade	Thermal expansion coefficient ×10 ⁻⁶ /°C 20-200°C	Thermal conductivity W/(m·K) 20°C	Young's modulus GPa
SLD-MAGIC	12.2	16.5	209
SLD	11.2	20.6	211
SGT	13.6	23.3	201
YCS3	14.3	25.9	207
YXM1	11.2	21.0	216
YXR3	11.3	18.7	212
HAP40	10.3	19.3	227



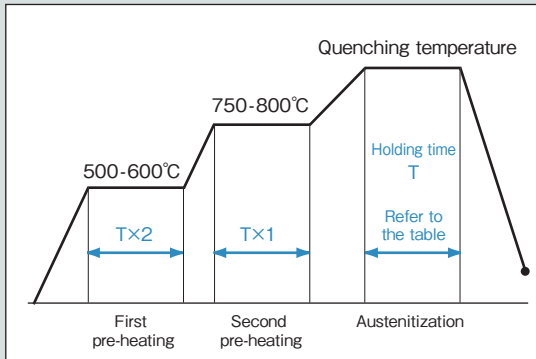
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Heat treatment of YSS cold work tool steels

Hardening

* Please refer to the standard heat-treatment condition of each grade for hardening and quenching condition.

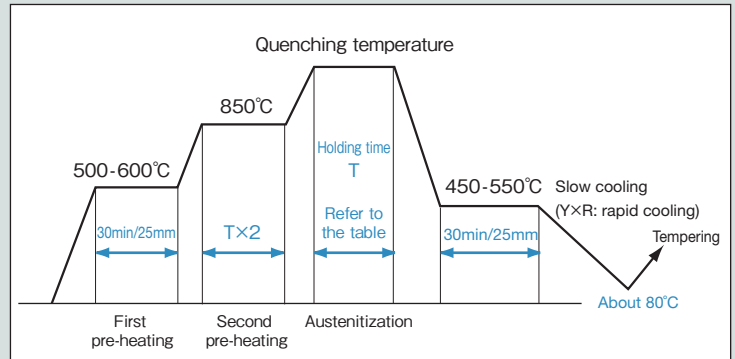
Alloy tool steels, Carbon tool steels



Holding time at austenitizing temperature

Thickness (mm)	≤15	25	50	75	100	125	150	200	300
Holding time (min)	15	25	40	50	60	65	70	80	100

High speed tool steels

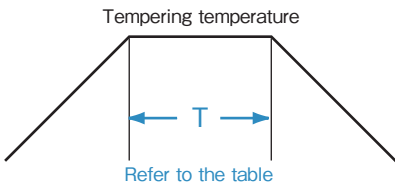


Holding time at austenitizing temperature

Heating furnace	Thickness (mm)	Time									
		5	10	20	30	40	50	60	70	80	90
Salt bath	Holding time (sec)	60	90	160	240	280	350	390	420	440	495
	Magnification (Holding time/Thickness)	x12	x9	x8	x8	x7	x7	x6.5	x6	x5.5	x5.5

Note: If you take preheating time, dipping time can be regarded as holding time.

Tempering



Note1: This standard is applicable to tempering at 500°C or more. When tempering at 250-500°C, holding time must be increased to 1.5 times longer and at lower than 250°C, 2 times longer than the standard.

Note2: Tempering is required no less than two times for grades containing no cobalt and at least three times for grades containing cobalt to improve toughness when high temperature tempering is done.

Note3: Because toughness deteriorates, tempering higher than 600°C must avoid for high-speed tool steels.

Thickness (mm)	≤25	26-35	36-64	65-84	85-124	125-174	175-249	250-349	350-499
Holding time for tempering (h)	1	1.5	2	3	4	5	6	7	8

Annealing

1. All material is delivered as spheroidized annealed condition.
2. After reforging, spheroidizing is to be done before hardening. Please refer to the standard heat treatment conditions.
3. Stress relief annealing is to be done to remove stress caused by cold working such as drawing and rolling and to soften or reduce distortion caused by subsequent hardening.
 - Heating temperature : 650-700°C
 - Holding time : 1h/25mm thickness



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Heat treatment of YSS cold work tool steels

Standard heat treatment conditions

	Grade	Hardness as delivering	Heating temperature		Tempered hardness (HRC)	Annealing			
			Hardening	Tempering					
Cold work tool steels	SLD-MAGIC	≦255	1,010-1,040	Air cool	480-530 or 150-250	Air cool	≧60	830-880	Slow cooling
	SLD	≦248	1,000-1,050	Air cool	480-530 or 150-200	Air cool	≧58	830-880	Slow cooling
	SLD10	≦248	1,020-1,070	Air cool	520-550	Air cool	≧62	830-880	Slow cooling
	ARK1	≦248	1,010-1,040	Air cool	480-530 or 150-250	Air cool	≧58	830-880	Slow cooling
	SGT	≦217	800-850	Oil quench	150-200	Air cool	≧60	750-780	Slow cooling
	YCS3	≦212	790-850	Oil quench	150-200	Air cool	≧63	750-780	Slow cooling
	ACD37	≦235	830-870	Air cool	150-200	Air cool	≧58	750-800	Slow cooling
	HMD5	≦235	Flame hardening 940-1100°C			—	—	825-875	Slow cooling
High speed tool steels	YXM1	≦255	(1) 1,200-1,240 (2) 1,160-1,200	Oil quench	550-570	Air cool	≧63	800-880	Slow cooling
	YXM4	≦277	(1) 1,230-1,250 (2) 1,210-1,230	Oil quench	560-580	Air cool	≧64	800-880	Slow cooling
	YXR7	≦241	(1) 1,160-1,180 (2) 1,120-1,160	Oil quench	540-580	Air cool	≧62	800-880	Slow cooling
	YXR3	≦241	(1) 1,150-1,170 (2) 1,130-1,150	Oil quench	560-590	Air cool	≧57	800-880	Slow cooling
	YXR33	≦241	1,080-1,140	Oil quench	550-600	Air cool	≧54	800-880	Slow cooling
P/M High speed tool steels	HAP5R	≦269	1,120-1,160	Oil quench	530-580	Air cool	≧58	820-870	Slow cooling
	HAP10	≦269	(1) 1,170-1,190 (2) 1,120-1,170	Oil quench	550-580	Air cool	≧63	820-870	Slow cooling
	HAP40	≦277	(1) 1,190-1,210 (2) 1,120-1,190	Oil quench	560-580	Air cool	≧66	820-870	Slow cooling
	HAP72	≦352	1,180-1,210	Oil quench	560-580	Air cool	≧68	820-870	Slow cooling

(1) Simple shape tools

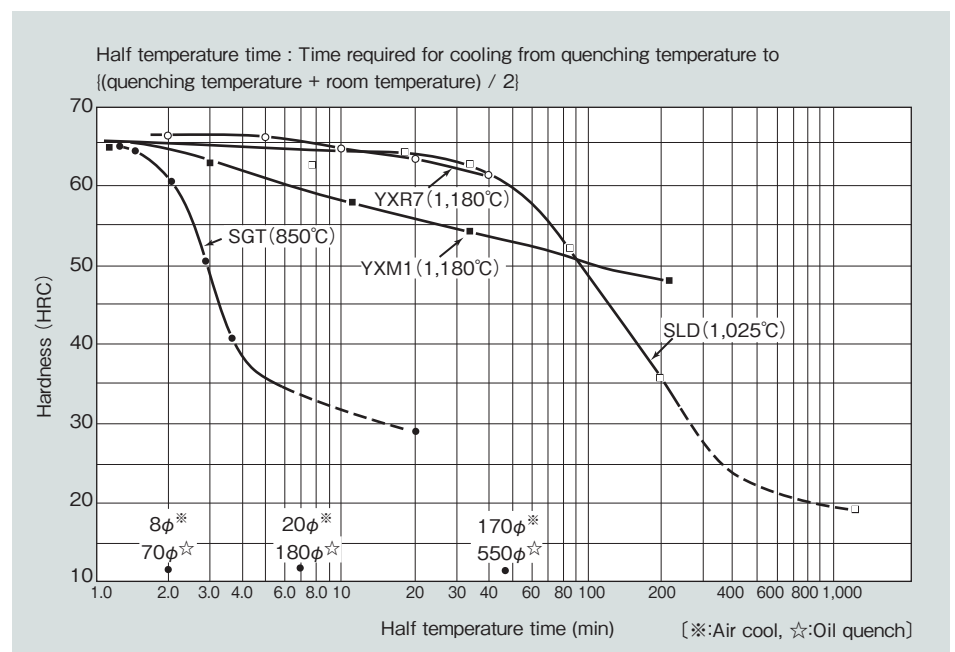
(2) Tools of complicated shape, requiring toughness in particular

* Specimen size is 15mm squire or round by 20 mm long in accordance with JIS standard hardness test.

Hardenability

The maximum diameter of a round bar stock that obtains 60 HRC hardness at its center by quenching.

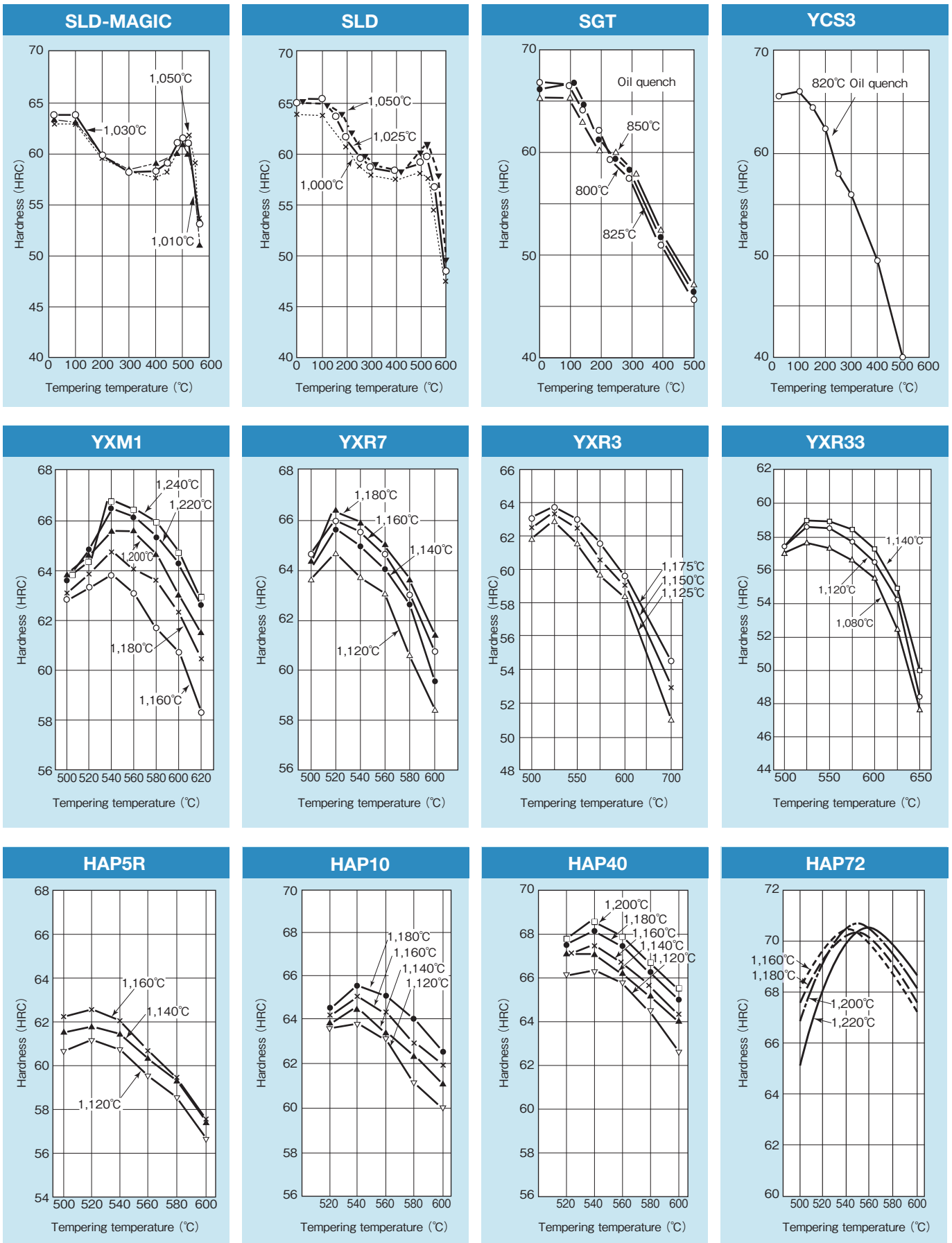
Grade	Cooling	
	Air cool	Oil quench
SLD-MAGIC	φ170	φ550
SLD	φ170	φ550
ACD37	φ120	—
SGT	φ8	φ70
YXM1	φ20	φ180
YXR7	φ170	φ550
HAP10	—	φ180



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Heat treatment of YSS cold work tool steels

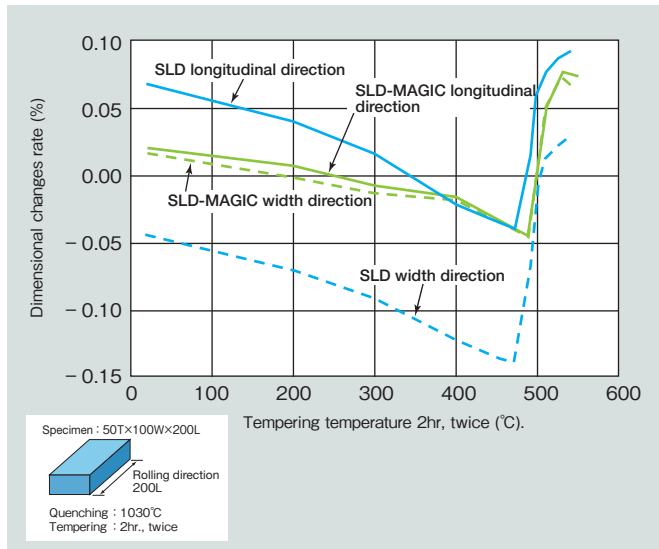
Quenched and tempered hardness curves



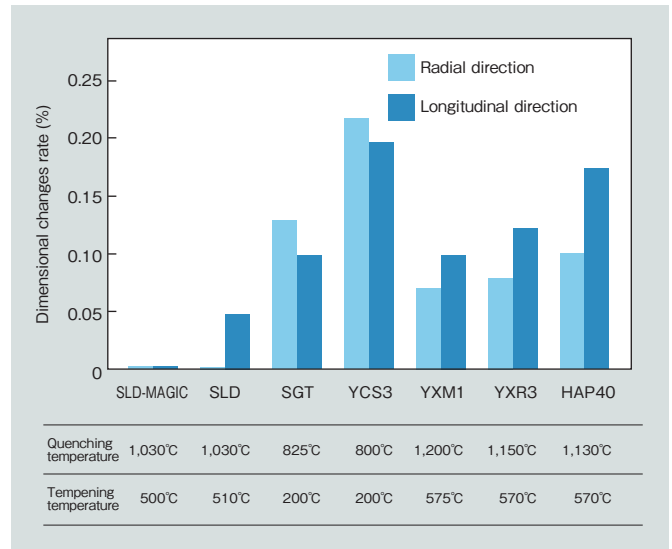
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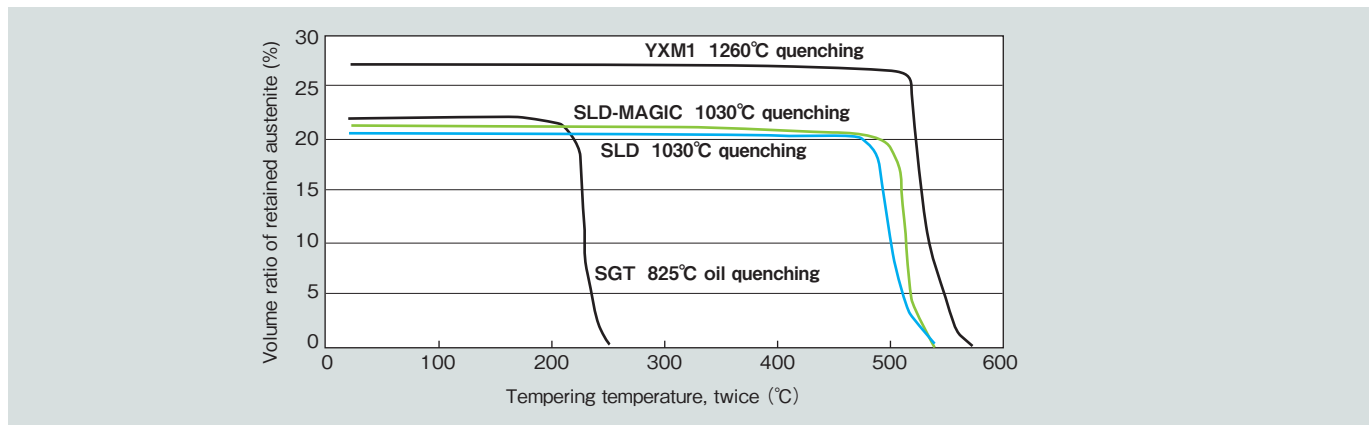
Dimensional change after heat treatment of cold dies steel



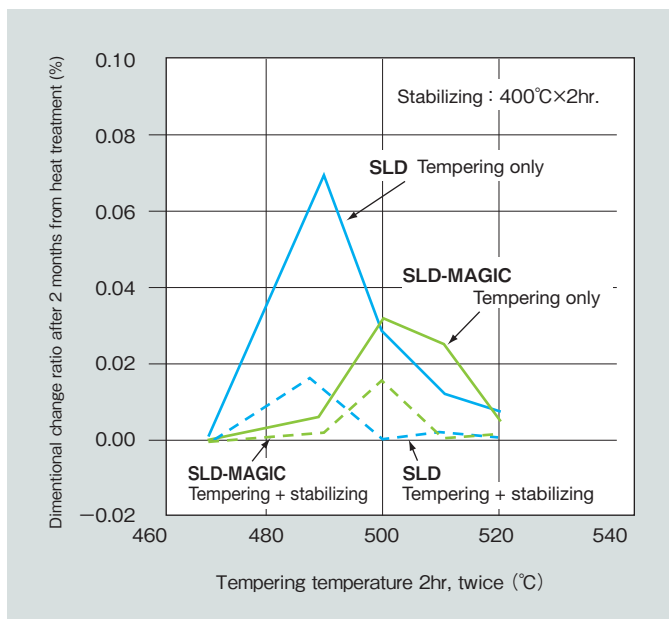
Dimensional changes after heat treatment



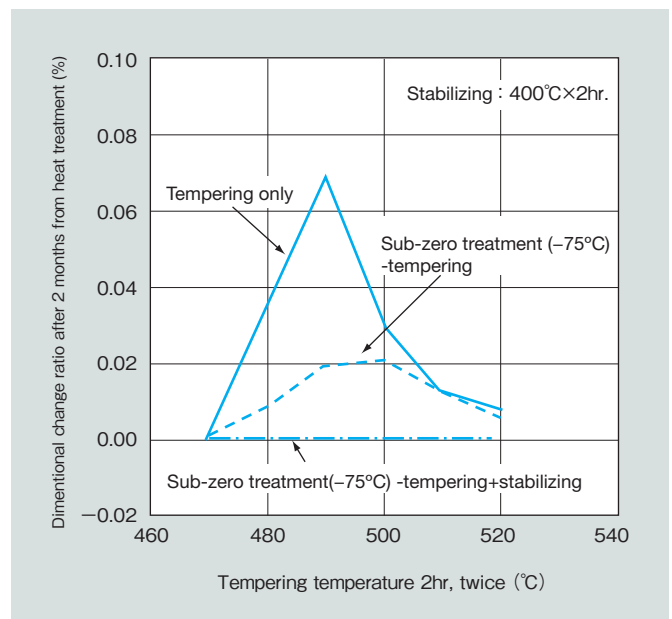
The retained austenite



Secular change and stabilizing treatment on cold work tool steel



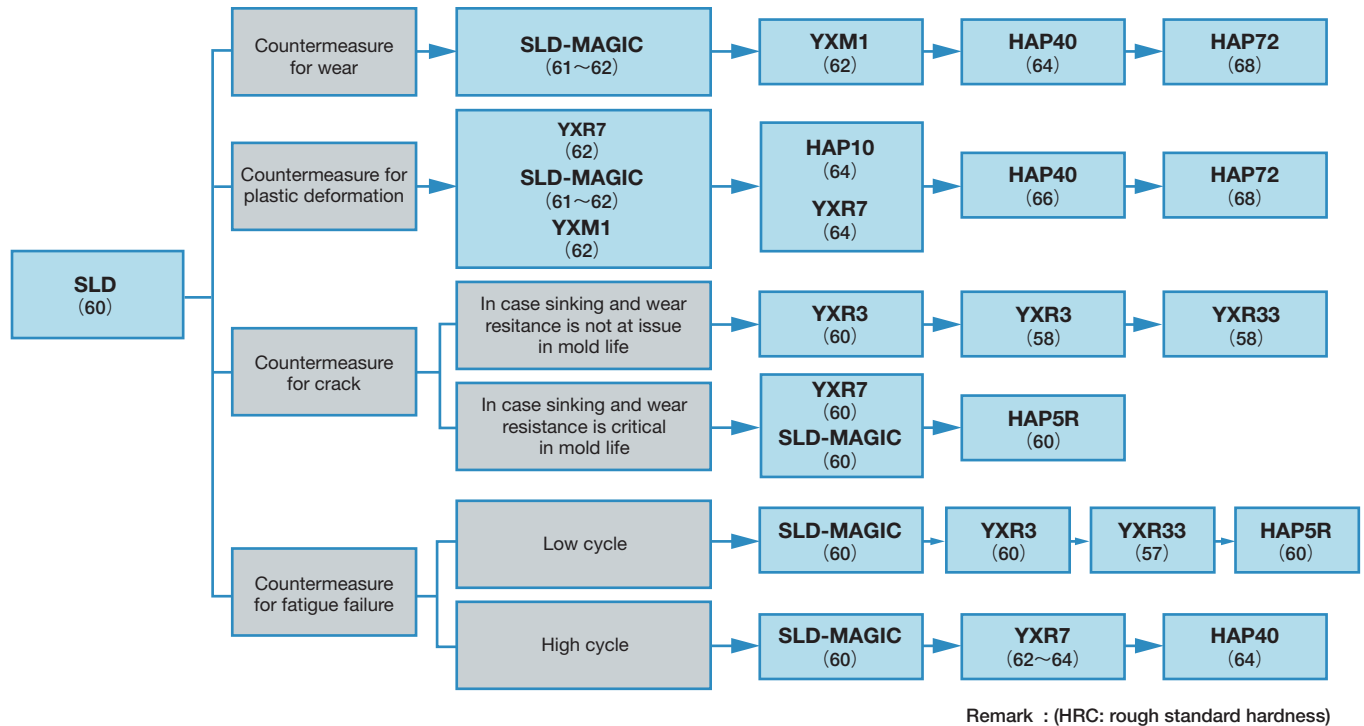
Secular change and sub-zero treatment



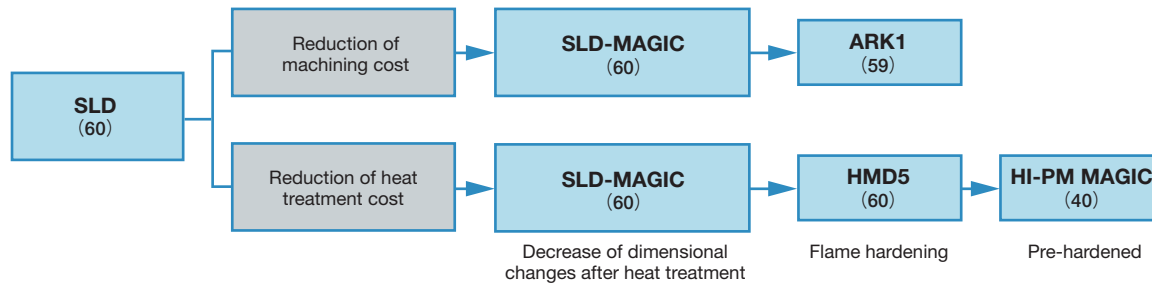
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Improvement processes of YSS cold work tool steels in terms of hardness and dies for various applications

Flowchart to improve die life of cold work tool steels



Flowchart to reduce die cost of cold work tool steels



Isotropy



Isotropy tool steels are so named because the difference in mechanical properties between its longitudinal (forging or rolling direction) and transverse directions is reduced, thus overcoming a weak point of ordinarily processed steels. This technological concept, which is highly evaluated by users of tool steels, is applied for the production of all our steels and contributes significantly to stabilizing their characteristics and enhance their service life.



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YSS High Quality Cold Work Tool Steel **SLD-MAGIC**



SLD-MAGIC is the high performance cold work die steel attaining both improved mold lifespan and easy mold fabrication.

SLD-MAGIC Features

Wear resistance

High hardness of 62HRC improves wear resistance by approximately 35%*

Surface treatment

Adherence between the coating layer and steel after surface treatment (CVD and other methods) is improved by approximately 30%*

Heat treatment

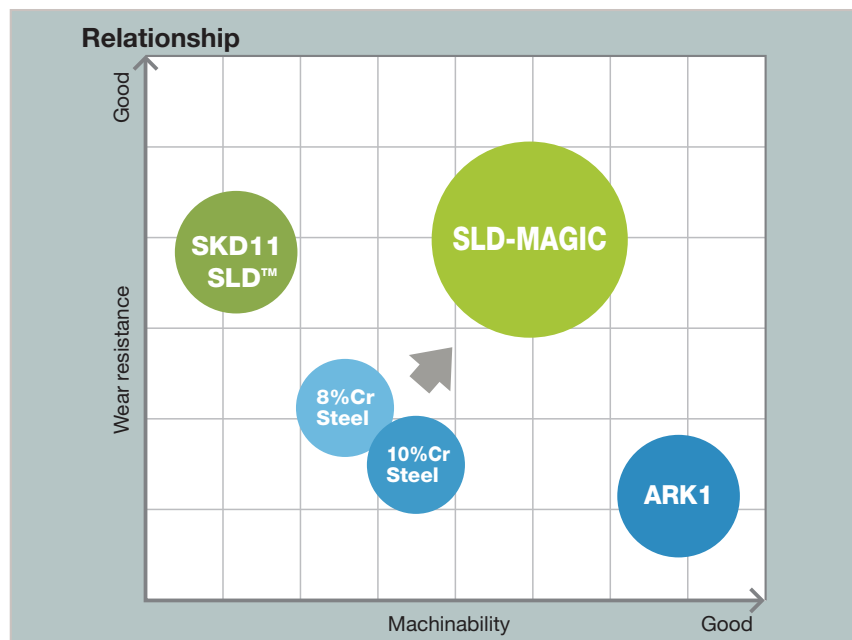
Minimal deformation during heat treatment for a reduction of approximately 40%* in dimensional changes

Machinability

Machinability improved by approximately 35%*

*Hitachi Metals comparison: Comparison against 8%Cr steel (Hitachi Metals product name:SLD8), a modified steel of SKD11

Concept



Effect

- Reduces reworking man-hours through minimal heat and surface treatment deformations.
- Prevents scuffing of high-tensile steels during bending and drawing.
- Improve mold lifespan.
- Shortens mold processing time via enhanced machinability.
- Reduces direct purchasing cost by improvement lifespan of cutting tool.

Comparison of Properties

Grade	SLD-MAGIC	8%Cr Steel	10%Cr Steel	SKD11
Hardness (HRC)	60-62	61-63	59-61	58-60
Wear resistance	A	B	B	A
Surface treatment**	A	C	C	B
Toughness	B	B	C	C
Machinability	B ⁺	C	B	D
Dimensional change by heat treatment	A	C	C	B
Weldability	B	B	C	C

Excellent "A" ←→ Poor "D"

**Surface treatment properties are based on adherence between the coating layer and steel after surface treatment.

8%Cr steel and 10%Cr steel offer improved machinability for better processing that reduces the volume of hard carbides within steel, but are inferior to SKD11 in terms of wear resistance and galling.

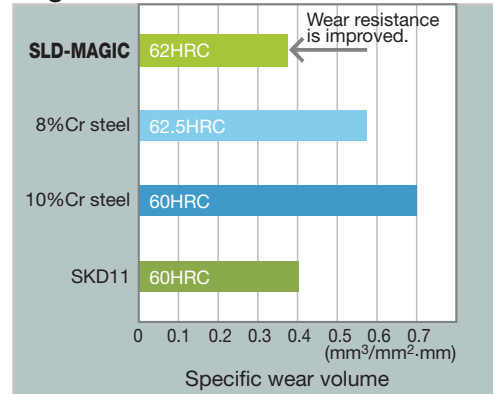


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Wear resistance

SLD-MAGIC increases wear resistance by approx. 35% compared with 8%Cr steel due to the control of carbide morphology.

Ohgoshi-method wear test

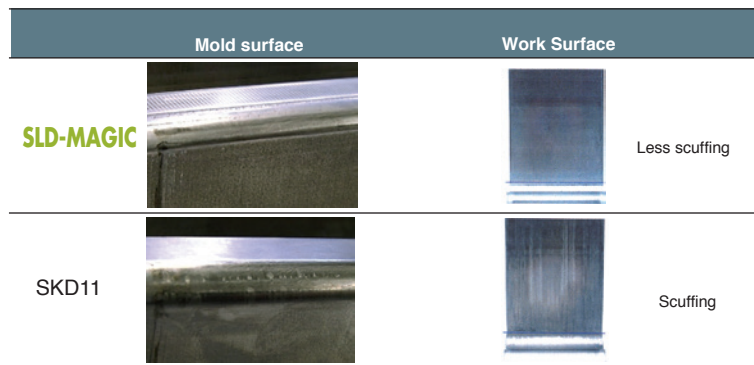


Work material: SCM415
Friction distance: 400m
Friction speed: 0.76m/s
Load: 67N

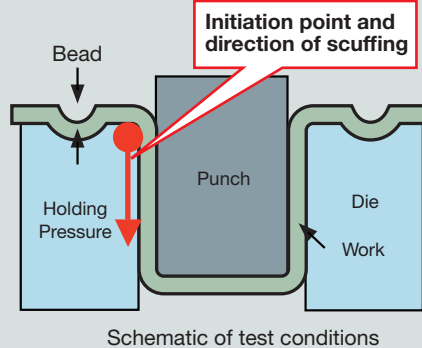
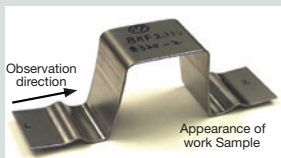
Scuffing resistance

SLD-MAGIC shows less scuffing on Hat Testing simulating practical mold wear phenomena.

Scuffing Observation



Scuffing Test

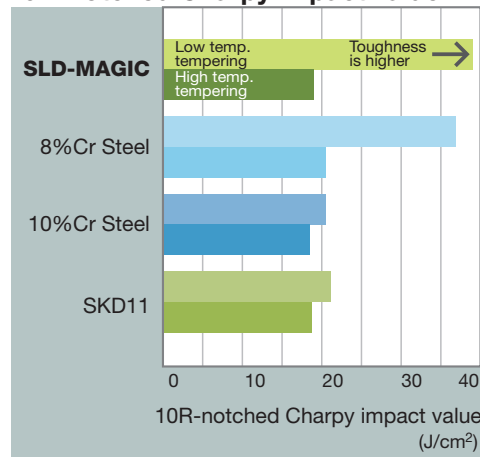


Scuffing Test Conditions
Press : 80ton Cranck Press
Velocity V : 40-75spm(19.2-36m/min)
Holding Pressure Ps : -2.4ton/cm²
Length of Stroke : 60mm
Lubricant : Anti-rustoil applied and wiped away
Work : High-tensile-strength steel (590MPa)
Thickness 1.6mm (No plating)
Surface Roughness of the mold: Polished by #1000 (Ra=0.04mm)

Toughness

SLD-MAGIC is superior to SKD11 in toughness. It can be used as a countermeasure to chipping and cracking with low temp. tempering.

10R-notched Charpy impact value



Low temp.: 200°C
High temp.: 510-520°C



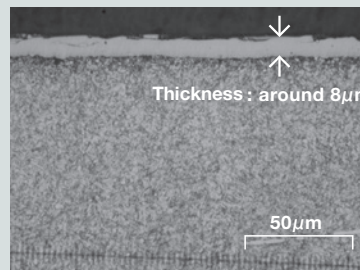
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Surface treatment

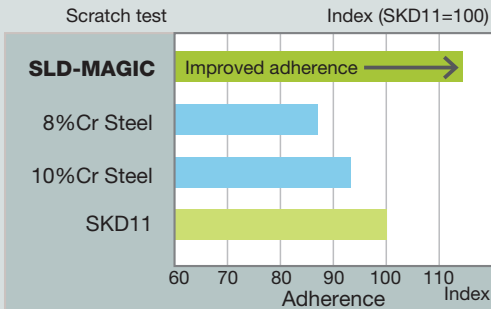
SLD-MAGIC can be treated with hard coating (CVD, TD treatment etc.) under the same conditions as SKD11.

SLD-MAGIC shows improved adherence between the coating layer and steel after 3-time surface treatment by approx. 30% when compared with 8%Cr steel, due to optimum alloy design.

Coating Layer by CVD method



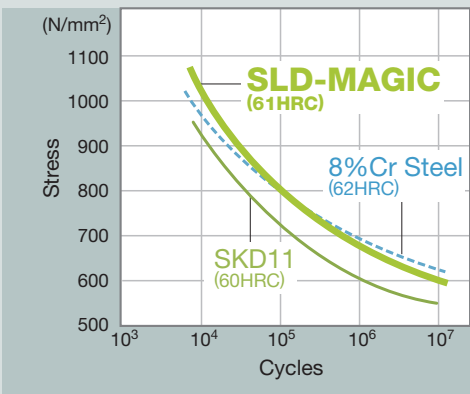
Adherence between the coating layer and steel after 3-time CVD treatment.



Fatigue strength

SLD-MAGIC shows improved fatigue strength in comparison to SKD11 due to the control of carbide morphologies.

Rotating bending fatigue test



Physical Properties

Thermal expansion coefficient ×10 ⁻⁶ /°C	20-100°C	20-200°C
	11.7	12.2

Thermal conductivity W/m·K	Room temperature
	16.5

Specific gravity	Annealed	Quenched and tempered
	7.77	7.76

Young's modulus GPa	209
------------------------	-----

Transformation temperature	Ac1	Ms temperature
	850°C	166°C



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Heat Treatment

It is possible to heat treat SLD-MAGIC under the same conditions as SKD11.

It is possible to obtain maximum hardness (60-62HRC) with tempering at around 500°C where dimensional change is near to zero, achieving both high hardness and less dimensional change.

Secular change of SLD-MAGIC after high temp. tempering is almost equivalent to that of SKD11, and smaller than 8% Cr steel. It is possible to reduce secular change via low temp. tempering, subzero treatment or stabilizing*.

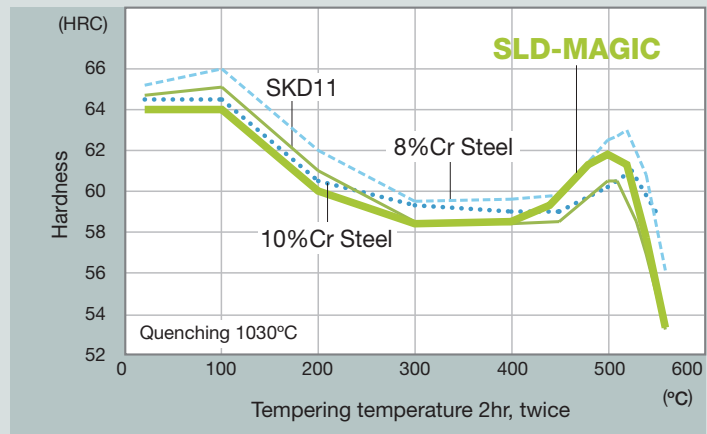
*Heat treatment process to add middle temp. tempering after high temp. tempering for the purpose of reducing secular distortion.

Size of test pieces: 45T × 90W × 200L
 Austenitizing: 1030°C
 Low temp. tempering: 180°C × 2times
 High temp. tempering: 520°C × 2times
 Measure: 200mm direction
 Dimensional change after 6 months posterior heat treatment

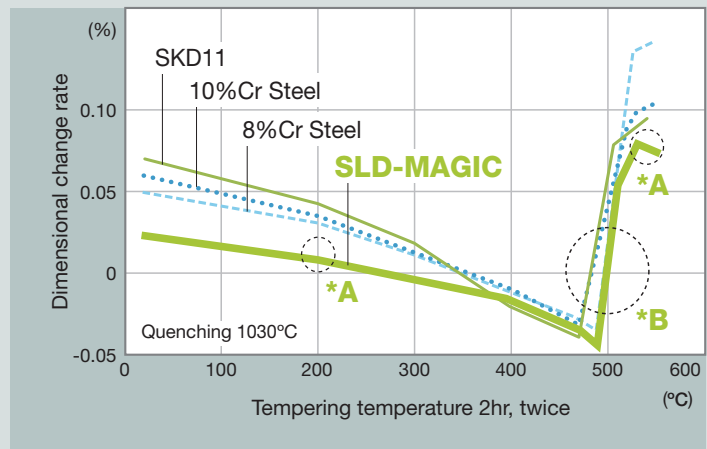
Standard Heat Treatment Conditions

Annealed Hardness	Hardening	Tempering	Hardness (HRC)
255HBW or under	1010 -1040°C Air quenching	480-530°C Air cooling or 150-250°C Air cooling	60HRC or over

Quenched and tempered hardness

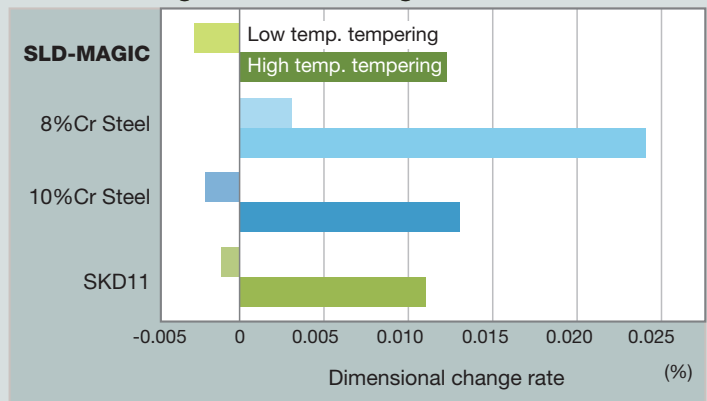


Dimensional change after heat treatment



*A: Minor dimensional change
 *B: Minor dimensional change with maximum hardness

Secular change / Dimensional growth



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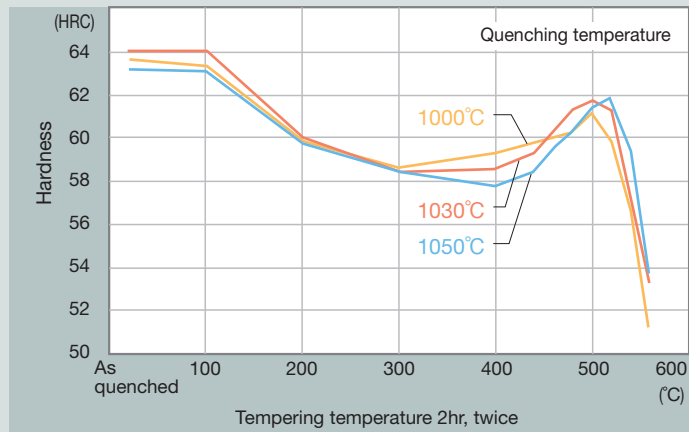
Heat Treatment

SLD-MAGIC shows stable both high hardness and very little dimensional change at around 1020-1030°C hardening temperature.

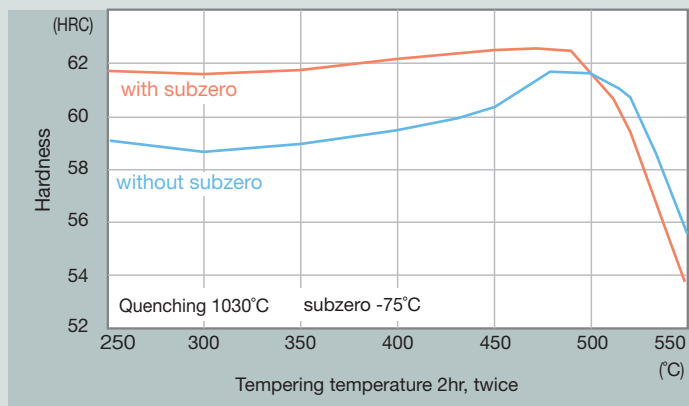
To add subzero treatment, SLD-MAGIC can achieve high hardness (62HRC) by both high and low temp. tempering. To combine subzero and stabilizing treatment is very effective for reducing secular distortion.

SLD-MAGIC shows almost the same decomposition behavior of the retained austenite, as that of conventional SKD11.

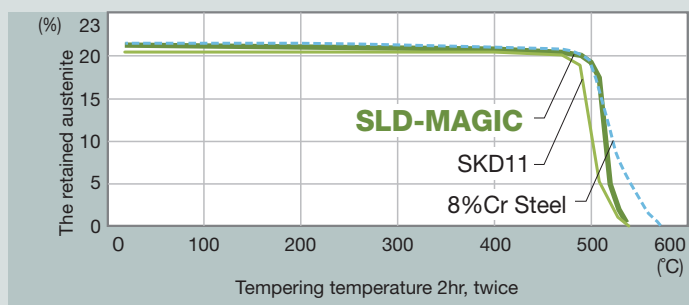
The difference of quenching temperature



The subzero treatment and hardness



The retained austenite



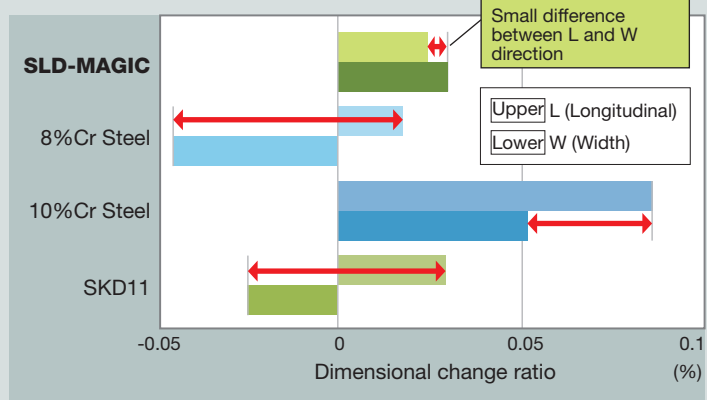
Heat Treatment

SLD-MAGIC shows smaller in dimentional change difference in the longitudinal, width and thickness directions, compared to SKD11 or 8%Cr steels.

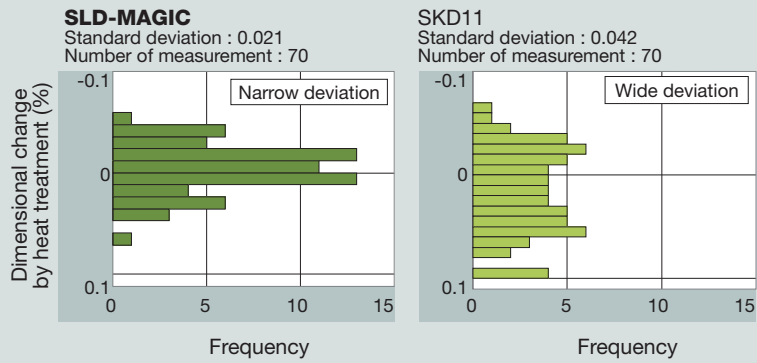
SLD-MAGIC shows narrow deviation of dimensional changes by heat treatment, as a result, the better dimensional tolerance can be attained.

For example, in case of separation type molds, mold set up time was largely decreased because of narrow dimensional deviation.

Secular change / Dimensional change



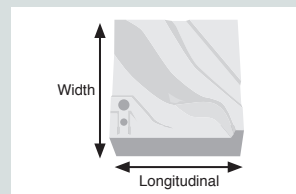
Deviation comparison of dimensional changes of actual mold after heat treatment.



Example of dimensional change for insert type mold.

Grade	Direction	Original dimension (mm)	Dimensional change (mm)	Dimensional change ratio (%)	Mold set up time
SLD-MAGIC	W	295	-0.030	-0.010	46 ←
	L	250	+0.010	+0.004	
SKD11	W	295	-0.090	-0.031	100(Index)
	L	250	+0.130	+0.052	

54% reduction of mold adjusting time after heat treatment



Machinability

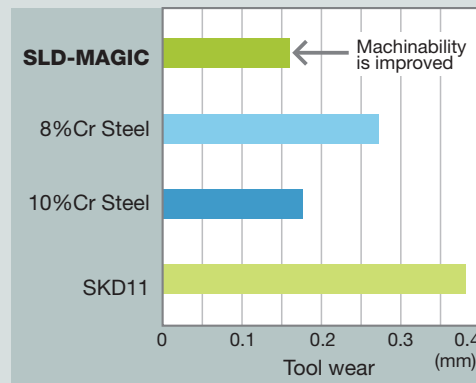
SLD-MAGIC improves machinability on face mill by over twice that of SKD11 and by approx. 35% compared to 8%Cr steel.

It also demonstrates superior machinability using other tools.

Mold processing time is expected shorten due to good machinability.

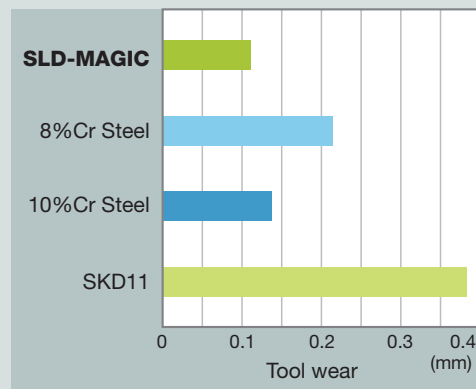
The direct purchasing cost of tools is expected reduce by improvement lifespan of cutting tools.

ø125 Face Mill



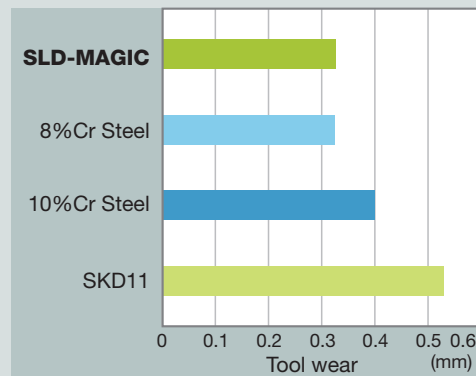
Work: Annealed condition
 Tool: Coated carbide chip, 1 chip only
 Cutting speed: 120m/min, Dry
 Feed: 0.13mm/blade
 Depth of cut: 2^z × 90^wmm,
 Cutting distance: 4m

End Mill



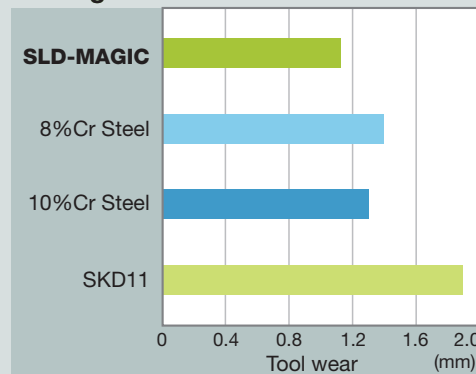
Work: Annealed condition
 Tool: End mill ø8 (Co-HSS)
 Cutting speed: 30m/min, Down-cut, Wet
 Feed: 0.05mm/tooth
 Depth of cut: 15^z × 0.5^wmm,
 Cutting distance: 5m

Drill



Work: Annealed condition
 Tool: Drill ø5 (Co-HSS)
 Cutting speed: 20m/min, Wet
 Feed: 0.05mm/rev
 Depth of hole: 25mm, 200Holes

ø63 High feed cutter



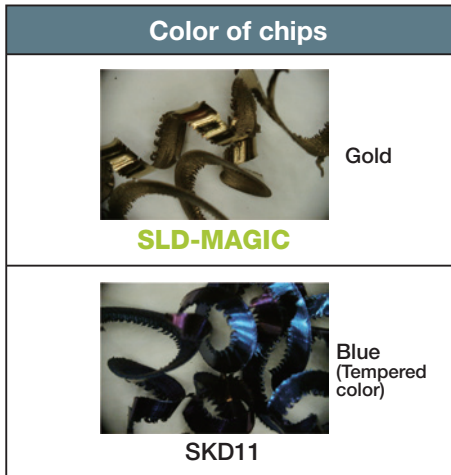
Work: Annealed condition
 Tool: Coated carbide chip
 Cutting speed: 150m/min, Dry
 Feed: 1.3mm/tooth
 Depth of cut: 1mm,
 Cutting distance: 60m



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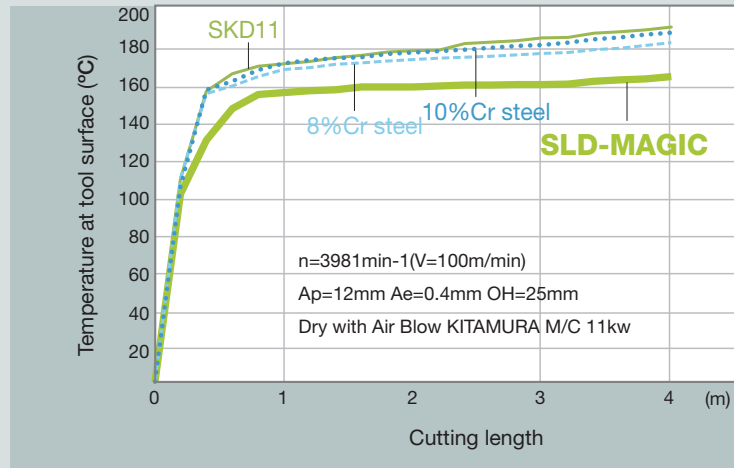
Machinability

SLD-MAGIC can enhance tool lives because of lower cutting tool temperatures.



Cutting tool temperature comparison

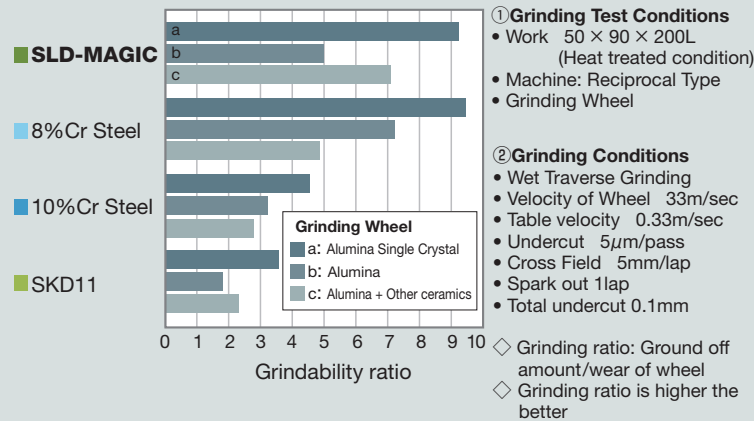
CEPR6080 (ultrafine particle WC) (ø8 × 6NT TiAlN)



Grindability

Grindability of SLD-MAGIC is better than those of SKD11 and 10%Cr steel, and almost equivalent to 8%Cr steel.

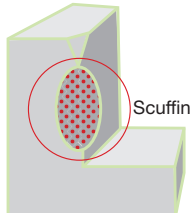
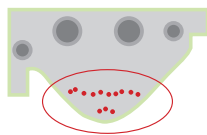
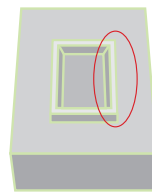
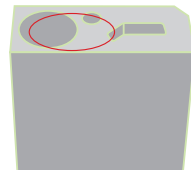
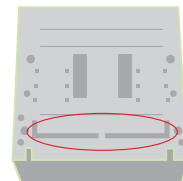
Grindability comparison as a function of different grinding wheels



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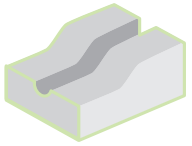
Application Examples

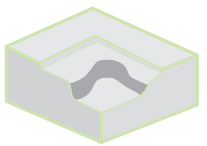
By achieving both improved mold lifespan and easy mold fabrication, SLD-MAGIC will contribute to reducing total cost and shortening delivery times of the automobile and mold industries.

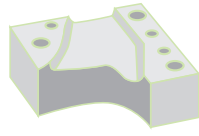
01 Bending die for automotive parts Inner parts Work 440MPa (t3.2)		Present condition	Evaluation	 <p>Scuffing</p> <p>Mold lifespan significantly improved</p>
	Grade	SKD11	SLD-MAGIC	
	Hardness	59-61HRC	60-62HRC	
	Heat treatment	High temp. Tempering	High temp. Tempering	
	Surface treatment	CVD (TiC)	CVD (TiC)	
	Lifespan	1,300 pcs	156,000 pcs	
	Cause	Severe galling	Less galling	
02 Blanking die for automotive parts Function parts Work 590MPa (t7.0)		Present condition	Evaluation	 <p>Chipping</p> <p>Mold lifespan more than doubles</p>
	Grade	SKD11	SLD-MAGIC	
	Hardness	58-60HRC	58-60HRC	
	Heat treatment	170°C Tempering	170°C Tempering	
	Machinability	Bad	Good	
	Lifespan	15,000 pcs Max.	40,000 pcs carrying on	
	Cause	Severe chipping	Less chipping	
03 Blanking die for electrical appliances Electrical appliances Work Film		Present condition	Evaluation	 <p>Mold lifespan around 50% up</p>
	Grade	SKD11	SLD-MAGIC	
	Hardness	58-60 HRC	58-60 HRC	
	Heat treatment	530°C Tempering	530°C Tempering	
	Machinability	Bad	Good	
	Lifespan	650,000 pcs	1,020,000 pcs	
	Cause	Early wear out	Less wear	
04 Blanking die for electrical appliances Optical parts Work SPCC (t0.8)		Present condition	Evaluation	 <p>Mold lifespan almost doubles</p>
	Grade	SKD11	SLD-MAGIC	
	Hardness	60-62HRC	60-62HRC	
	Heat treatment	200°C Tempering	480°C Tempering	
	Machinability	Bad	Good	
	Lifespan	100,000 pcs	100,000 pcs carrying on	
	Cause	Burr (Wear out)	Reduce wear by half	
05 Blanking die for electrical appliances Liquid crystal panel parts Work SUS304 (t0.3)		Present condition	Evaluation	 <p>Mold lifespan around 30% up</p>
	Grade	8%Cr Steel	SLD-MAGIC	
	Hardness	60-62HRC	60-62HRC	
	Heat treatment	505°C Tempering	480°C Tempering	
	Dimensional change	within 0.05%	-0.01-0.02%	
	Lifespan	30,000 pcs	40,000 pcs carrying on	
	Cause	Burr (Wear out)	Less wear	


! Note: The above-listed data is for application examples only and this data does not assure performance. It is not suited for molds with EDM finished surface that require a high degree of mirror finish such as plastic molds.

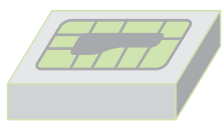
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06 Die for hydroforming Exhaust pipe Work Steel tube		Present condition	Evaluation	 Mold adjusting time is reduced because of small dimension change of upper and lower die blocks by heat treatment
	Grade	SKD11	SLD-MAGIC	
	Hardness	56HRC	58HRC	
	Heat treatment	High temp. Tempering	High temp. Tempering	
	Distortion by heat treatment	Very hard to adjusting the upper and lower die blocks due to large dimensional changes	Reduction of adjusting time of the upper and the lower die blocks	
	Machinability	Bad	Improved. Adjusting is finished only by one chip used.	

07 Die for cold press Automobile parts Work High-tensile -strength steel		Present condition	Evaluation	 Small dimension deviation
	Grade	SKD11	SLD-MAGIC	
	Hardness	58~60HRC	60-62HRC	
	Heat treatment	High temp. Tempering Large dimensional change	High temp. Tempering Deviation is reduced to 1/2. Adjusting time is reduced	
	Surface treatment	TD	TD	
	Cause	Ball End Miuing Exchanging chips quite often	The number of exchanged chips is reduced to 1/5-1/10 compared to SKD11. Feed rate is increased to 1.7 times.	

08 Die for cold press Inner parts Work 440MPa (t2.3)		Present condition	Evaluation	 Mold lifespan is improved by almost 3 times.
	Grade	SKD11	SLD-MAGIC	
	Hardness	58-60HRC	60-62HRC	
	Heat treatment	High temp. Tempering	High temp. Tempering	
	Surface treatment	TD	Dimensional Changes by TD is within 5/100	
	Lifespan	5,500 pcs	Continuing beyond 15,000	
	Problem	Scuffing		

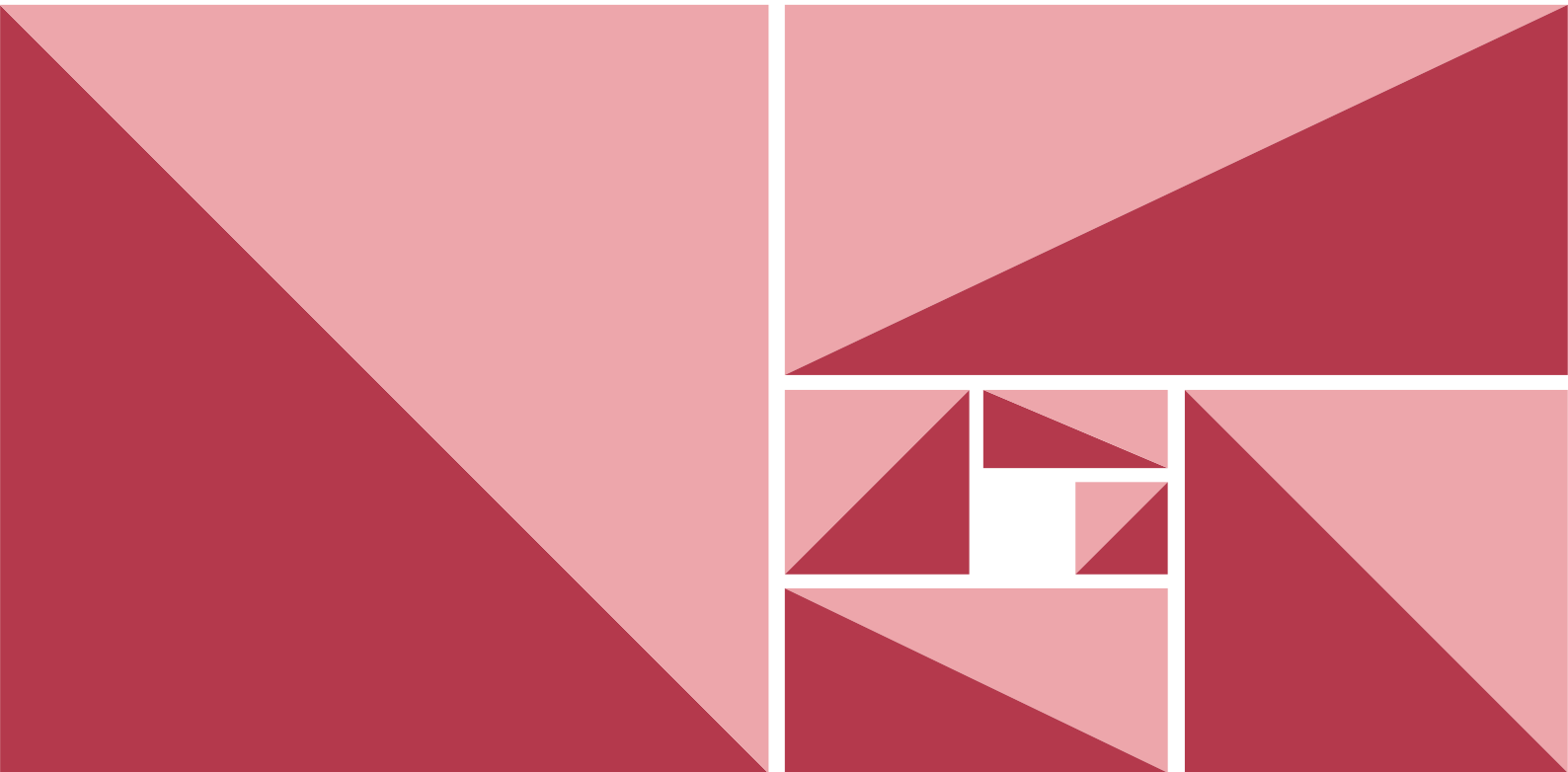
09 Die for cold press Inner parts Work 780MPa (t2.3)		Present condition	Evaluation	 Small dimension changes after TD treatment
	Grade	SKD11	SLD-MAGIC	
	Hardness	59-61HRC	60-62HRC	
	Heat treatment	High temp. Tempering	High temp. Tempering	
	Surface treatment	TD	Dimensional Changes by TD is small	
	Machinability	Bad	The life of chips used is 10 times longer than SKD11 cases.	
	Problem	Machinability and dimension change		

10 Die for cold press Insert blocks		Present condition	Evaluation	 Adjustment time is reduced because of reduced the number of deformed blocks.
	Grade	SKD11	SLD-MAGIC	
	Hardness	59-60HRC	59-60HRC	
	Heat treatment	High temp. Tempering	High temp. Tempering	
	Deformation of datum plane	All 26 pieces deformed over 0.02mm	Only 1 piece out of 26 pieces deformed 0.02mm.	
	Adjustment time	100 min.	0 min.	

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YSS

Hot Work Tool Steels



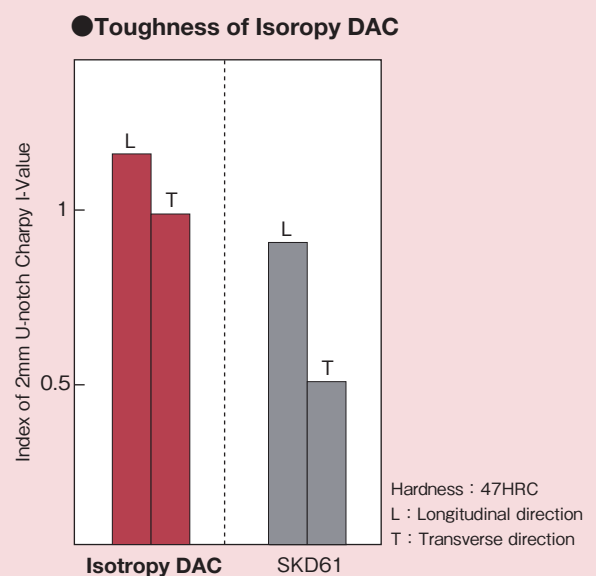
Chemical compositions of YSS hot work tool steels

Grade		Chemical composition (%)								
YSS	JIS equivalent	C	Si	Mn	Ni	Cr	W	Mo	V	Others
DAC	SKD61	0.4	1.0	0.4	—	5.2	—	1.3	0.9	
DAC-MAGIC	SKD61 modified	Original steel								
DAC10	SKD61 modified	0.3	0.3	0.6	—	5.2	—	2.7	0.9	
DAC55	SKD61 modified	0.4	0.2	0.6	0.6	5.2	—	2.2	0.8	Other special elements added
DAC3	SKD61 modified	0.4	0.3	0.6	0.6	5.1	—	1.6	0.7	
DAC40	SKD7 modified	0.4	0.5	0.5	—	4.3	0.7	2.1	0.9	
YEM-K	SKD7 modified	0.4	0.3	0.9	0.9	3.4	—	2.5	0.6	Other special elements added
MDC-K	SKD8 modified	0.4	0.3	0.5	—	4.4	2.0	1.6	1.7	Other special elements added
FDAC	SKD61 free cutting	0.3	1.0	0.7	—	5.2	—	1.3	0.4	S : 0.1
DM	SKT4	0.5	0.3	0.9	1.8	1.3	—	0.4	0.2	
YXR33	Matrix HSS	0.5	0.2	0.5	—	4.2	1.6	2.0	1.2	

※Impurities such as P and S are controlled below the levels specified in JIS by using Hitachi Metals' own high-quality raw materials.

Isotropy

Isotropy tool steels are so named because the difference in mechanical properties between its longitudinal (forging or rolling direction) and transverse directions is reduced, thus overcoming a weak point of ordinarily processed steels. This technological concept, which is highly evaluated by users of tool steels, is applied for the production of all our steels and contributes significantly to stabilizing their characteristics and enhance their service life.



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Applications of YSS hot work tool steels

Application		Standard hardness	Recommended YSS steel			
			for general use	for mass production use		
for die casting	for Aluminium alloys	41-51HRC	DAC	DAC-MAGIC, DAC10		
	for Magnesium alloys		FDAC (38-42HRC)	DAC55		
	for Zinc alloys	41-49HRC	DAC, FDAC (38-42HRC)			
	for Copper alloys	41-49HRC	MDC-K			
	Core pin for die casting	40-50HRC	DAC	—		
		52-58HRC	—	YXR33		
	Sleeve	Nitriding >64HRC	DAC			
Goose neck	for Magnesium	35-45HRC	AHD32			
for extrusion tool	Dies	for Aluminium	45-49HRC	DAC	DAC3, DAC40	
		for Copper	45-49HRC	DAC, MDC-K	HRD10 (56-60HS)	
	Container tyre	for Aluminium	44-50HS	DM	DAC, DAC3	
		for Copper	44-50HS	DM	DAC	
	Outer sleeve	for Aluminium	60-65HS	DAC	DAC3	
		for Copper	60-65HS	DAC	YEM-K	
	Inner sleeve (Liner)	for Aluminium	60-69HS	DAC, DAC3	YEM-K	
		for pure Copper	46-60HS	HRD20 (46-51HS)	HRD10 (56-60HS)	
		for Brass	46-51HS	HRD20		
	Stem	for Aluminium	60-65HS	DAC	DAC3, YAG300 (69-75HS)	
		for Copper	60-69HS	DAC	DAC3	
	Die holder	for Aluminium	60-65HS	DAC	DAC3	
		for Copper	60-65HS	DAC, DAC3	HRD10 (56-60HS)	
	Die backer	for Aluminium or copper	60-65HS	DM, DAC	DAC3	
	Mandrel	for Aluminium	60-65HS	DAC	DAC3	
		for Copper	60-65HS	DAC	YEM-K	
Dummy block	for Aluminium	60-65HS	DAC	DAC3		
	for Copper	60-65HS	DAC, DAC3	HRD10 (56-60HS)		
Mandrel holder	for Aluminium or copper	60-65HS	DM, DAC	DAC3		
Bolster	for Aluminium or copper	55-60HS	DM, DAC	DAC3		
for forging die	for press forging	for small size dies	55-65HS	DAC, DAC3	YEM-K, MDC-K	
		for middle size dies				52-62HS
		for large size dies	46-56HS	DAC	DAC3	
	for hammer forging	for small size dies	55-59HS	DM		
		for middle size dies	53-57HS			
		for large size dies	50-55HS			
	Warm forging dies		50-59HRC	MDC-K	YXR3, YXR33	
Header dies*1		45-49HRC	YEM-K	MDC-K		
Upset tool		46-50HRC	DAC	YEM-K		
Shear blade*2		37-45HRC	DAC, DM	—		
Glass molds		28-45HS	HI-PM38	ZHD11, SUS310S		
Glass shear		>80HS	YXM1	—		

*1 Use for bolt hot forming

*2 Use for thick billet shearing



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Types and features of YSS hot work tool steels

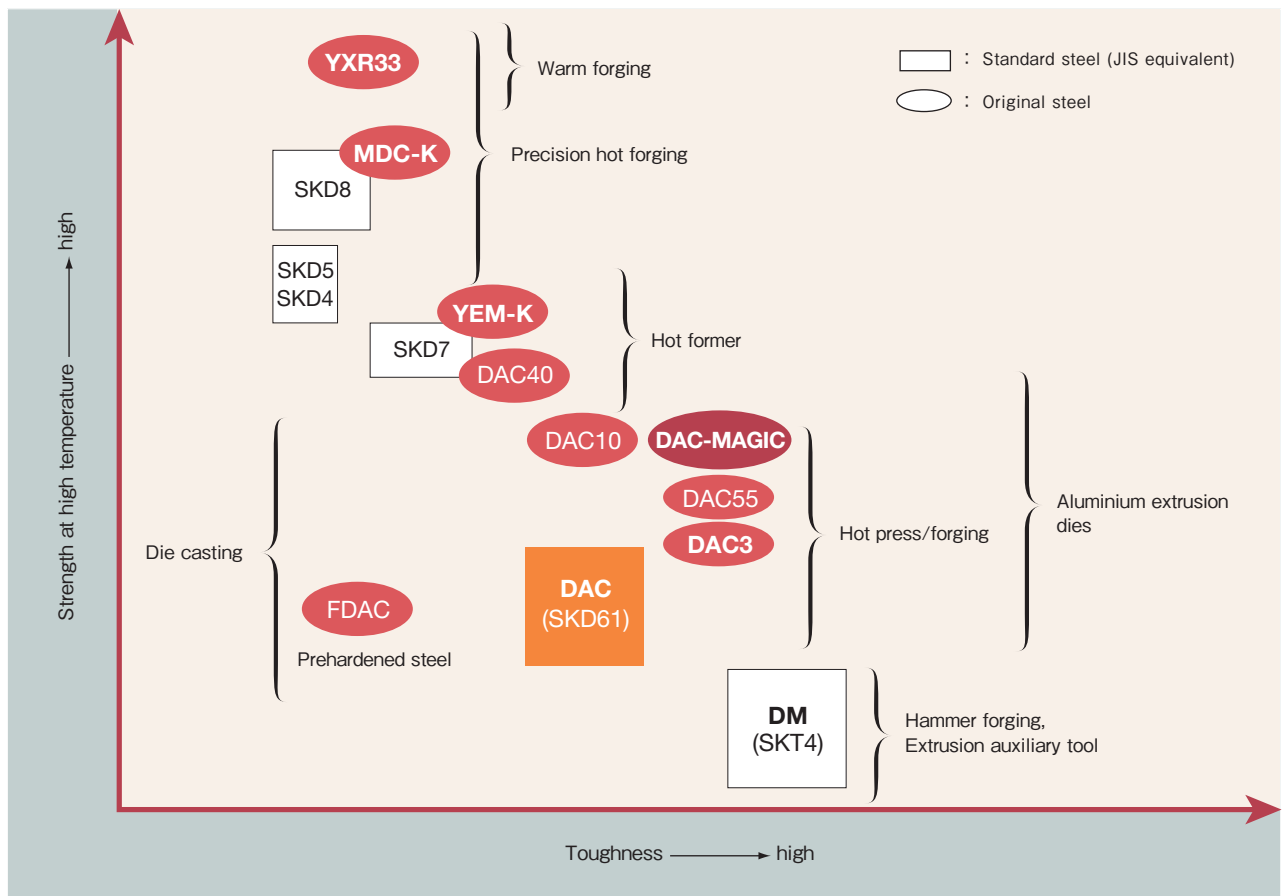
Grade		Features
YSS	JIS equivalent	
DAC	SKD61	Standard grade for general use with good balance of toughness, strength at elevated temperature and with excellent hardenability.
DAC-MAGIC	SKD61 modified	High performance die steel for die casting with well balanced strength and toughness and strength at elevated temperature. Excellent heat crack and stress corrosion crack resistance.
DAC10	SKD61 modified	Excellent heat crack and wear resistance at elevated temperature. Steel for precision die casting and hot press die.
DAC55	SKD61 modified	Die casting die steel with excellent heat crack resistance and toughness.
DAC3	SKD61 modified	Hot work tool steel with higher toughness than DAC for Al extrusion dies with high hardness or hot forging press dies with good crack resistance.
DAC40	SKD7 modified	Al extrusion die steel with higher strength and better softening resistance at elevated temperature than DAC.
YEM-K	SKD7 modified	Hot work tool steel with higher toughness and strength at elevated temperature than SKD7 for forging die of mass production use such as hot former.
MDC-K	SKD8 modified	High strength hot work tool steel with higher toughness than SKD8 for high heat load applications such as Cu extrusion and Cu alloy die casting dies.
FDAC	SKD61 free cutting	Free cutting hot work tool steel (supplied in prehardened condition) for dies of small production use or dies associated parts requiring good machinability.
DM	SKT4	Hot work tool steel with excellent toughness, used for hammer forging dies, Aluminium forge dies, forging bolsters and extrusion die backers, etc.
YXR33	Matrix HSS	Matrix-type high speed steel with high toughness. Excellent strength and wear resistance at elevated temperature and excellent erosion resistance. Steel for warm and hot precision forging dies and insert pins for die casting.



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Characteristics of YSS hot work tool steels

Characteristics of hot work tool steels



Comparison of properties

Grade	Strength at elevated temperature	Softening resistance	Toughness	Wear resistance	Hardenability
DAC	C	C	A	C	A
DAC-MAGIC	B	B	A ⁺	B	A
DAC10	B	B	A	B	A
DAC55	B ⁻	B ⁻	A ⁺	B ⁻	A
DAC3	C ⁺	C ⁺	A ⁺	C ⁺	A ⁺
DAC40	B ⁺	B ⁺	B ⁺	B ⁺	B ⁺
YEM-K	A ⁻	A ⁻	B	A ⁻	A ⁻
MDC-K	A	A	C	A	B
FDAC	C	C	C	C	—
DM	D	D	A ⁺⁺	D	B
YXR33	A ⁺	A ⁺	C	A ⁺	B

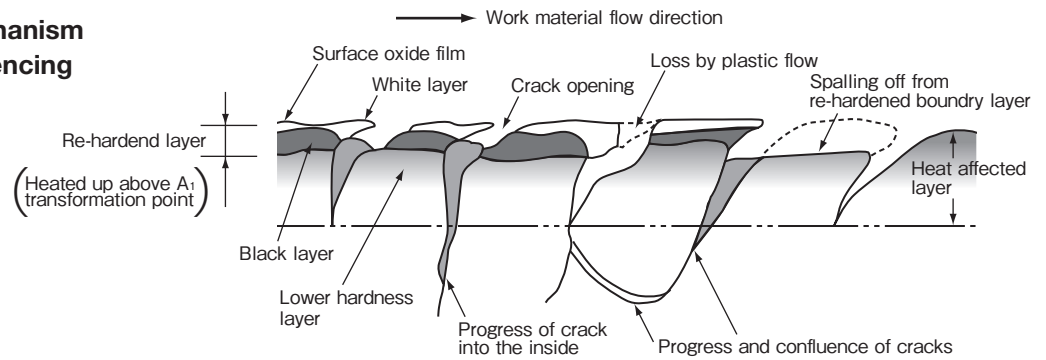
Ratings: A—Best C—Ordinary D—Poor
 (Remarks) Please use above ratings only for general reference.



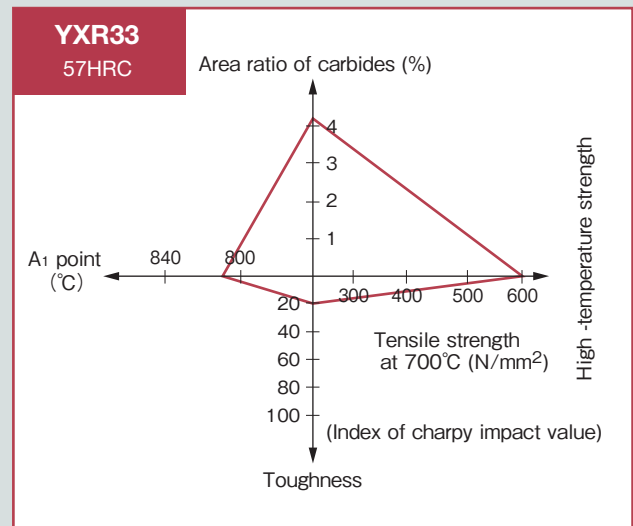
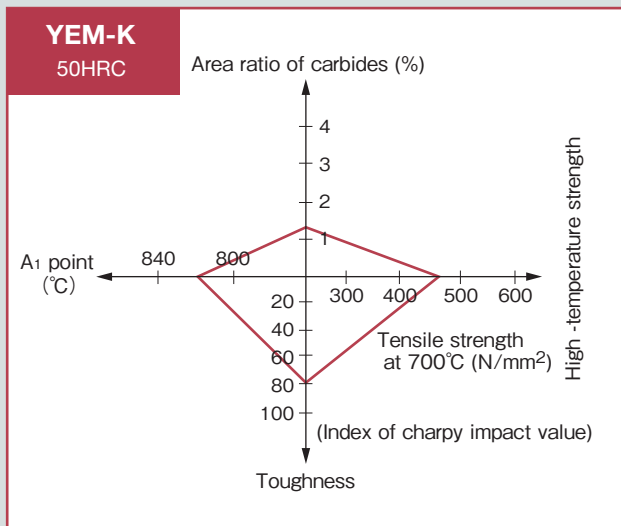
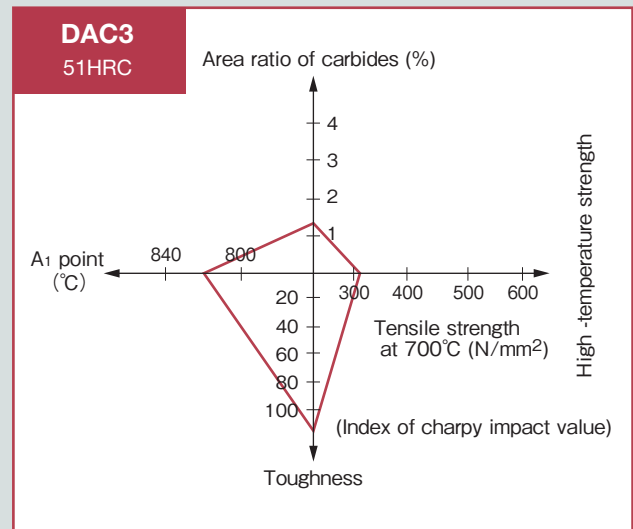
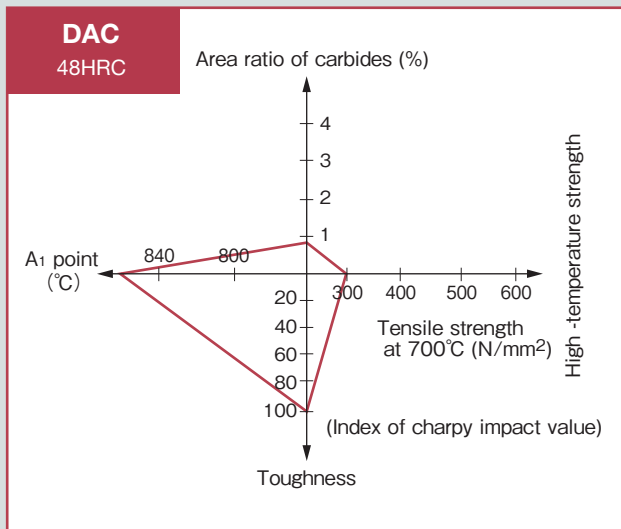
<Attention> The characteristics, photos, charts, rankings and evaluations of this catalog are representative value by our test data, it does not guarantee the quality of the product. This catalog and its contents are subject to change without notice.

Properties of YSS hot work steels

Hot forging die wear mechanism
"microstructure" and influencing factors.



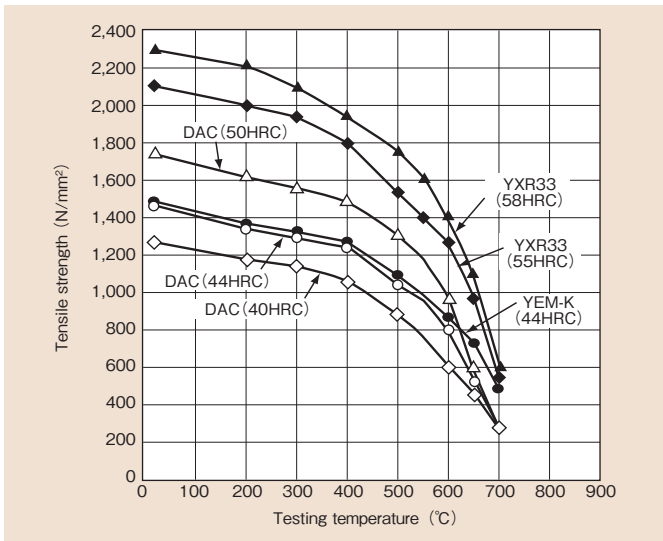
Properties	Influencing factors	Extent of impact on die damage		
		Sliding wear	Softening to abrasion	Minor crack → Catastrophic crack
Area ratio of carbides	Sliding property of die surface (Friction property)	○		
A ₁ point	Anti-rehardenability	○	△	
Strength at elevated temperature	Deformation resistance	○	○	
Toughness	Catastrophic crack resistance			○



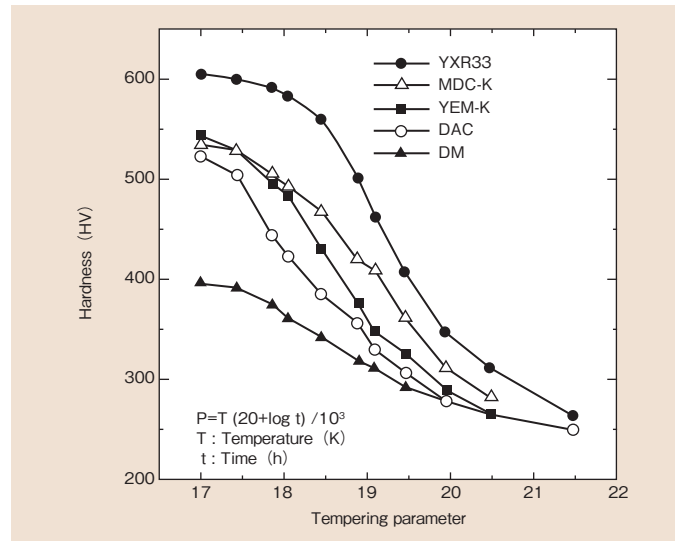
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Properties of YSS hot work steels

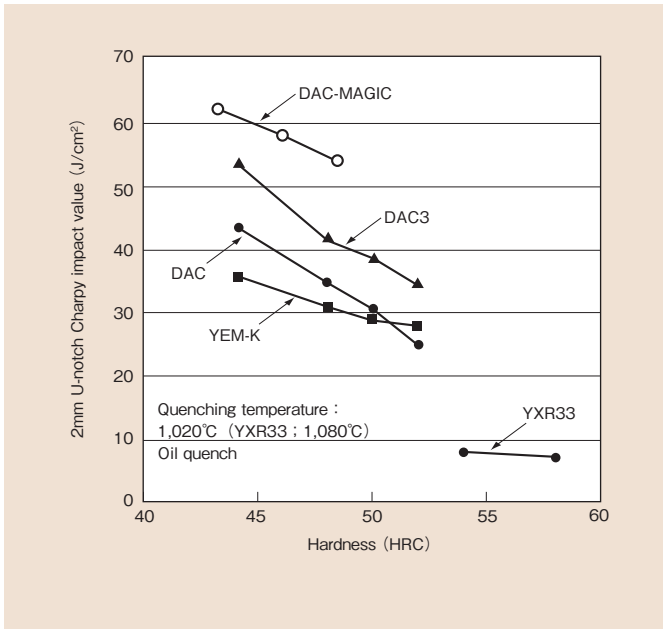
Tensile strength at elevated temperature



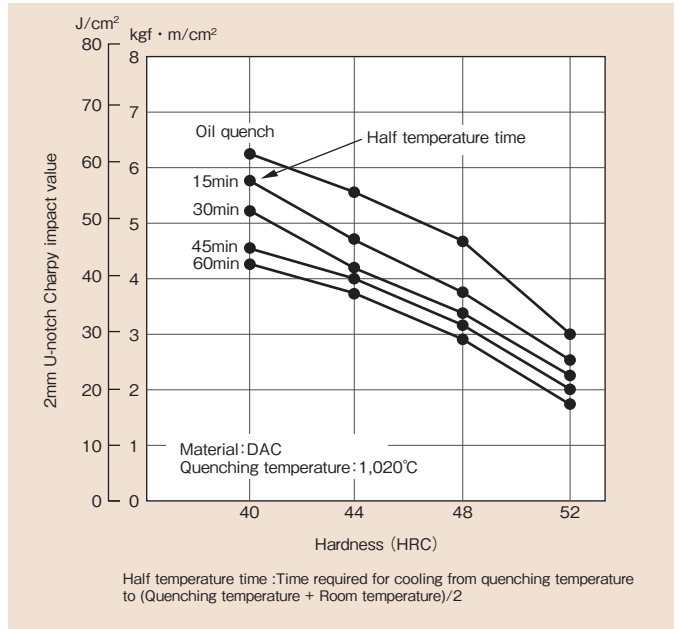
Tempering parameter



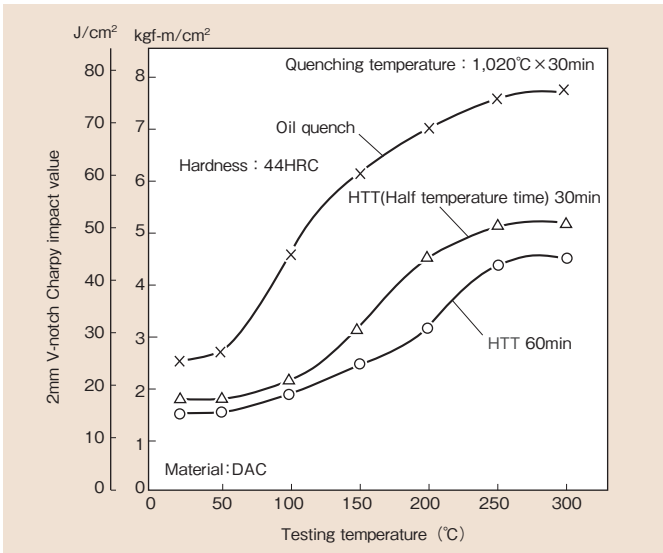
Charpy impact value at room temperature



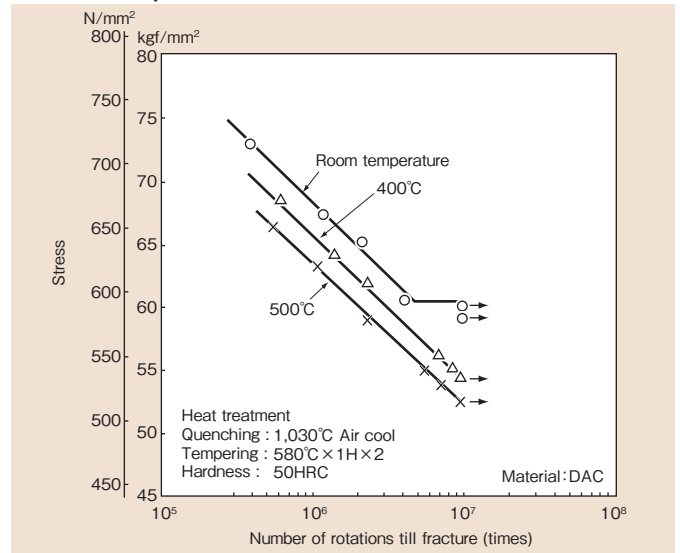
Quenching speed vs charpy I-value



Transition property of charpy impact value



Fatigue strength (Rotating bending fatigue test by Ono method)



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Standard heat treatment conditions for YSS hot work tool steels

Grade	Annealed Hardness HBW	Heat treatment condition (°C)		Quenching and tempering hardness	Annealing condition (°C)
		Quenching	Tempering	HRC	
DAC	229 MAX	1,000 - 1,050 Air cool (Oil quench)	550 - 650 Air cool	50 MIN	820 - 870 Slow cooling
DAC-MAGIC	229 MAX	1,010 - 1,030 Air cool (Oil quench)	550 - 640 Air cool	50 MIN	820 - 870 Slow cooling
DAC10	229 MAX	1,010 - 1,030 Oil quench (Air cool)	550 - 650 Air cool	50 MIN	820 - 870 Slow cooling
DAC55	241 MAX	1,010 - 1,030 Oil quench (Air cool)	550 - 650 Air cool	50 MIN	820 - 870 Slow cooling
DAC3	229 MAX	1,000 - 1,050 Air cool (Oil quench)	550 - 650 Air cool	50 MIN	820 - 870 Slow cooling
DAC40	229 MAX	1,000 - 1,050 Oil quench	550 - 650 Air cool	50 MIN	820 - 870 Slow cooling
YEM-K	229 MAX	1,000 - 1,050 Oil quench (Air cool)	550 - 650 Air cool	46 MIN	820 - 870 Slow cooling
MDC-K	241 MAX	1,050 - 1,140 Oil quench	600 - 700 Air cool	48 MIN	820 - 870 Slow cooling
FDAC	Prehardened steel (Delivery in hardened condition)			38 - 42	—
DM	248 MAX	830 - 880 Oil quench	400 - 650 Air cool	42 MIN	740 - 800 Slow cooling
YXR33	241 MAX	1,080 - 1,140 Oil quench	550 - 600 Air cool	54 MIN	800 - 880 Slow cooling

Quenching and tempering time of YSS die steels

1. Holding time at quenching

(1) Preheating time

First stage: 500-550°C×quenching holding time×2

Second stage: 750-800°C×same length of quenching holding time

(2) Holding time at quenching

Furnace	Thickness (mm)	≤15	25	50	75	100	125	150	200	300
Vacuum furnace, Salt bath	Holding time (min)	15	25	40	50	60	65	70	80	100

Notice : If you take preheating time, dipping time can be regarded as holding time.

2. Holding time at tempering

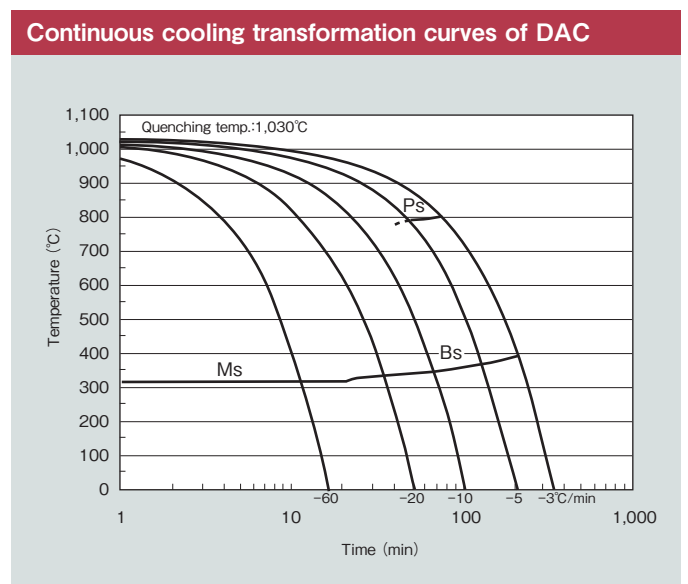
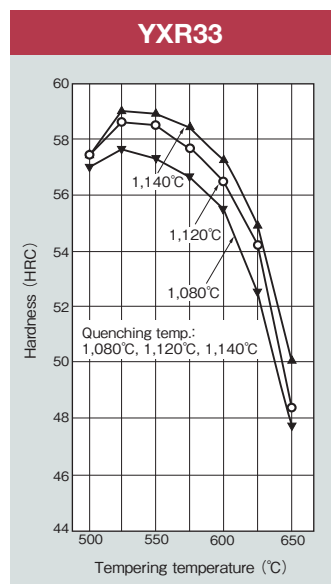
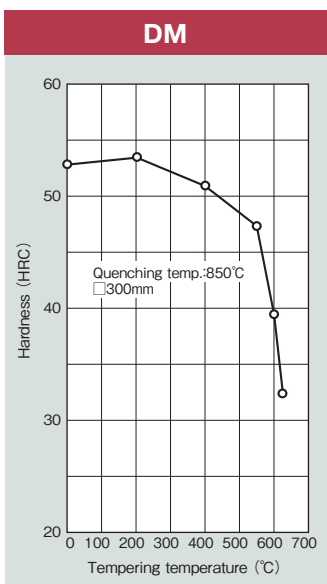
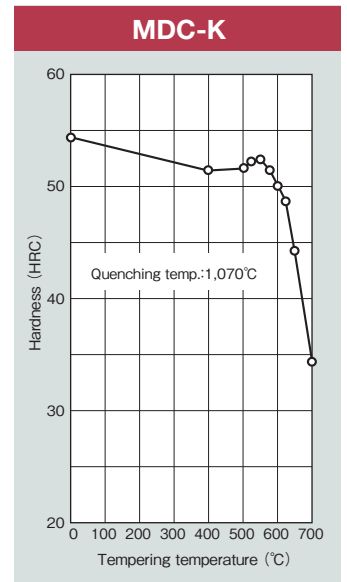
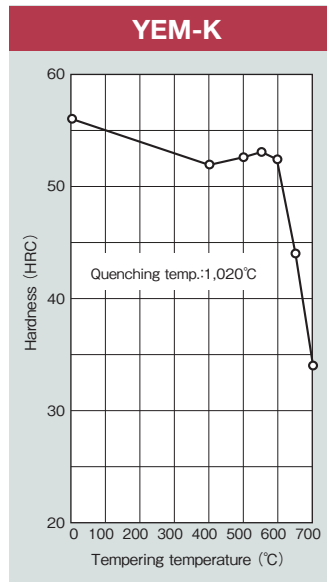
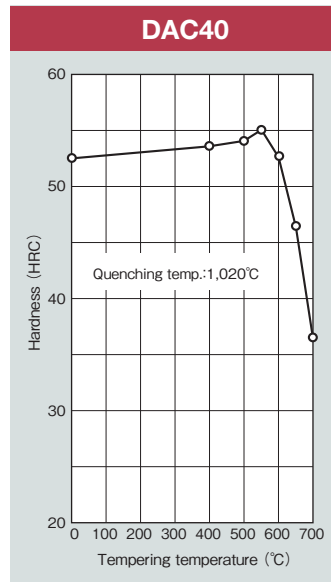
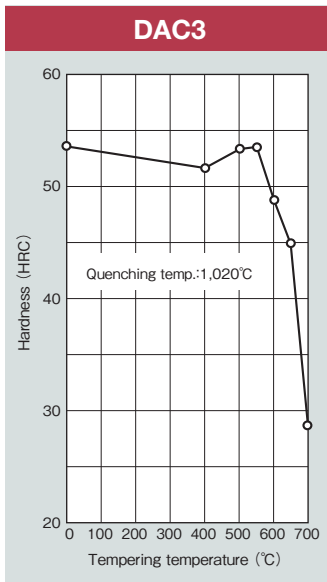
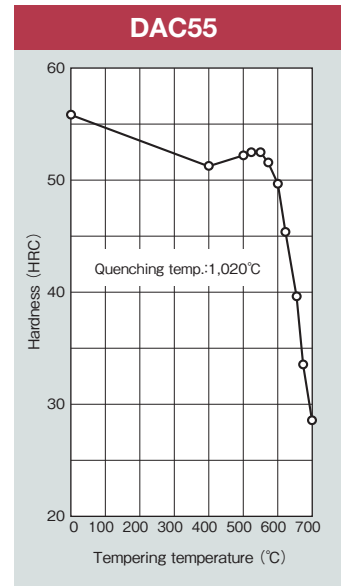
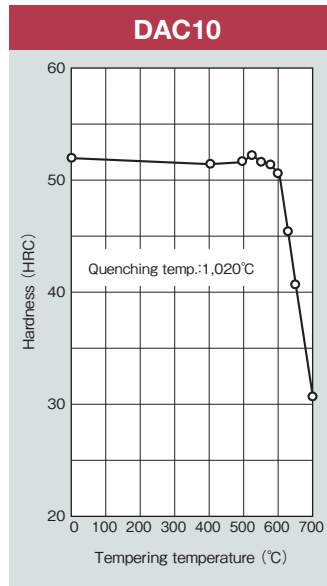
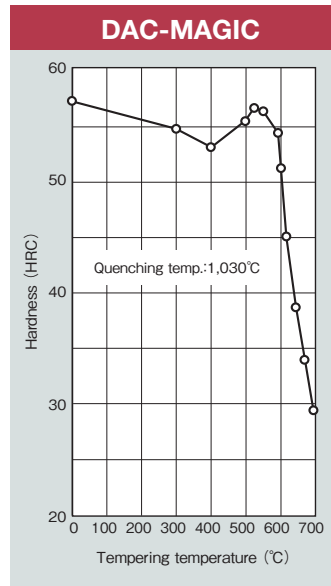
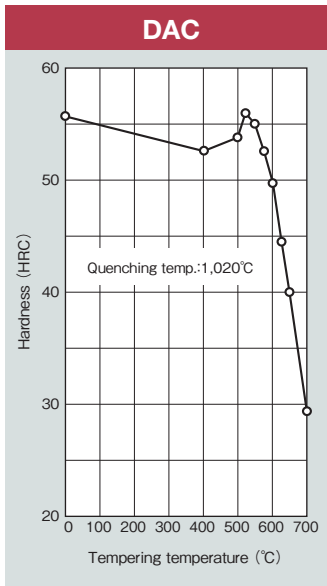
Thickness (mm)	≤25	26 - 35	36 - 64	65 - 84	85 - 124	125 - 174	175 - 249	250 - 349	350 - 499
Holding time (h)	1	1.5	2	3	4	5	6	7	8

Notice : Tempering is needed more than 2 times.



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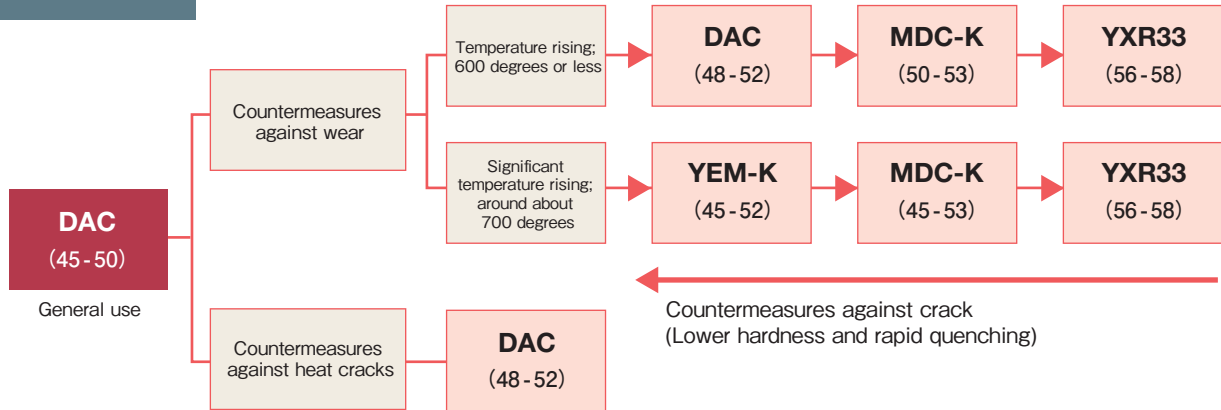
Quenched and tempered hardness curve



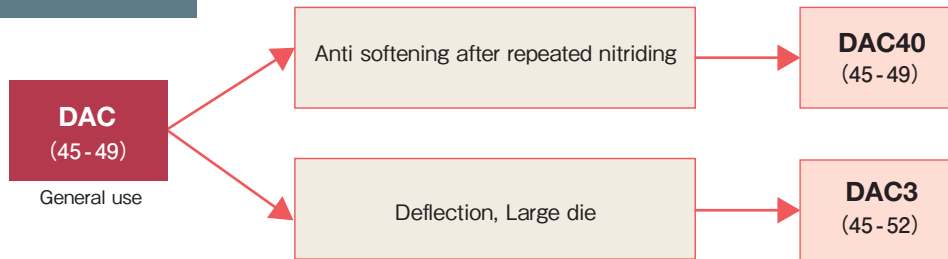
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Guide for selecting YSS die materials (Example)

Hot forging dies



Extrusion dies



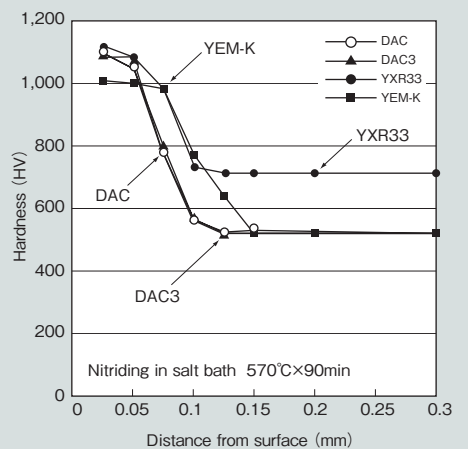
Remark 1 : HRC hardness
 Remark 2 : By surface treatment such as nitriding, the wear resistance is improvable.

Comparison of various nitrided layers

	TYPE A	TYPE B	TYPE C	TYPE D
Nitriding depth and form (In the case of nitrided SKD61)	ϵ phase (Compound layer) 0.1mm >1000HV	Grain boundaries in the nitride layer 0.2mm >1000HV	Sulfide, oxide layer 0.2mm >1000HV	No compound layer 0.05~0.1mm 600~800HV
Heat crack resistance	2	3	3	1
Flaking resistance	2	3	3	1
Wear resistance	2	2	1	3
Erosion resistance	2	2	1	3

Excellent "1" → Good "2" → Ordinary "3"

Nitriding property

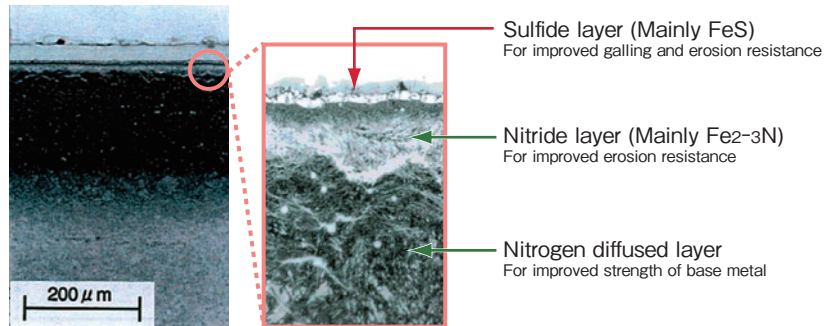


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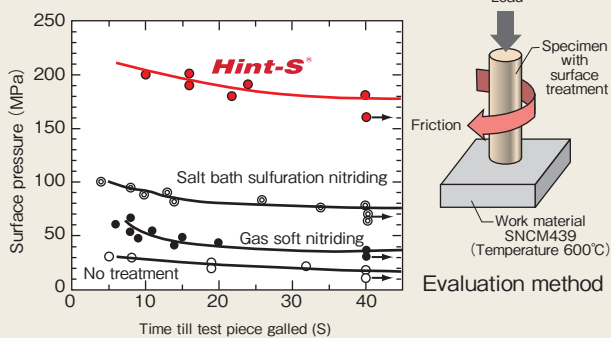
Sulfuration nitriding for hot work die *Hint-S*[®]

Hint-S[®]: Hitachi Improved Nitriding Treatment S-type

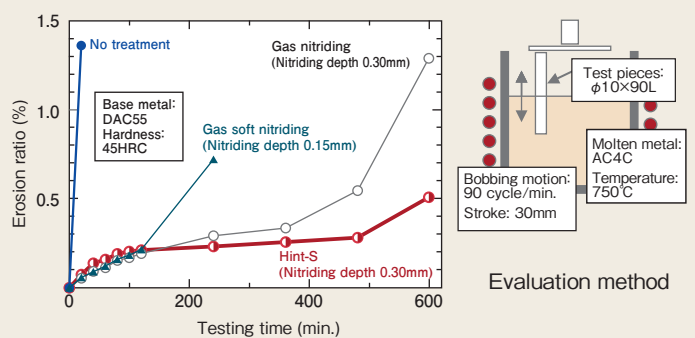
The Hint-S is a surface treatment technique developed by Hitachi Metals which improves significantly wear and erosion resistance of a die by forming both sulfides and nitrides on its surface.



Simulation test of hot galling resistance (On forging die)



Simulation test of erosion resistance (On casting die)



Data sheet

1. Coefficient of thermal expansion

Average value from 20°C to each temperature. (×10⁻⁶/°C)

Grade	HRC	200°C	400°C	600°C
DAC	45	11.3	12.2	12.8
DAC-MAGIC	45	11.3	12.3	13.1
DAC10	45	11.2	12.0	12.7
DAC55	45	11.3	12.1	12.8
DAC3	45	11.4	12.3	12.9
DM	42	12.2	13.1	13.4
YXR33	57	11.3	12.2	12.9

2. Thermal conductivity

(W/(m·K))

Grade	HRC	20°C	200°C	400°C	600°C
DAC	45	24.6	29.1	31.0	32.6
DAC-MAGIC	45	25.7	30.9	34.8	35.8
DAC10	45	26.1	31.1	33.0	34.5
DAC55	45	26.2	29.8	32.7	34.1
DAC3	45	25.2	30.2	31.8	33.7
DM	42	36.0	39.3	37.7	36.0
YXR33	57	25.0	32.4	34.8	35.5

3. Modulus of elasticity

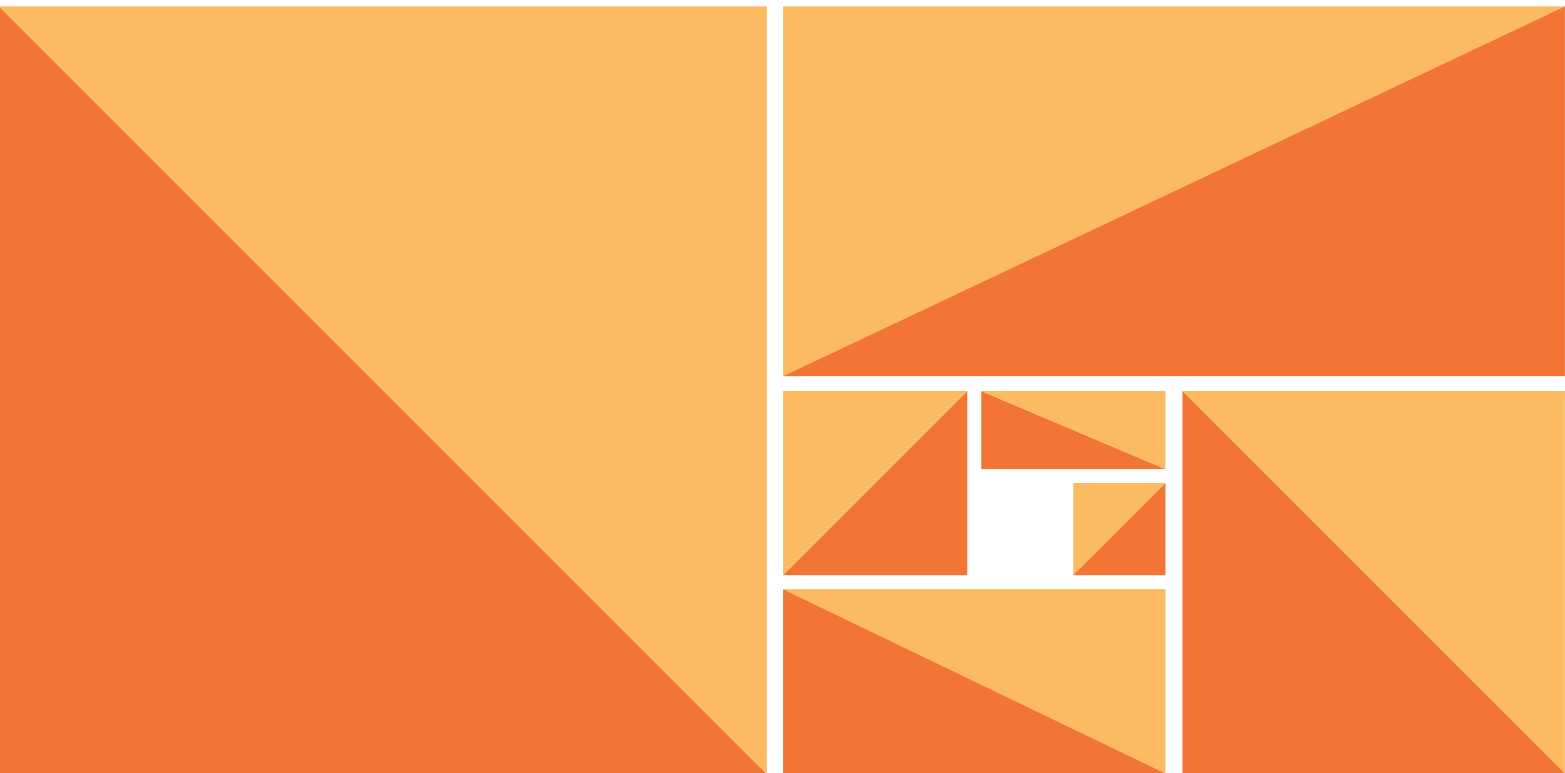
(GPa)

Grade	HRC	20°C	200°C	400°C	600°C
DAC	45	210	200	190	170
DAC-MAGIC	45	210	200	190	—
DAC10	45	210	200	190	170
DAC55	45	210	200	190	—
DAC3	45	210	200	190	150
DM	42	210	200	190	140
YXR33	57	210	200	190	170



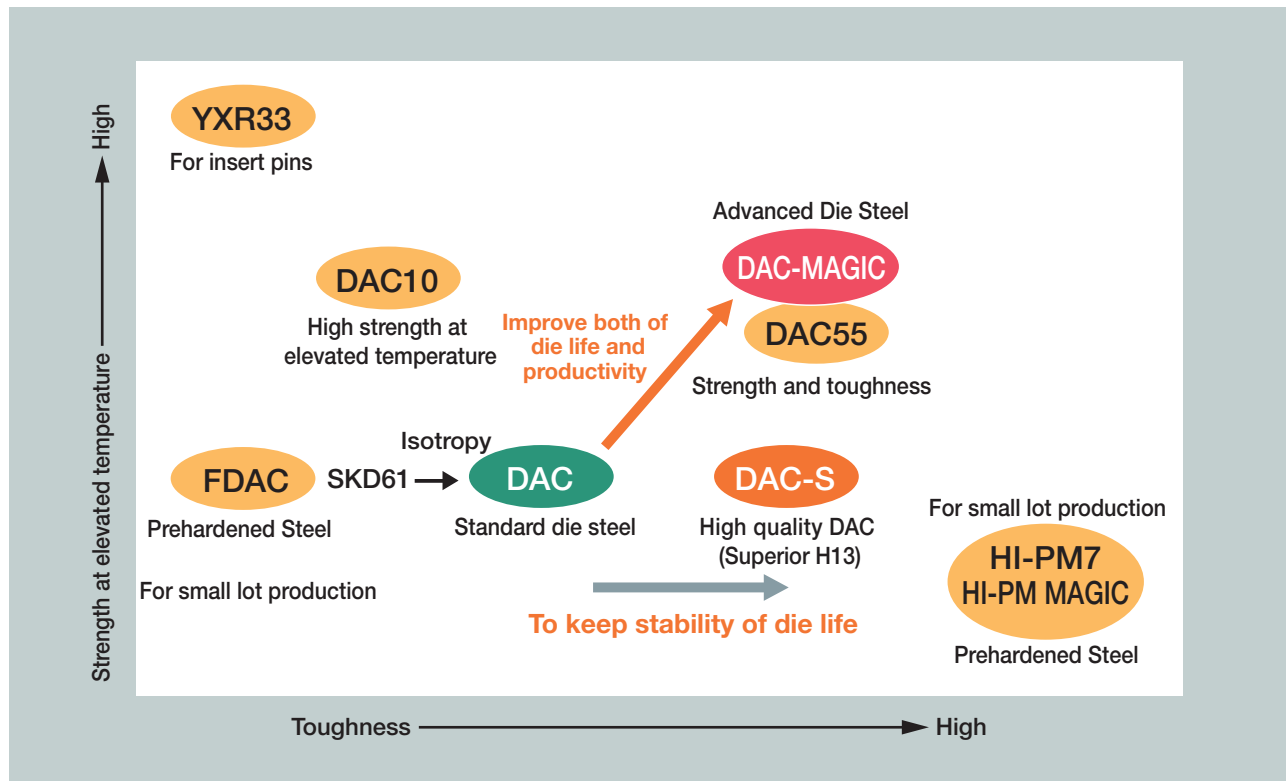
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YSS Die Steels For Die Casting **DAC Series**



Characteristics of Diecasting Die Steels

In compliance with diversification of diecasting technology, variety of steel grades is prepared in order to best fit for each individual application.



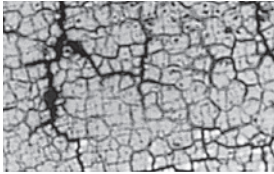
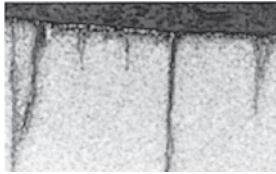

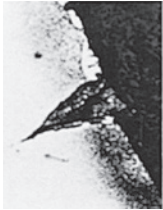
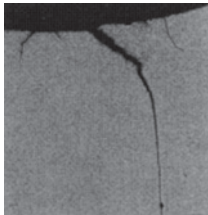
Applications of YSS Die-casting Die Steels and Their Features

Applications	YSS Grade	Features
Die for Aluminium/Zinc Alloy in general use	DAC, DAC-S equivalent to JIS SKD61 0.4C-5.2Cr-1.3Mo-V	Strength at elevated temperature and toughness are well balanced. Good machinability and less deformation after heat treatment
Advanced Die Steel for Die Casting	DAC-MAGIC Original steel	High performance die steel which balanced high strength at elevated temperature and high toughness. Excellent heat crack resistance, stress corrosion cracking resistance and better machinability
High performance die, Squeeze die	DAC55 5.2Cr-2.2Mo-V-Ni	Good heat crack resistance Higher toughness enables initial hardness of dies much higher.
For Precision Die Casting	DAC10 5.2Cr-2.7Mo-V	Higher strength at elevated temperature and excellent heat crack resistance
Longer pin life, insert die parts	YXR33 Matrix HSS 4.2Cr-1.6W-2.0Mo-1.2V	Highest strength at elevated temperature Excellent erosion resistance
Die for small lot production, low cost die	FDAC 5.2Cr-1.3Mo-V-S	40HRC prehardened steel Free cutting steel
	HI-PM7 HI-PM MAGIC P20 modified	Prehardened to 32HRC(HI-PM7), 40HRC(HI-PM MAGIC). Good machinability and toughness. Least difference of hardness between surface and center of large die.



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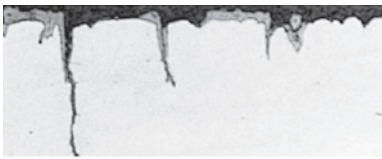


Heat Crack Appearance

Heat crack	Appearance	Cross Section
Diecast in general use On the surface of dies Network Temperature of molten material 680°C		
Precision/Hi-Si Al-alloy Diecast On the edge of dies Crack opening Temperature of molten material 760°C		
Diecast in SQ use At the corner of dies Stress concentration Temperature of molten material 720°C		

Results of Heat Crack Generation Test

* Number of cycles of heat crack generation and cross section

Specimen: φ 90 mm Test procedure: repeated induction heating and cooling by spray water on end face

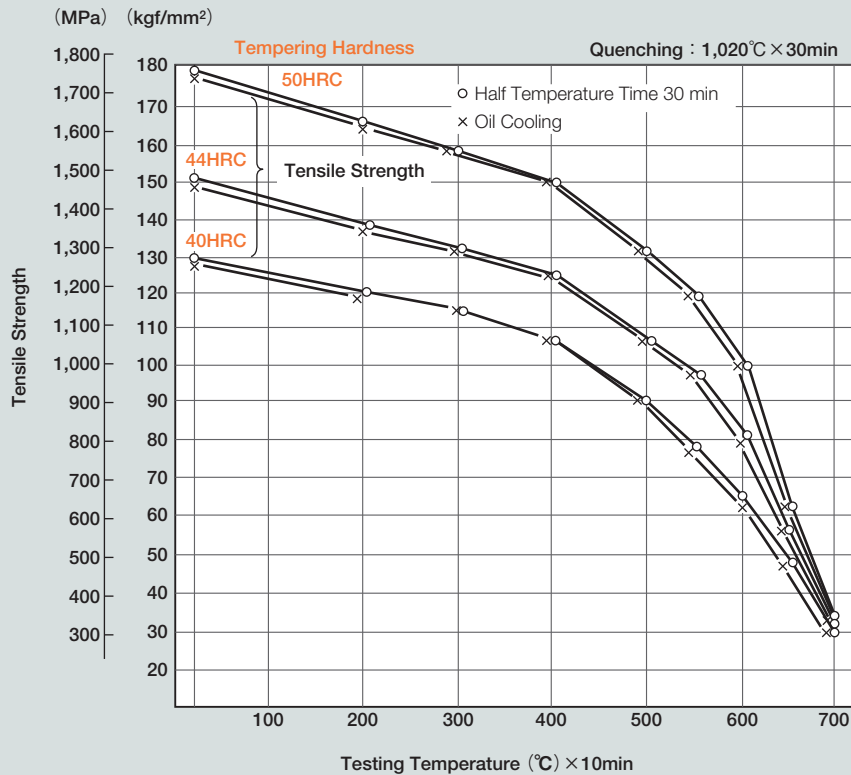
YSS Grade	HRC	No. of test cycle			Cross section after test cycles
		1000	2000	3000	
DAC	43	Heat crack generation			
DAC	47	Heat crack generation	Observation of heat crack		
DAC	51	Heat crack generation			
DAC55	50	Heat crack generation			
DAC55	53	Heat crack generation			



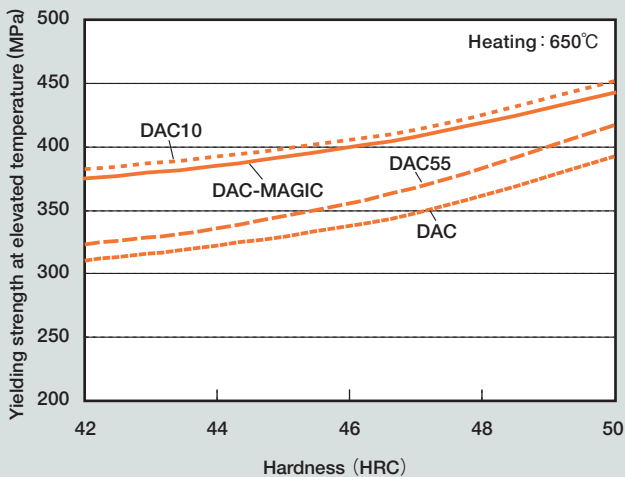
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Mechanical Properties

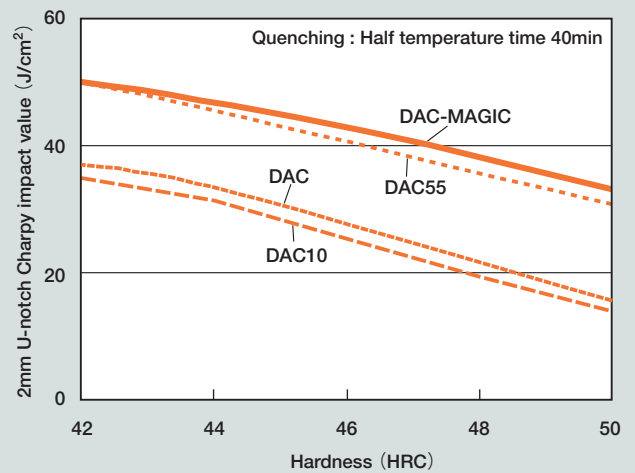
Tensile Strength at elevated temperature



Tempered hardness vs Yielding Strength at elevated temperature



Tempered hardness vs Charpy I - Value



Physical Properties

YSS Grade	Thermal expansion coefficient ($\times 10^{-6}/^{\circ}\text{C}$) Average value from 20°C to each temperature			Thermal conductivity (W/m·K)				Young's modulus (GPa)
	200°C	400°C	600°C	20°C	200°C	400°C	600°C	
DAC	11.3	12.2	12.8	24.6	29.1	31.0	32.6	210
DAC-MAGIC	11.3	12.3	13.1	25.7	30.9	34.8	35.8	210
DAC55	11.3	12.1	12.8	26.2	29.8	32.7	34.1	210
DAC10	11.2	12.0	12.7	26.1	31.1	33.0	34.5	210
YXR33	11.3	12.2	12.9	25.0	32.4	34.8	35.5	210



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Standard Quality for Aluminium Diecasting

DAC (JIS SKD61)

DAC is most widely used as Die for Aluminium and Zinc Diecasting. DAC is hot working tool steel with good balance of strength, toughness and heat resistance.

With introduction of Isotropy technology DAC has become tougher and more isotropic to help life of dies longer and stable.

Features

- *Good balance of both strength at elevated temperature and toughness
- *Good machinability with less distortion after heat treatment

Applications

- *General die for Aluminium Diecasting
- *Die for Zinc Diecasting
- *Die for low pressure casting

(Remarks)
Both forged and cast steel available for low pressure casting die in prehardened condition of 30-40HRC.

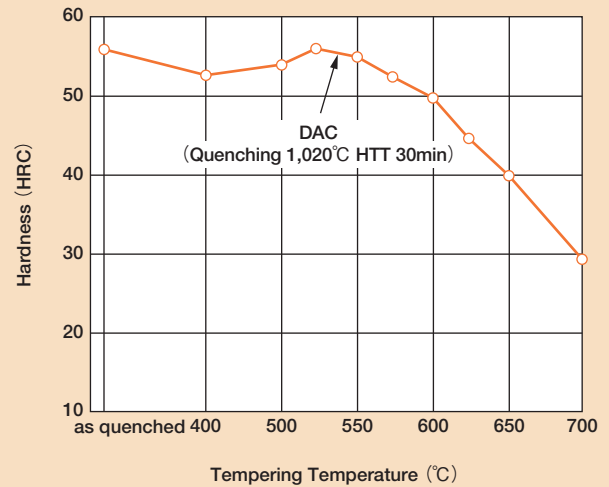
Hardend hardness

- *45-48HRC general size dies
- *43-46HRC big size dies

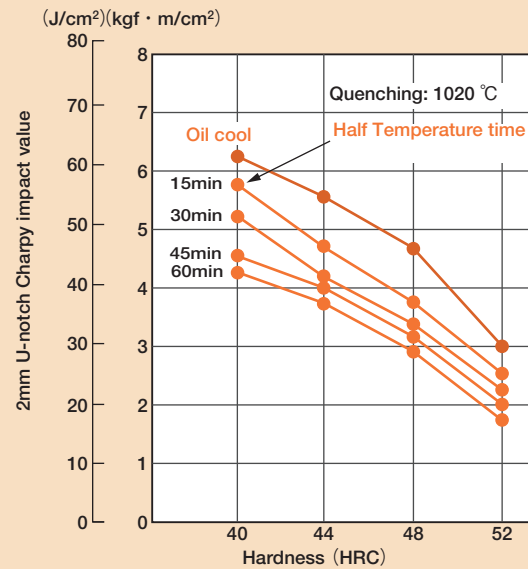
Quench cooling speed and Microstructure (×400)

Oil cool	Half Temperature Time (30min)
Half Temperature Time (60min)	Quenching Temperature 1020°C Hardness 44HRC

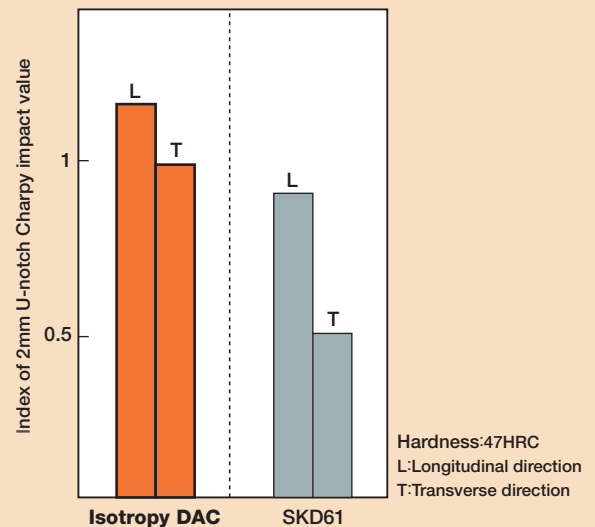
Quenched and tempered hardness



Tempered hardness vs Charpy I-Value



Toughness of Isoropy DAC



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Advanced Die Steel for Die Casting

DAC-MAGIC

The range of applications of diecast products for weight saving and recycling is expanding while awareness of environmental protection is increasing. This fact requires bigger diecast products to be produced with higher quality in short cycle. In order to meet such needs, DAC-MAGIC is one of the best materials for diecasting which has not only good heat crack resistance but also good toughness and machinability.

Features

- *High strength at elevated temperature and excellent heat crack resistance
- *High toughness prevents gross crack of die
- *Improved stress corrosion cracking resistance reduces crack problem from cooling channel
- *Better machinability than conventional SKD61 improved steel (high toughness type) possible to reduce manufacturing time and total cost

Applications

- *Die casting in general use
- *Squeeze die casting
- *Precision die casting

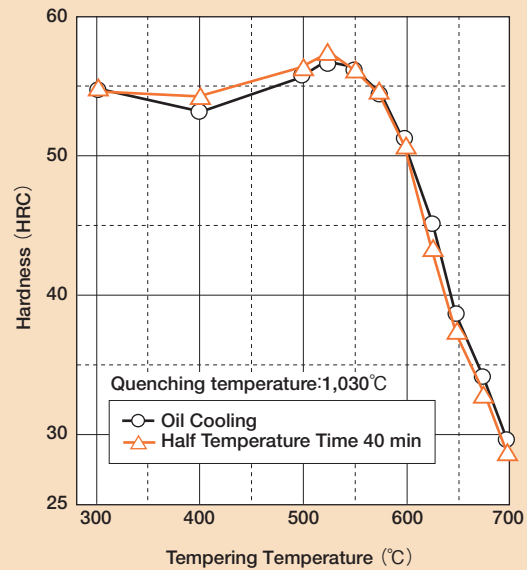
Standard Heat Treatment

- *Quench: 1010-1030°C rapid cooling
- *Temper: 550°C-640°C

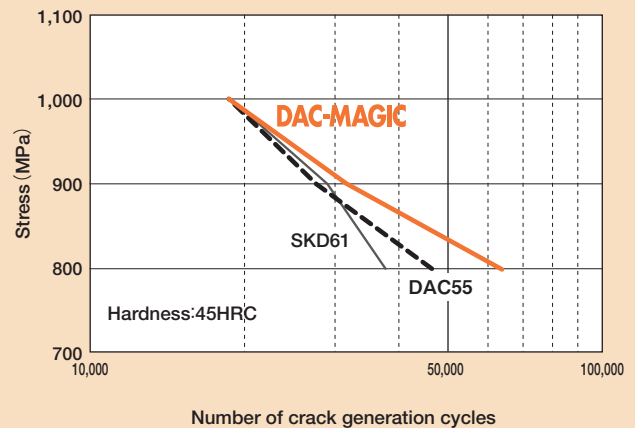
Recommended hardness

- *45-52HRC small/medium size dies
- *42-46HRC large size dies

Quenched and tempered hardness of DAC-MAGIC



Resistance to stress corrosion cracking



Heat crack resistance

YSS Grade	HRC	Number of heat crack generation cycle		
		1000	2000	3000 (cycle)
DAC-MAGIC	45	~1000	~2000	~3000
DAC55	45	~1000	~1500	~2000
SKD61	45	~1000	~1000	~1500

Specimen: ϕ 80 mm
 Test procedure: repeated induction heating and cooling by spray water on end face



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For High Performance Diecasting

DAC55

DAC55 has been developed in responding to the needs for a longer die life or a steel with good hardenability as well as heat crack resistance and toughness for large and medium size dies.

Features

- *Good heat crack resistance
- *Higher service hardness of 50-53HRC
- *Higher resistant to crack propagation
- *Higher strength at elevated temperature
- *Good hardenability

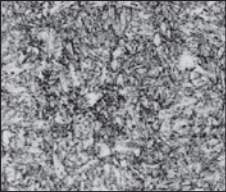
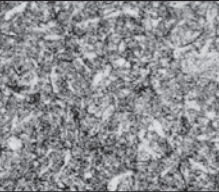
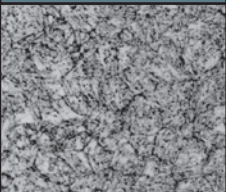
Applications

- *Precision die casting
- *Large and medium size dies for die casting
- *Squeeze die casting

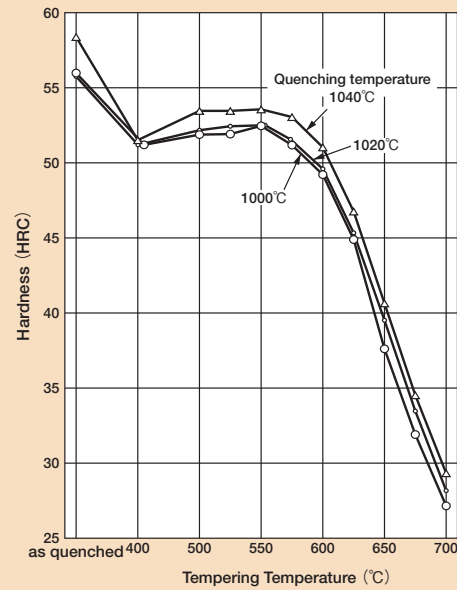
Standard Heat Treatment

- *Quench 1010-1030°C rapid cooling
- *Temper 550°C -640°C
- *Hardness 43-53HRC

Quench cooling speed and Microstructure (×400)

Oil cool	Half Temperature Time (15min)
	
Half Temperature Time (30min)	Quenching Temperature 1020°C Hardness 44HRC
	

Quenched and tempered hardness

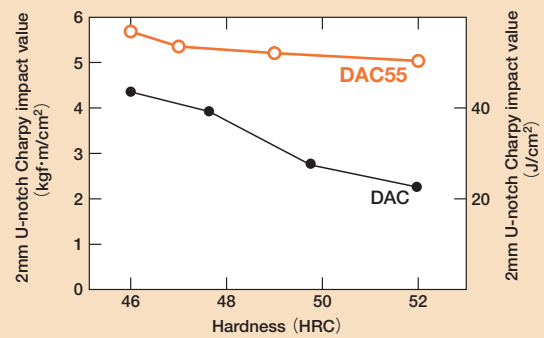


Recommended hardness

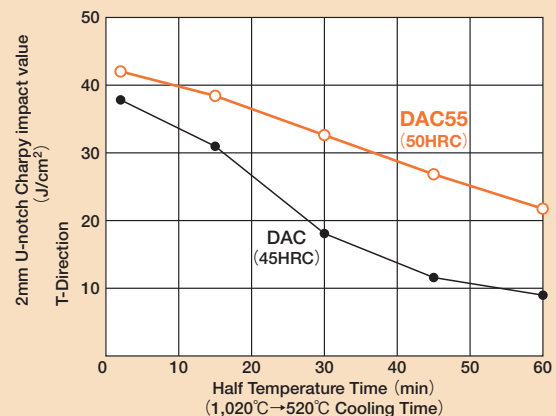
Hardness (HRC)	Application
50-53	Small Die, Squeeze Die (Anti-Heat Crack)
46-50	General Use Die
43-46	Large Die (Priority:Toughness)

(Remarks) Recommended hardness may not apply depending on projection or casting conditions

Tempered hardness vs Charpy I-Value



Quench Cooling Speed vs Charpy I-Value (Test Result of 250mm Qubic Block)



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DAC10

As material of die for diecast products which requires higher level of surface, heat crack resistance has been intensified.
 Most useful for small and medium size dies of their longer life.

Features

- *Higher strength at elevated temperature and excellent heat crack resistance
- *Good erosion resistance

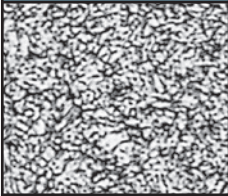
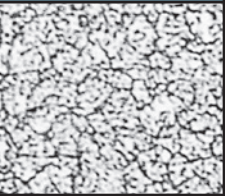
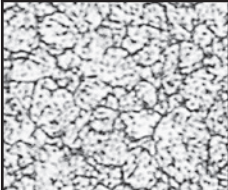
Applications

- *Small / Medium size dies of which O-ring grooves require heat crack resistance
- *Medium dies for products like headcover which requires good appearance
- *Small dies for OA components which require erosion resistance

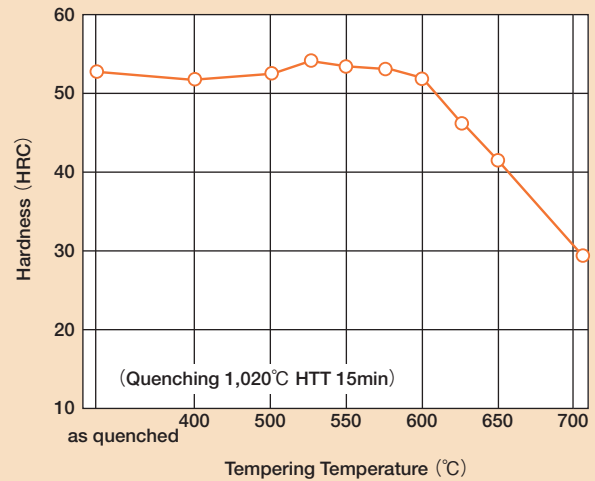
Standard Heat Treatment

- *Quench 1,010-1,030°C rapid cooling
- *Temper 570°C-610°C
- *Hardness 44-51HRC

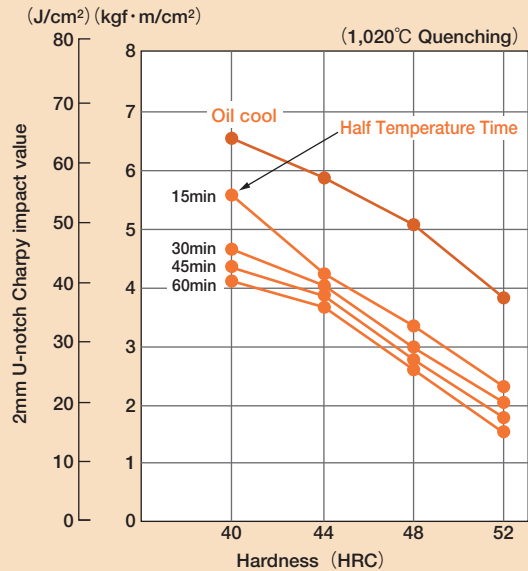
Quench cooling speed and Microstructure (×400)

Oil cool	Half Temperature Time (15min)
	
Half Temperature Time (30min)	Quenching Temperature 1020°C Hardness 44HRC
	

Quenched and tempered hardness

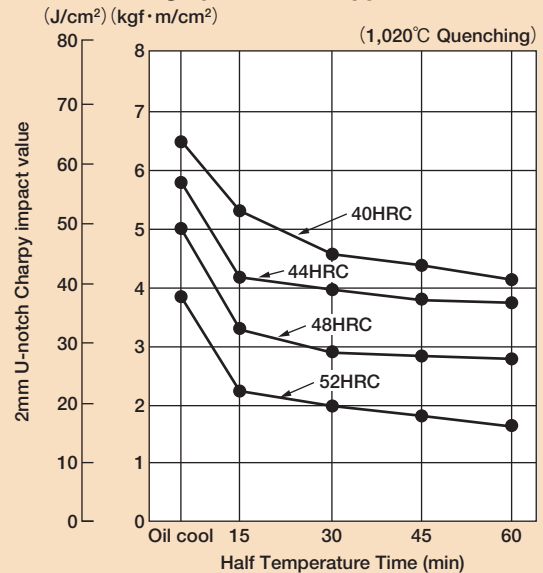


Tempered hardness vs Charpy I-Value



*Oil Cool Test Piece Size:10×10×55mm

Quench Cooling Speed vs Charpy I-Value



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High Quality DAC (Superior H13)

DAC-S

DAC-S has higher toughness than general-purpose diecasting die steel DAC, which has excellent resistance to gross crack generation of die.

Features

- *Higher toughness than general-purpose diecasting die steel DAC
- *DAC-S meets a minimum Charpy impact value specification of the NADCA 207 - 2003 Superior.
- *DAC contributes to the stability of die life

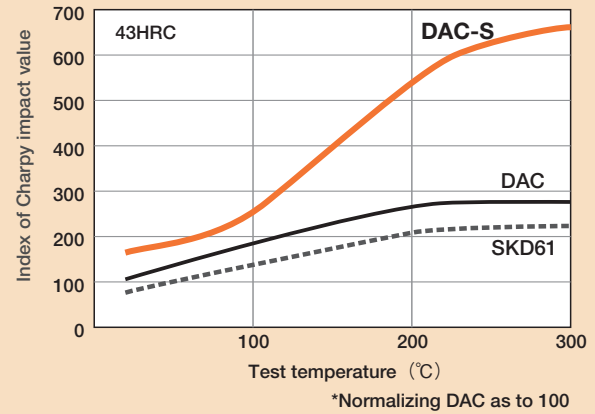
Applications

- *Large and medium dies for die casting

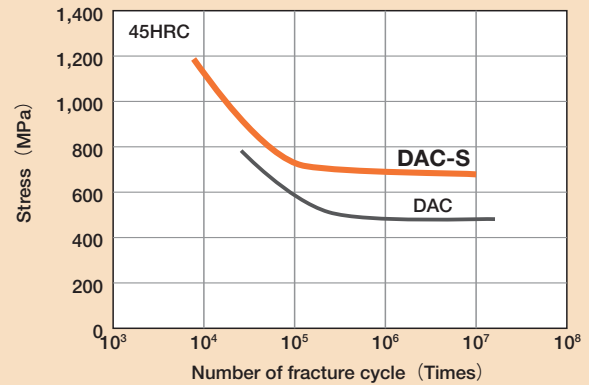
Standard Heat Treatment

- *Quench 1,000°C - 1,050°C rapid cooling
- *Temper 550°C - 680°C
- *Hardness 45- 48HRC (general size dies), 43-46HRC (large size dies)

Index of Charpy impact value



Fatigue strength of DAC-S



YXR33

YXR33 is a HSS with higher toughness which solved breakage problem often existed in SKH51. Fitted for insert pin or other inserts exposed to critical wear due to erosion.

Features

- *Highest strength at elevated temperature among HSS and Alloy Tool Steel.
- *Toughness is more than 5 times as big as SKH51
- *Excellent nitridability

Applications

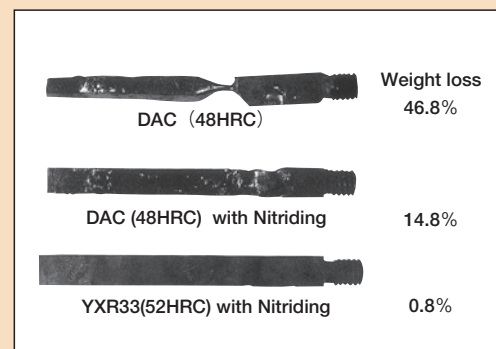
- *Erosion resistant insert pin
- *Insert die parts

Standard Heat Treatment

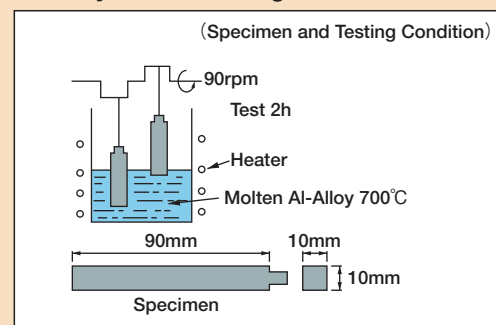
- Quench 1080°C - 1140°C oil cool
- Temper 550°C - 600°C
- Hardness 52 - 58HRC

For High Performance Insert Pin

Specimen after Erosion test by molten casting metal



Erosion test by molten casting metal



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FDAC, HI-PM7, HI-PM MAGIC

For small lot production

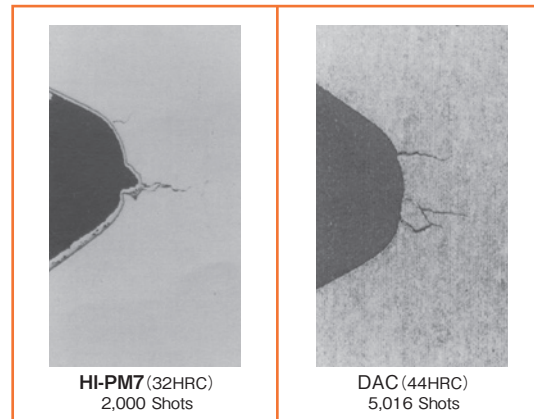
These materials whose strength and toughness are less than those of general die-casting die steels (ex. DAC) can be used for dies for small lot production or holding blocks.

FDAC is based on chemical composition of DAC with the addition of some Sulfur for machinability. As delivered pre-hardened to 38-42HRC, direct cavity making is possible.

HI-PM7 is prehardened to 29-33HRC and has good machinability.

HI-PM MAGIC is prehardened to 37-41HRC and has good machinability and toughness.

Heat Crack Test (0.5R ditch)



Features

- *Good machinability
- *As delivered prehardened, farther heat treatment is necessary
- Possible to reduce manufacturing time and total cost

Applications

Die for small lot production, low cost die, holding block
 FDAC: priority heat resistance
 HI-PM7 and HI-PM MAGIC: high toughness and good machinability

Mechanical Properties (Reference)

YSS Grade	Hardness (HRC)	0.2% Yielding Strength (MPa)	Tensile Strength (MPa)	Elongation (%)	Reduction of Area (%)
DAC	40	1,070	1,250	12	58
FDAC	40	1,060	1,240	11	20
HI-PM7	32	860	980	20	55
HI-PM MAGIC	40	1,020	1,200	18	45

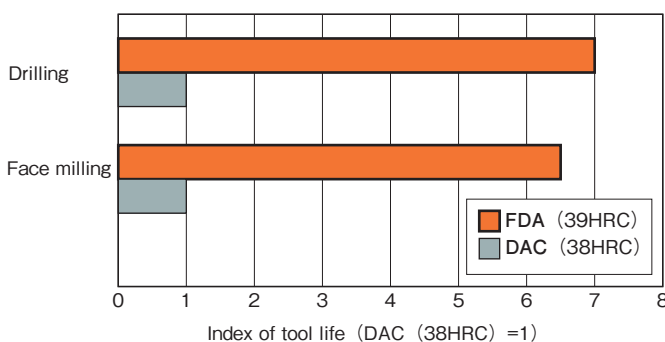
2mm U-notch Charpy I-Value (Reference)

YSS Grade	Hardness (HRC)	Longitudinal direction (J/cm ²)	Transverse direction (J/cm ²)
DAC	40	58	39
FDAC	40	19	10
HI-PM7	32	65	40
HI-PM MAGIC	40	60	35

Size of Raw Material : 280×640

Position of Specimen : w/2×t/4

Machinability of FDAC



Cutting condition

Face milling		Drilling	
Cutter	φ63	Tool	HSS Co φ4
Insert	Coated cemented carbide	Cutting speed	20m/min
Number of inserts	1	Feed	0.1mm/rev
Cutting speed	130m/min	Depth	40mm Blind
Feed	0.15mm/Tooth	Coolant	Water-Soluble
Depth	0.5mm	Life	Number of cutting hole
Coolant	Dry		
Life	VB=0.3mm		



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Actual Performance

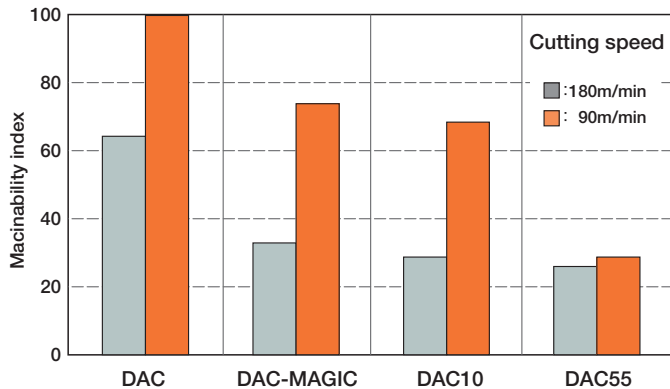
Diecast Products YSS Grade	Die Clamping Force (die size mm)	Comparison of Actual Performance		Effect
		Current	Application	
Autoparts surface priority	800 ton 120×210×300	DAC (44HRC) Primary heat crack at 37K shots	DAC (48HRC) Primary heat crack at 50K shots	1.35 times
Autoparts DAC-MAGIC	2,500 ton Insert	DAC (43HRC) heat cracks	DAC-MAGIC (44HRC) Less heat cracks	More than 1.5 times
Autoparts DAC-MAGIC	1,250 ton WJ Insert	Life span of DAC55, DAC10, material A and material B are 20K- 50K shots	DAC-MAGIC (46HRC) Still on service after 100K shots	About 2 times
Autoparts DAC-MAGIC	1,600 ton	Life span of other company material (46-47HRC) is 29K shots	DAC-MAGIC (47-48HRC) Still on service after 62K shots	More than 2.1 times
Autoparts surface priority DAC55	2,000 ton	DAC (47HRC) Heat crack at 60K shots	DAC55 (50HRC) Still on service after 100K shots	More than 1.6 times
Autoparts (thin insert) DAC55	n.a.	DAC Breakage at 20K shots	DAC55 More than 40K shots	2 times
OA Components (precision die) DAC10	250 ton 80×200×300	DAC Primary heat crack at 15K shots, repair at 30K shots, scrap at 80K shots	DAC10 Primary heat crack at 24K shots, no grinding repair, scrap at 120K shots	More than 1.6 times
OA Components (precision die) DAC10	650 ton 90×215×380	DAC Primary bite at 1K shots, scrap at 30K shots	DAC10 No bite at 10K shots	More than 3 times
Autoparts YXR33	Insert Pin	DAC Meltdown and galling at 3K shots	YXR33 Still on service after 10K shot	3 times
High melting point Al-alloy autoparts YXR33	Insert Pin	SKH51 (60HRC) Breakage at 2K shots	YXR33 (54HRC) +TiN Meltdown at 20K shots	10 times



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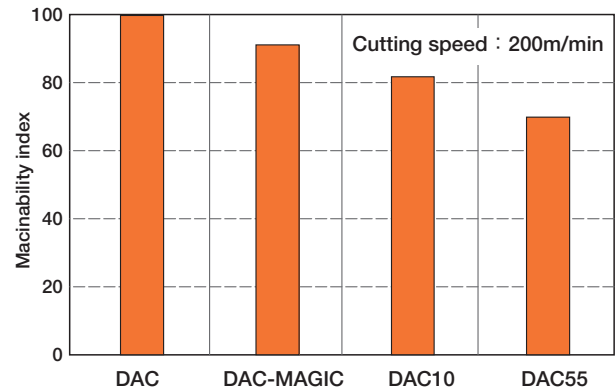
Machinability

Comparison of machinability by High feed radius milling (annealed)



<Cutting conditions>
 φ63 High feed radius mill
 Cutting speed = 90,180m/min
 Feed = 2.0mm/tooth
 Cutting depth = 1.0mm
 Cutting width = 42mm

Comparison of machinability by Ball end milling (45HRC)



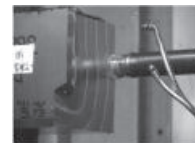
<Cutting conditions>
 φ6-R3
 Coated carbide ball end mill
 Cutting speed = 200m/min
 Feed = 0.1mm/tooth
 Cutting depth = 0.6mm
 Cutting width = 0.6mm

Simulated Die Machining Example

High feed radius milling

Work	State of tool wear	Cutting chips
DAC-MAGIC	 Wear width : 0.13 mm	
DAC55	 Wear width : 0.25 mm	

<Cutting conditions>
 Tool: ASR4050-4 (Hitachi Tool Engineering)
 TB6045 (φ50-4 teeth)
 Protrusion = 200mm
 Cutting speed = 96m/min
 Feed = 1mm/tooth
 Rotation = 610min⁻¹
 Feeding speed = 2440mm/min
 Cut width = 36mm
 Air blow
 Work = Annealed condition



Ball end milling

Work	DAC-MAGIC	DAC55
State of tool wear	 Wear width : 0.03 mm	 Wear width : 0.05mm

<Cutting conditions>
 Tool: EPBT2100 (Hitachi Tool Engineering)
 TH coated (φ10-R5)
 Protrusion = 200mm
 Feed = 0.15mm/tooth
 Rotation: 3500min⁻¹
 Feeding speed = 1050mm/min
 Cut width = 0.5mm
 Air blow
 Work = Heat treated condition (45HRC)



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Repair Welding

Followings show standard repair welding method in build-up welding due to design change or repair welding due to heat crack.

Material involved : DAC, DAC-MAGIC, DAC55, DAC10, FDAC.

State of Die	Welding	Welding Method	Welding Condition	Welding Process Chart	Temp. between weld layers
Annealed State	DAC or same steel	TIG	○Welding bar 1.6 - 4.0φ ○Current 80 - 200A ○Flux of Ar gas 8 - 15ℓ/min	<p>Anneal 2 times in case of Large block.</p>	250°C Above
Hardened State	YAG				250°C Above

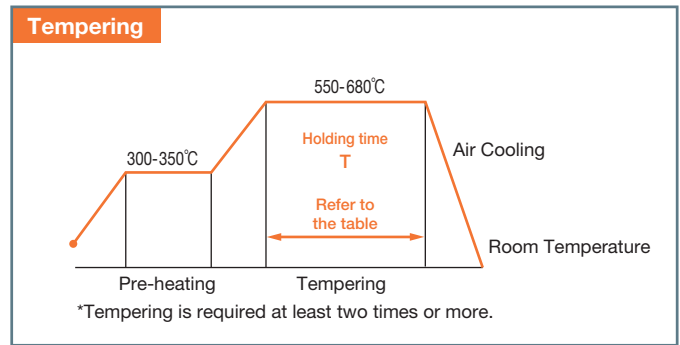
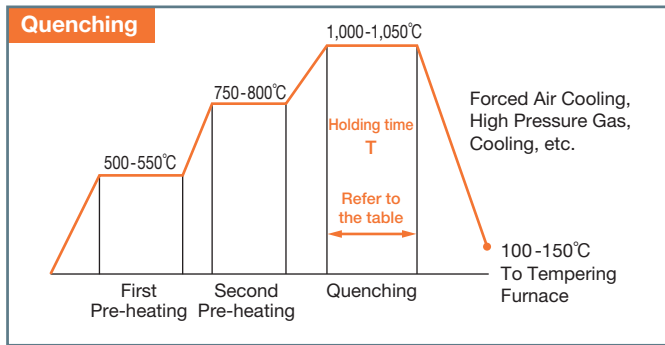
(Remarks)

1. YAG is a brand name of Hitachi Maraging Steel used for various applications including high grade welding rod. Using YAG welding rod remarkably decreases such welding defects as "bead crack" or "pin holes".
2. TIG Welding Method (Tangsten Inert Gas Welding Method) is to make arc between tangsten electrode covered by argon gas and objects to be welded, and then wire is inserted into the heat pool generated by the arc.
3. Use lower current and finer welding wire in order to get better efficiency of welding metal. In order to prevent crater cracks, avoid an overlap of the crater of backward pass on the crater of foregoing pass. To avoid an overheat of mother material, conduct an interrupted welding with short bead.
4. Keeping time of Temper and Anneal after welding should be 1h/25mm in thickness.
5. A careful attention is to be paid of crack during grinding.



Heat Treatment

Standard Heat Treatment Process



Holding time for quenching

Thickness (mm)	≤15	25	50	75	100	125	150	200	300
Holding time (min)	15	25	40	50	60	65	70	80	100

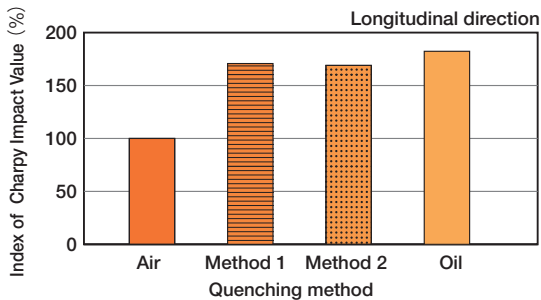
Holding time for tempering

Thickness (mm)	≤25	26-35	36-64	65-84	85-124	125-174	175-249	250-349	350-499
Holding time (h)	1	1.5	2	3	4	5	6	7	8

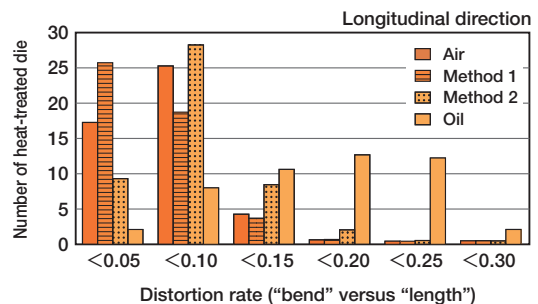
Quenching Method to Reduce Distortion

As the cooling rate of quenching becomes faster, the heat-treated microstructure becomes finer and the toughness is improved. However, the distortion after heat treatment increases. By optimizing the quenching pattern, Hitachi Metals Group has established heat treatment method which not only reduce distortion but also improve toughness.

Examples of measuring impact values of heat-treated products (DAC10/160×400×500)



Examples of distortion of heat-treated products



Nitriding

Properties and characteristics of the nitrided layer vary depending on nitriding methods and conditions. Please choose the type of nitriding according to the right figure.

Comparison of various nitrided layers

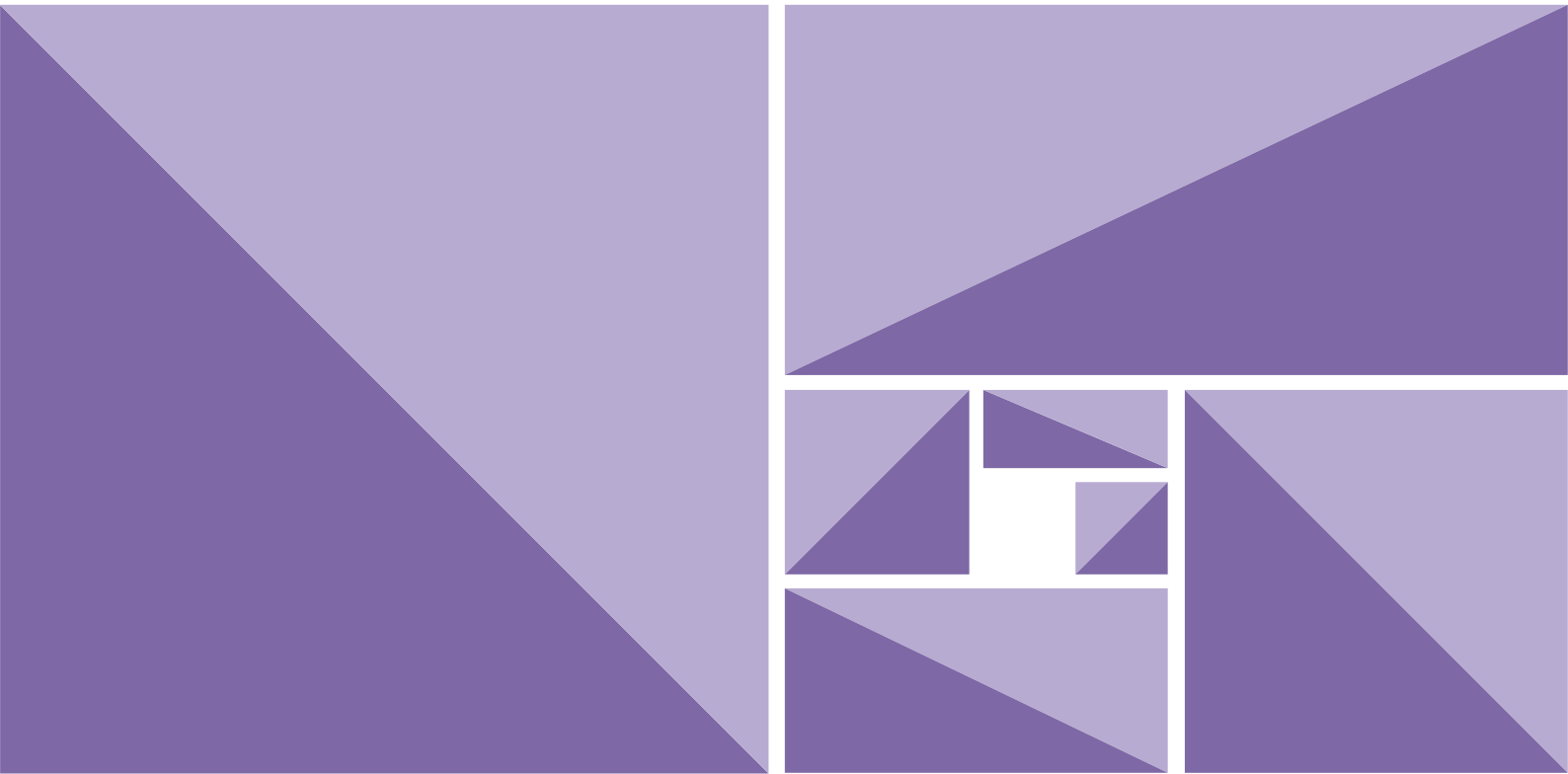
	TYPE A	TYPE B	TYPE C	TYPE D
Nitriding depth and form (In the case of nitrided SKD61)	ε phase (white layer) 0.1mm >1000HV	Grain boundaries in the nitride layer 0.2mm >1000HV	Sulfide, oxide layer 0.2mm >1000HV	No compound layer 0.05 - 0.1mm 600 - 800HV
Heat crack resistance	B	C	C	A
Flaking resistance of the nitrided layer	B	C	C	A
Melting Resistance	B	B	A	C
Type of Nitriding	General nitriding	Deep nitriding	Sulfurizing and nitriding	Shallow nitriding

Excellent "A" → Good "B" → Ordinary "C"



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YSS High Quality Plastic Mold Steels HI-PM Series



Mold Material and Application

Group	Hardness Employed (HRC)	Grade	Material Type	Application Example
Prehardened	29 - 33	HI-PM7	P20 improved	Mold required good weldability and machinability (Autoparts, Home electronics, House equipment)
		HI-PM38	420 improved	Flame retardant resin, Transparent parts, Rubber
		HI-PM77	420 improved and resulphurized	Corrosion resistant mold bases, Rubber mold
	(Round Bar) 38 - 42 (Flat Bar) 33 - 37	PSL	630 improved	Mold for polyvinyl chloride, Frothy resin, Rubber
	37 - 42	CENA1	Cr contained NiAl precipitation grade	Rust resistant mold with sensitive surface as mirror polishing, creping, EDM, Weldless Mold
	37 - 41	HI-PM MAGIC	P20 improved	General Mass-Production Mold (Autoparts, OA equipment, Home Electronics)
		HI-PM PRO	P21 improved	Parts associated with automobile headlamp production, Exterior of cellular phone
		HI-PM1	P21 improved and resulphurized	Mold for general use (Home electronics etc), Plate and holder
	38 - 42	FDAC	H13 improved and resulphurized	Engineering resin, Slide core
For Quench and Temper	50 - 55	HI-PM38	420 improved	Mold for Anti-corrosion / Mirror polish (Medical instruments, Food container, etc)
		HI-PM38S	420 improved	Mold for super mirror polish (Optical disc / Aspheric lens)
	56 - 62	HI-PM31	D2 improved	Wear resistant mold for engineering resin (Gear, Connector, IC)
		HAP5R	P/M HSS	Mold required high toughness and high hardness (Core pin, Thin wall)
	60 - 63	ZCD-M	D2 improved	IC mold
	60 - 65	ZDP4	P/M Cold Die Steel	Reinforced and flame retardant engineering resin, IC mold, Slide parts, Cutter required exceptional wear resistance
For Aging	35 - 45	HI-PM75	High hardness, non-magnetic, resulphurized	Molding in magnetic field (Plastic magnet)
	52 - 57	YAG	Maraging Steel	Mold required exceptional toughness (Core pin, Thin wall), Super mirror polish (Optical lens)



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Resin Types and Grade Selection

Resin		Required Properties for Mold	Required Life and Grade Recommended			
			SHORT <100,000	MEDIUM <500,000	LONG <1,000,000	MASS PRODUCTION >1,000,000
Thermo-plastic	General	Machinability	HI-PM7	HI-PM7 HI-PM MAGIC CENA1 HI-PM PRO	HI-PM MAGIC CENA1 HI-PM PRO FDAC	HI-PM MAGIC FDAC) + Nitriding
	Engineering Resin	Wear Resistivity	HI-PM7	HI-PM7 HI-PM MAGIC FDAC) + Nitriding	HI-PM MAGIC FDAC) + Nitriding	HI-PM38 HI-PM31
	Reinforced	High Wear Resistivity	HI-PM MAGIC HI-PM PRO FDAC, HI-PM1	HI-PM MAGIC FDAC) + Nitriding Plating	HI-PM31	HI-PM31 + Plating ZDP4 HAP5R, HAP40
	Flame Retardant	Corrosion Resistivity	HI-PM38 (Prehardened) CENA1	HI-PM38 PSL	HI-PM38	HI-PM38 + Plating
	Transparent	Mirror Polishability	CENA1	CENA1 HI-PM38	HI-PM38	HI-PM38
Thermo-set	General	Wear Resistivity	HI-PM MAGIC HI-PM PRO FDAC, HI-PM1	HI-PM MAGIC HI-PM PRO) + Plating FDAC	HI-PM31	HI-PM31
	Reinforced	High Wear Resistivity	HI-PM MAGIC FDAC) + Nitriding	HI-PM31	HI-PM31 ZCD-M) + Plating	ZDP4 + Plating

General Resin : PS, PE, PP, AS, ABS etc.
 Engineering Resin : PC, PPE, PA, POM, PBT, PET etc.
 Advanced Engineering Resin : PPS, PI, PES, PEEK etc.

Properties Comparison Table

Material	Machinability	Dimensional change by heat treatment	EDM/Creping texture	Mirror polishability	Weldability	Rust resistance	Wear resistance	Toughness	Cost
HI-PM7	A	-	C	C	A	D	D	B	B
HI-PM77	B	-	D	D	C	B	D	C	C
PSL	D	-	B	C	A	A	D	B	D
CENA1	C	-	A	B	C	C	D	C	D
HI-PM MAGIC	B	-	B	C+	A	D	D	B	C
HI-PM PRO	B	-	A	B	B	D	D	C	D
HI-PM1	A	-	D	D	D	D	D	D	C
FDAC	C	-	D	D	C	D	C	C	C
HI-PM38	C	A	A	A	C	B	C	C	D
HI-PM38S	C	A	A	A+	C	B	C	C	E
HI-PM31	C	B	A	B	D	C	B	C	D
HAP5R	C	C	A	B	D	E	B	B	E
ZCD-M	D	C	A	D	E	C	B	D	D
ZDP4	E	D	B	B	E	C	A	E	E
HI-PM75	E	B	D	D	E	B	C	C	E
YAG	D	B	A	A	A	D	C	A	E
S55C	A	-	C	E	C	E	E	C	A
SCM440	C	-	C	D	D	D	D	C	B

Ratings : A--Best C--Ordinary D, E--Poor
 (Remarks) Please refer above as general concept.

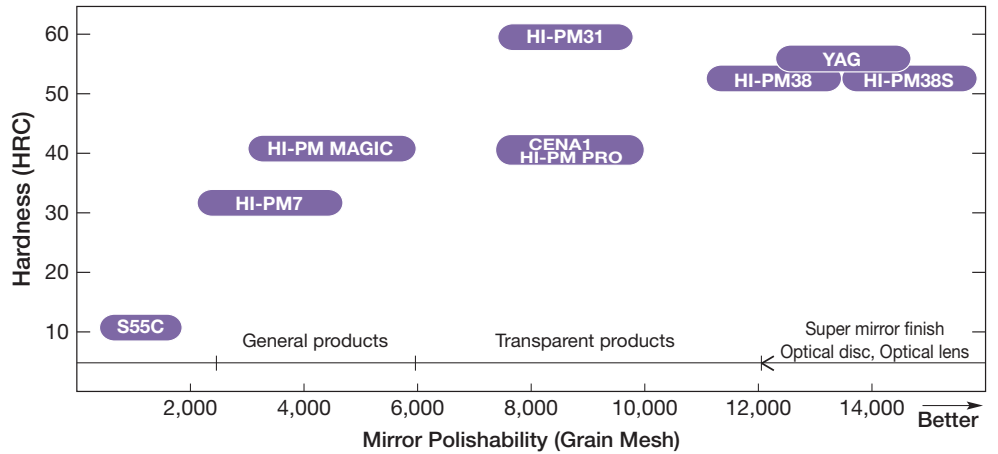


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Properties Comparison

Polishing Property

(Schematic Diagram)

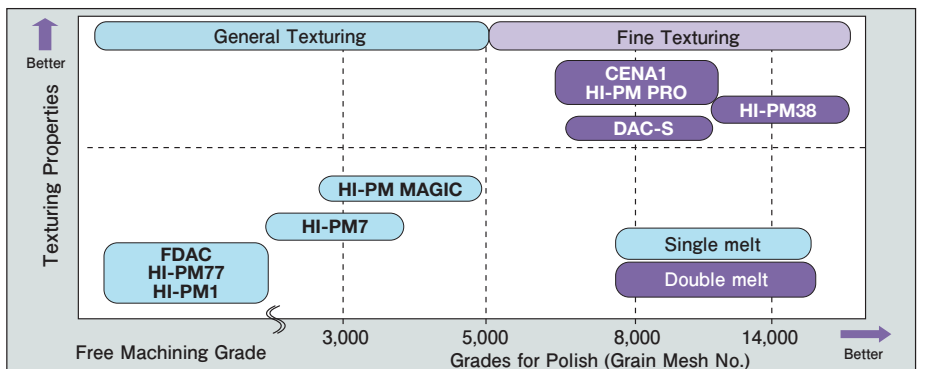


Texturing Properties

(Schematic Diagram of Uniformity by Etching)

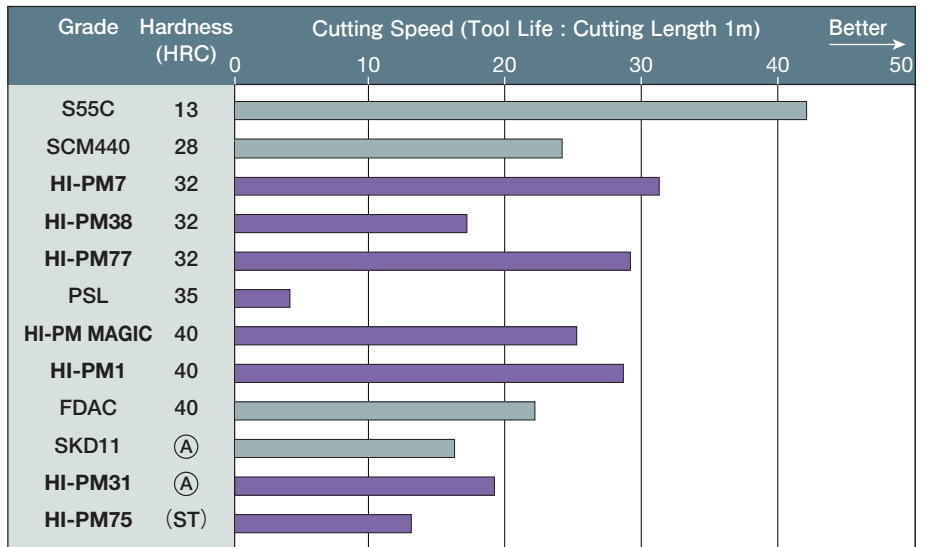
(Remarks)

This diagram does not show etching efficiency. (Etching efficiency is inversely proportional to the corrosion resistance.)



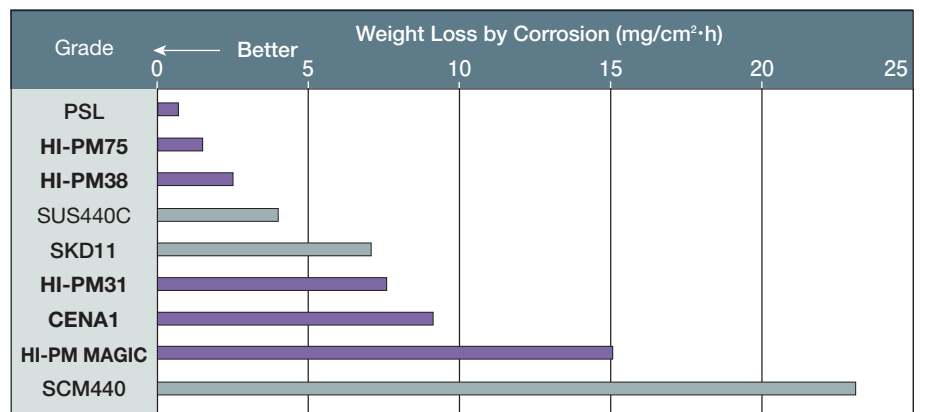
Machinability

Drilling
 Tool: SKH51 ϕ 10
 Feed: 0.15mm/rev
 Depth: 30mm
 Dry



Corrosion Resistance

(5% Sulfuric Acid Solution)

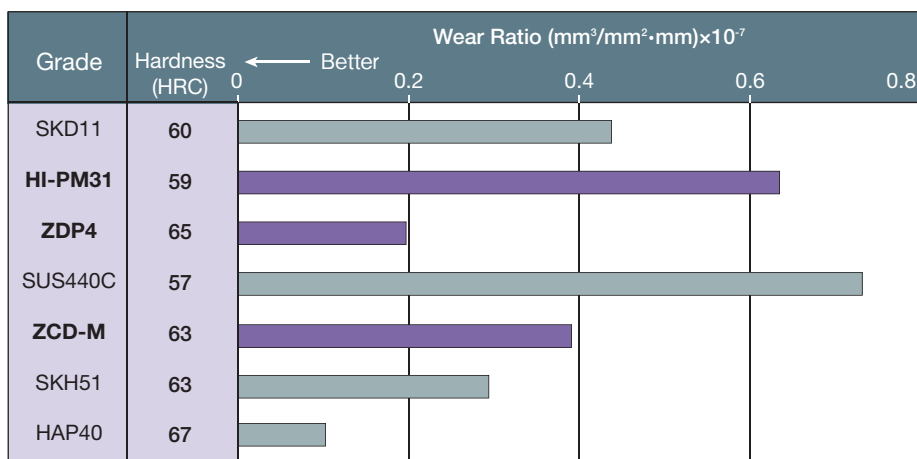


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Properties Comparison

Wear Resistance

Ohgoshi-method Wear Test
Work Material SCM415
Load 67N
Friction Distance 400m
Friction Speed 0.78m/sec



Mechanical Properties

Grade	Hardness (HRC)	Tensile Strength (N/mm ²)	0.2% Yield Strength (N/mm ²)	Elongation (%)	Reduction of Area (%)	
HI-PM7	32	975	855	20	55	
HI-PM38	52	1,910	1,620	13	35	
HI-PM77	32	990	845	16	41	
PSL	39	1,170	1,100	11	34	
CENA1	40	1,225	1,150	15	50	
HI-PM MAGIC	40	1,200	1,020	18	45	
HI-PM PRO	40	1,200	1,020	17	45	
HI-PM1	40	L	1,225	1,030	18	40
	40	T	1,215	1,010	10	25
HI-PM75	42	1,305	1,110	11	28	
YAG	53	2,010	1,910	10	48	

Physical Properties

Grade	Thermal Expansion Coef. (×10 ⁻⁶ /°C) Averaged value from 30°C to each temp.				Thermal Conductivity (W/m·K)				
	100°C	200°C	300°C	400°C	20°C	100°C	200°C	300°C	400°C
HI-PM7	11.6	12.2	12.8	13.4	34.3	38.3	39.8	40.4	40.6
HI-PM38	10.4	11.1	11.5	11.8	22.1	25.5	26.7	28.5	29.6
HI-PM77	10.1	10.7	11.1	11.5	22.3	24.9	26.3	27.9	29.5
PSL	10.6	11.1	11.9	12.1	15.8	20.0	22.2	24.2	25.5
CENA1	10.8	11.5	12.0	12.4	20.5	22.9	25.9	28.2	30.5
HI-PM MAGIC	11.5	12.3	12.9	13.4	31.4	34.1	37.7	40.2	41.1
HI-PM PRO	12.7	13.0	13.3	—	28.3	31.9	35.4	38.3	—
HI-PM1	11.4	11.8	12.3	12.8	31.5	36.6	38.4	39.4	40.1
HI-PM31	12.4	13.1	13.6	14.1	26.5	—	34.4	—	39.8
ZCD-M	10.5	10.8	11.5	11.9	16.4	19.4	22.0	25.3	24.4
HI-PM75	16.1	17.2	18.0	18.6	12.3	14.5	16.4	18.7	20.4
YAG	—	10.8	—	—	20.9	—	25.5	—	27.6



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40HRC Prehardened Grade

CENA1

Prehardened : 37- 41HRC
Precipitation Hardening,
Rust-Resisting Grade for
Precise Mold

CENA1 is a high performance plastic mold with rust resistivity and excellent machinability. CENA1 has exceptional high purity and suits for critical surface finish.

Features

- No heat treatment is necessary. Uniform hardness distribution. (37- 42HRC)
- Higher rust resistivity compared with P21 type grade.
- Excellent mirror polishability, crepe- and EDM finishability.
- Good weldability with least hardness elevation.
- Good nitriding hardenability and can be used for wear resisting application.

Application

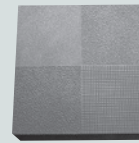
- Most suitable for weldless molding.
- Countermeasure against corrosion by gas generated from resin.
- Other critical surface finish molds. Engineering resin products.



TV Glossy Frame
(Weldless Molding)



Non-glare Treatment Sample



Creping Sample

HI-PM PRO

Prehardened: 37- 41HRC
Precipitation Hardening Grade
for Precise Mold

HI-PM PRO is the steel for plastic molds which precisely pursues consistency in production to meet requirement for elaborately designed products.

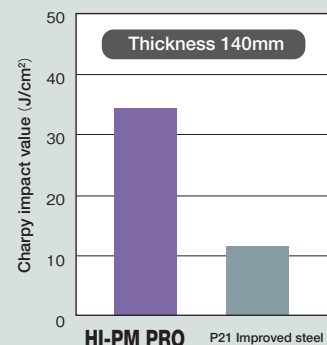
Features

- "Hardness" (37 to 41HRC) which is suitable for mass production of resin products by precision molding.
- "Excellent machinability for high quality appearance" supports excellent mirror polishability, creping, EDM surface (thanks to the special melting method).
- "Toughness and machinability" supports stable mold making and productivity.

Application

- The parts associated with automobile headlight production
- The exterior of cellular phone

Toughness



Comparison of 2mmU notch Charpy impact values



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40HRC Prehardened Grade

HI-PM MAGIC

Prehardened : 37-41HRC
Advanced Plastic Mold Steel
for general purposes

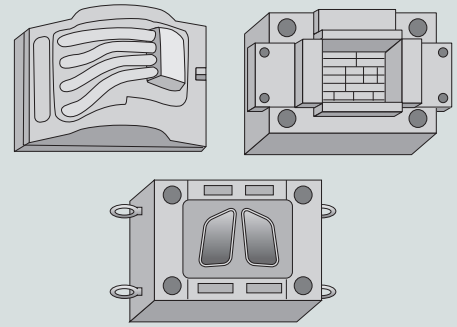
HI-PM MAGIC is a newly developed grade which has both high durability and excellent processability. Easy weldability will make setup of the new products of home electronic, OA equipment or Auto parts smoother.

Features

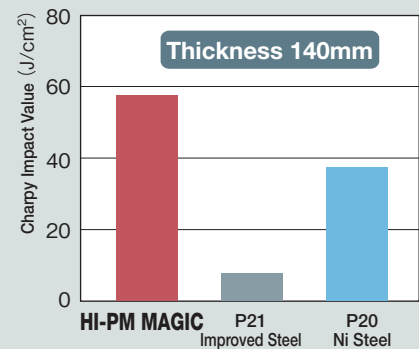
- No heat treatment is necessary (37-41HRC)
- Stable polishability
- Steady machinability. Fits for high-speed high feed cutting
- Higher toughness compared with conventional 40HRC grades
- Easy Weldability
- Good EDM finishability
- Excellent nitriding properties
- Satisfying Cost Performance

Application

- General resin products for home electronics, equipment OA Auto and so on.



Home electronics, OA equipment, Auto parts



Comparison of 2mmU notch Charpy impact values (example of measurement by our company)

HI-PM1

Prehardened : 37-41HRC
Free Machining Precipitation
Hardening Grade for Precise Mold

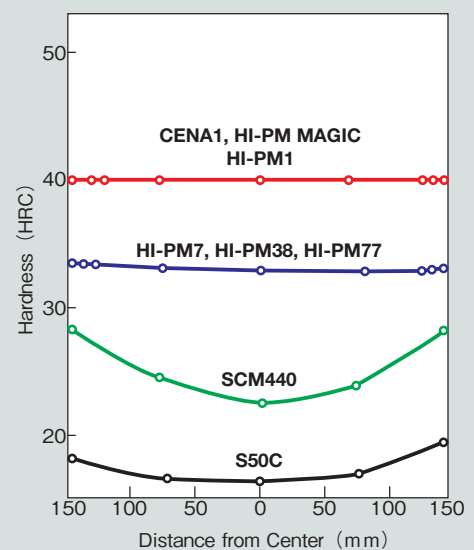
HI-PM1 is free machining plastic mold steel prehardened to 40HRC. With superb machinability, HI-PM1 is fitted for general applications.

Features

- No heat treatment is necessary. (37-41HRC)
- Excellent machinability among 40HRC prehardened grades.

Application

- General Plastic Products
- Precise Rubber Mold, etc. For Smooth Cut Surface.



Cross Section Hardness Distribution (300mm Square Size)



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32HRC Prehardened Grade

HI-PM7

Prehardened: 29-33HRC
For Medium and Large Mold
for General Application

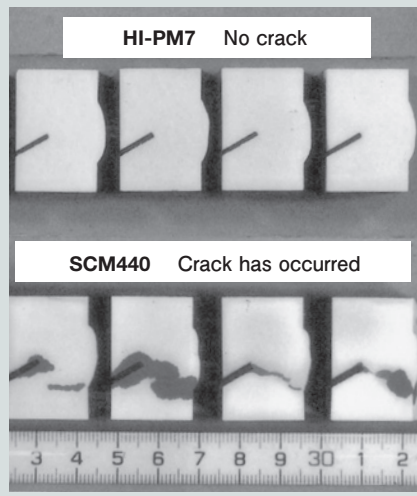
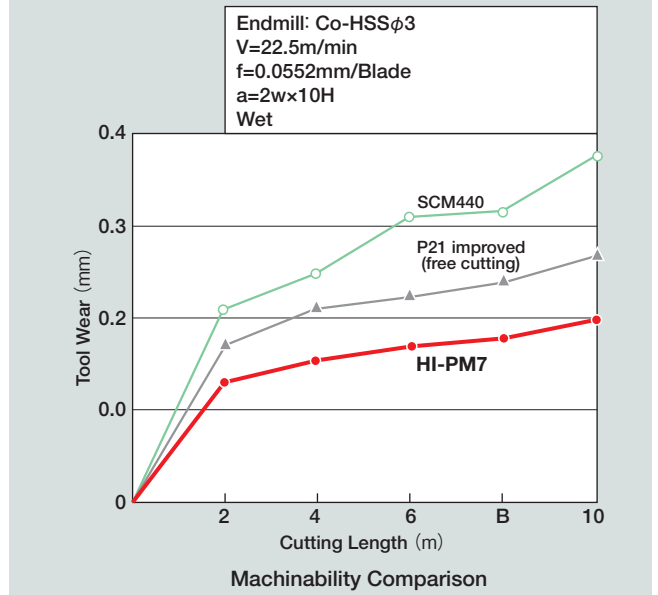
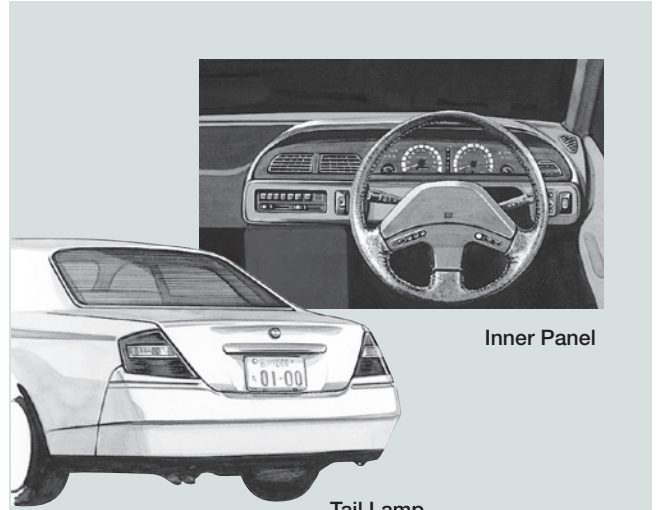
HI-PM7 is a plastic mold steel prehardened to 29-33HRC fitted for medium and large size mold, having good machinability and weldability. In addition, it has good mirror polishability and EDM machinability to make itself one of the best steel in this class grade.

Features

- Uniform hardness distribution even in large crosssection. (29-33HRC)
- Machinability is better than P20 or free machining steel.
- Excellent weldability with least hardness elevation.
- Stable mirror polishability.
- Less streak texture and least hardness elevation on EDM surface make finishing easier.
- Excellent toughness.
- Excellent nitriding property.

Application

- Auto parts: Headlamp, Tail lamp, Inner panel, etc.
- Home electronics, OA equipment, House equipment: TV cabinet, Air conditioner, etc.
- Other large daily goods, Large container, Pipe, Rubber



y-groove Weld Crack Test
JIS Z 3158
TIG Welding
No pre-heating / No post-heating



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Stainless Steel for Quench and Temper

HI-PM38

Prehardened : 29-33HRC
Hardenable to : 50-55HRC
For Anti-Corrosion and Mirror Polish Mold

HI-PM38 is Mo contained 13Cr martensitic stainless steel prehardened to 29-33HRC, manufactured by consumable electrode remelting method, further hardenable to 50-55HRC. It is fitted for molds which require corrosion resistance and superb mirror polishability. In addition, it suits for precise heat treatment. Excellent corrosion resistance also makes mold storage easier.

Features

- Excellent mirror polishability
- Better corrosion-resistivity than 420. Chromium plating is not necessary.
- Least heat treatment deformation, best fitted for precise mold.
- As HI-PM38 is supplied as prehardened condition, it can be used without further heat treatment also.

Application

- Transparent items: Lense, Container for cosmetics, etc.
- Flame retardant resin products: Home electronics, OA equipment
- For omitting plating: Food container, Medical instruments

Heat Treatment

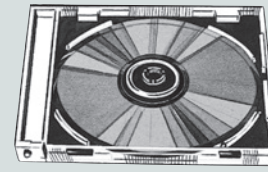
- Quenching : 1,000-1,050°C Air Cooling
- Tempering : 200-500°C Air Cooling

HI-PM38S

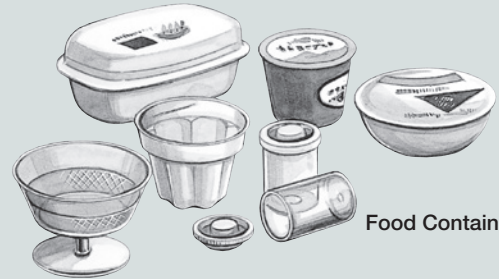
Prehardened : 29-33HRC
Hardenable to : 50-55HRC
For Super Mirror Polish Mold

Features

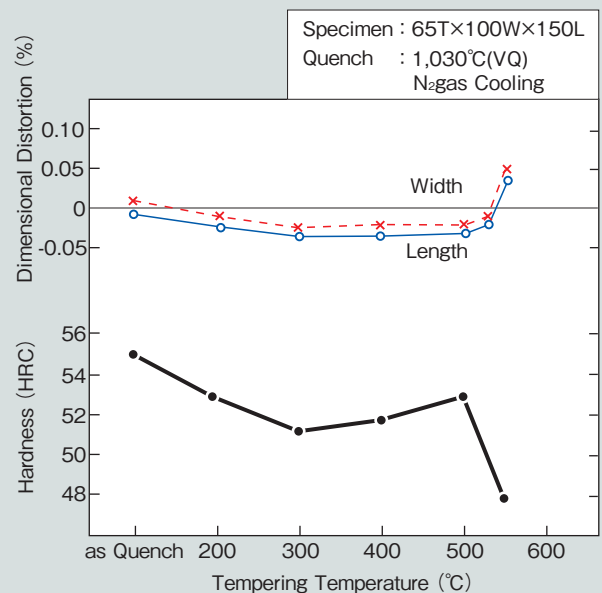
- Superior mirror polishability to below 0.01 μ m surface roughness.
- Other features are same as HI-PM38.
- CD, DVD, and optical lens.



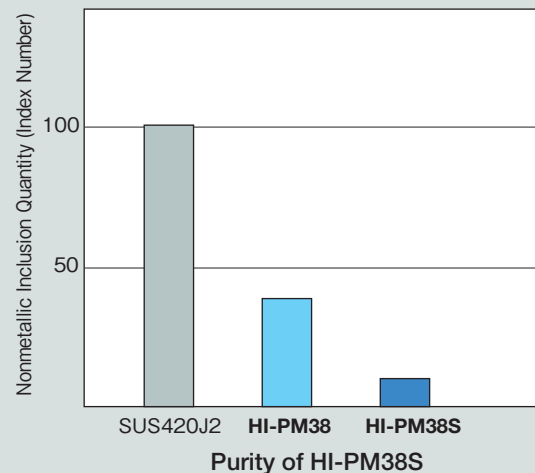
CD, DVD



Food Container



Heat Treatment Properties of HI-PM38



Purity of HI-PM38S



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Prehardened Stainless Grade

PSL

Prehardened :
 33-37HRC (Flat bar)
 38-42HRC (Round bar)
 For Higher Grade
 Anti-Corrosion Mold

PSL is precipitation hardening stainless steel which shows superior corrosion resistance as used for corrosive gas yielding resins or resins with flame retardant additives without plating.

Features

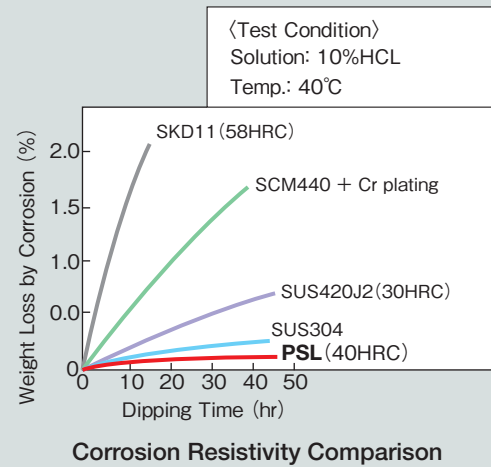
- Best corrosion resistance among plastic mold steels. Plating is not needed.
- Least hardness elevation on EDM or welded surface and easier finishing jobs.

Application

- Polyvinyl chloride : Pipe fittings, Pipe, Sash, etc.
- Resins with flame retardant additives
- Precision mold for rubber



PVC Extruded Products



HI-PM77

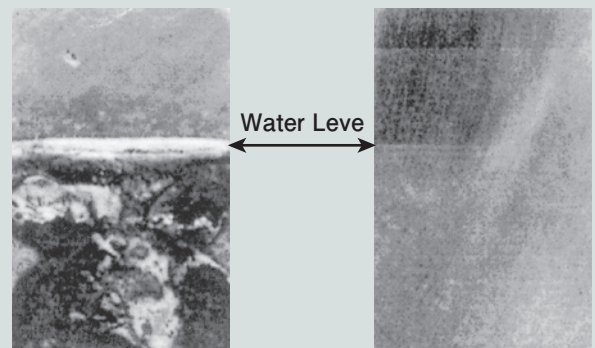
Prehardened : 29-33HRC
 Free Machining Martensitic
 Stainless Grade for Mold Base

Features

- Good corrosion resistance and well fitted for rust protection of water cooling holes or surface of mold base.
- Excellent machinability
- Prehardened and good mechanical properties

Application

- Holder for compact disc mold or lens mold.
- Holder for food or medical container mold and precise engineering resin mold.
- Mold for rubber
- Anti-corrosive support tools



S55C

HI-PM77

Rust after 1 month dipping in water



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High Wear Resistance Grade

HI-PM31

Hardenable to : 55-60HRC
High Wear Resistant Grade
for Mass Production

HI-PM31 is wear resistant plastic mold steel with fine carbide uniformly distributed by means of appropriate alloy design and consumable electrode remelting process. Least heat treatment distortion, it suits for precise heat treatment.

Features

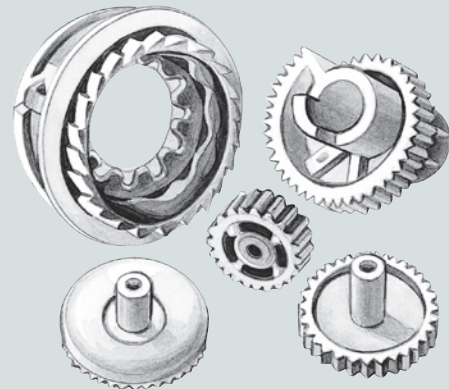
- Wear resistance is as high as JIS SKD11.
- Much better machinability and grindability than JIS SKD11.
- Least heat treatment deformation, best fitted for precise mold.
- Good mirror polishability crepe and EDM finishability
- High hardness and toughness, enough against chipping or breakage

Application

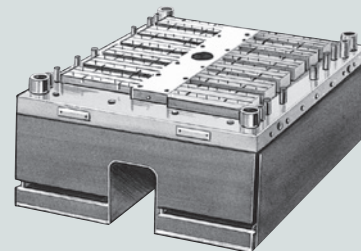
- Engineering resin products and thermosetting resin products
- Precise mold: IC mold, Connector, Watch parts, Camera parts

Heat Treatment

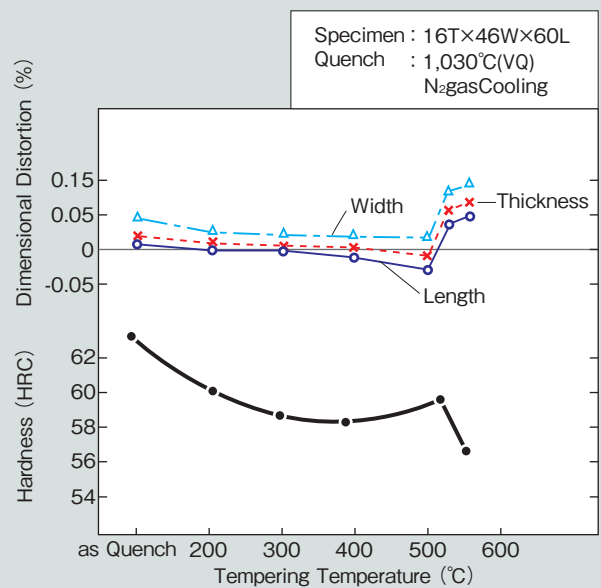
- Quenching : 1,000-1,050°C Air Cooling
- Tempering : 200-550°C Air Cooling



Engineering Resin Gear



IC Mold



Heat Treatment Properties of HI-PM31



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Aging Grade

YAG

Hardenable to : 52-57HRC
Super High Toughness
Maraging Steel

As YAG is delivered as solution heat treated condition, you are advised to conduct aging at 480-520°C in order to get hardness between 52-57HRC after engraving cavity.

(Remarks)

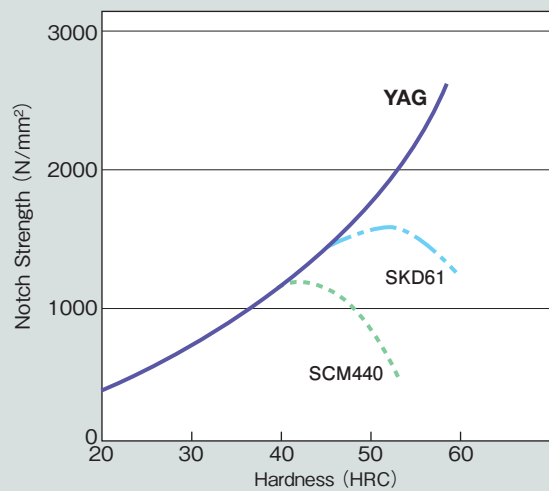
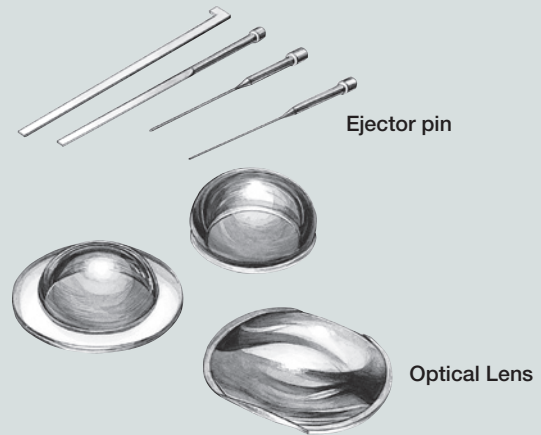
This product might correspond to the Export Trade Control Order. When you export this product, you might need apply for export licenses to the authorities in your country.

Features

- Excellent toughness and mechanical properties under high hardness and best fitted against breakage
- Super mirror polishability
- Hardness of 55HRC is obtainable by aging at 500°C with least distortion

Application

- Optical lens
- Thin core pin
- Ejector pin, either of small diameter or of long length



Relationship between Hardness and Notch Strength

HI-PM75

Hardenable to : 35-45HRC
Non-Magnetic High Hardness
Free Machining Plastic Mold
Steel

Features

- Permeability(μ) is 1.01, equally non-magnetic as 304
- 35-45HRC is obtainable by aging of 700°C×5h and has higher wear resistance.
- Good nitriding properties

(Remarks)

Slower machining recommended as it is easily hardened by machining.

Application

- Plastic magnet
- Wear resistant, non-magnetic supportive tools



Plastic Magnet



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Higher Grade Polishing Method of Plastic Mold

Polish procedure Example

<ul style="list-style-type: none"> ● Polish by oil grinding stone (use kerosene) ----- ● Polish by oil sand paper (use kerosene) ----- ● Finish Polishing by diamond compound (use felt cloth) 	<p>#180→#240→#320→#400→#600→#800</p> <p>#600→#800→#1000→#1200→#1500</p> <p>#1800→#3000→#8000→#14000 (9μm) (6μm) (3μm) (1μm)</p>
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Important points of polishing

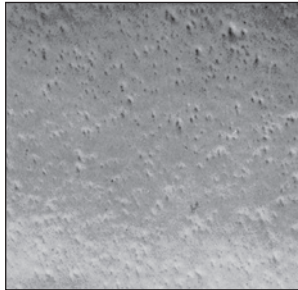
1. Each procedure is to be strictly kept.
2. When changing from one number to another, check if there are remained scratches by changing polishing direction. (move 45-90 degrees)
3. When changing numbers, wash and remove last polishing grains completely.
4. Polishing by diamond compound needs to be done in short times. Excessive polish can produce pinholes or orange peel.
5. Avoid alumina and chromium oxide as the polish capabilities are lower than diamond.
6. During long interruption, the object must be protected from the rust.

Remarks:

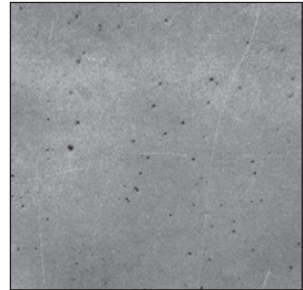
- A. For superior polishing use diamond compound.
 Don't use alumina nor chromium-oxide compound.



Diamond Compound Finish



Aluminium Oxide Finish Not Good



Chromium Oxide Finish Not Good

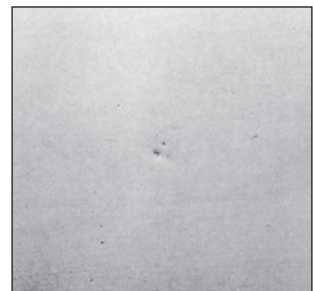
- B. Load for polishing should be kept the lowest possible.
 C. Foregoing polish should be done prudently.
 D. Rust proof measures must be taken in any interruption of jobs.



Scratch remains due to overload.



Seam and pinhole texture at crossing by less foregoing polish



Pinhole texture by inappropriate rust proof.



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Welding of Plastic Mold

Attentive points

1. Preparations before welding

- A. Form of location to get welded should be made smooth as Figure 1.
- B. Cracks and treated surface (nitrided or plated) must be eliminated.
- C. Oil, dust, moisture and scale must be removed thoroughly.

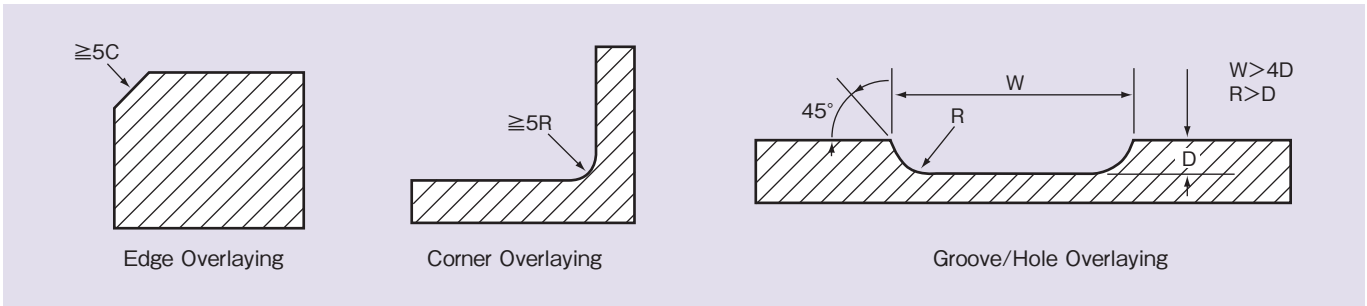


Figure 1. Standing shapes for build up welding

2. Welding rod

- A. Welding rod of similar composition as mold is to be used so that welding may not bring about unevenness of mirror finish or creping surface.
When the mold is made from HI-PM MAGIC, use welding rod made from HI-PM MAGIC-W. Likewise, in case fo TIG welding there are T-HTM-31 and T-HTM38 in the market for welding for mold made from HI-PM31 and HI-PM38.
- B. In case of using coated electrode, welding rod should be dried by heating to 250-300°C before using.
- C. For cavity welding, TIG welding should be applied.
(TIG : Tungsten Inert Gas)

3. Welding

- A. Figure 2 shows example of actual welding jobs of representative grades.
- B. Tempering should be conducted soon after welding in case of prehardened steel or hardened and tempered steel according to Figure 2.
Tempering is effective to protect mold from crack and to stabilize mirror finish and creped surface by having uniform hardness and structure.

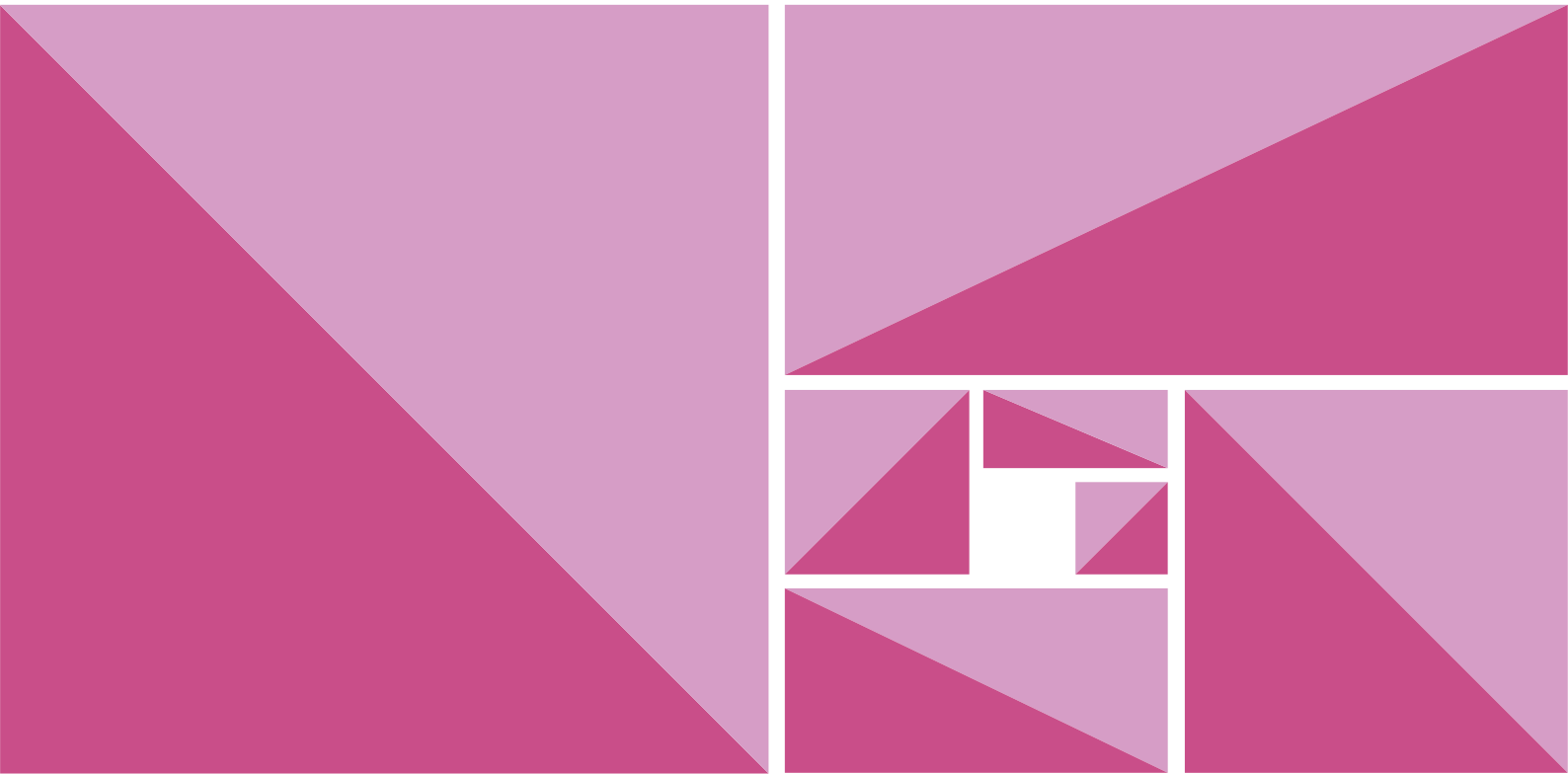
Mold Steel Grade	Welding	Welding Rod	Condition	Heat Cycle
HI-PM MAGIC	TIG	HI-PM MAGIC -W	<ul style="list-style-type: none"> ●TIG Welding Rod Current { 2.4φ 80-160A 3.2φ 110-200A Flow Rate 10-15l/min 	<p>(Stress relieving for correcting deformations and precise creping)</p>
HI-PM7	TIG	HI-PM7-W	<ul style="list-style-type: none"> ●Shielded Metal Ark Welding Rod Current { 3.2φ 90-120A 4.0φ 130-160A 	
	Shielded Metal Ark	TH-50		

Figure 2. Welding procedure



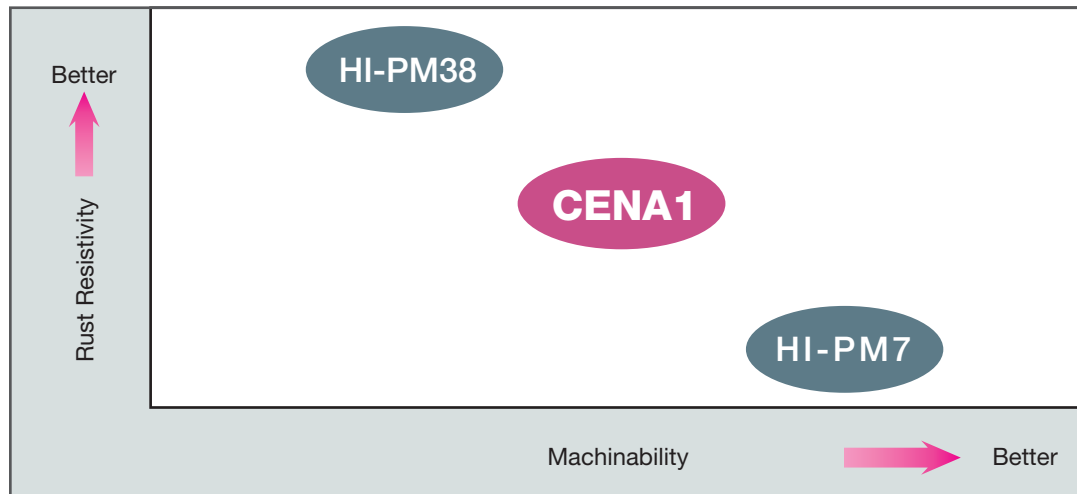
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YSS Plastic Mold Steel **CENA1**



Concept of CENA1[®]

CENA1 is a high performance plastic mold with rust resistivity and excellent machinability. CENA1 has excellent purity and suit for critical surface finish.



Properties Comparison

Grade	Hardness (HRC)	Machinability	Rust Resistivity	Mirror Polishability	Crepeability	EDM Finishability
CENA1	37-42	B	B	A	A	A
HI-PMPRO	37-41	B	C	A	A	A
HI-PM7	29-33	A	D	C	C	C
HI-PM38	50-55	C	A	A	B	A

(excellent "A" ⇔ poor "D")

Application

- **Weldless molds, Heat & cool molds (Molds that rust preventing)**
e.g. Glossy molding of TV bezel, Glossy molding, Molding for products with high quality surface of mobile equipments parts, OA equipments parts, auto parts. thick transparent parts for game machine, etc.
- **Mold requiring sensitive surface as mirror polishing, creping and EDM**
e.g. Mold of housing of mobile equipments, video camera, home electronics (ex. Vacuum cleaner, Air conditioner), auto parts (ex. Inner panel, Transparent cover), cosmetics case, bottle
- **General molds for long life: Making the maintenance easy by rust resistance increase**
- **Mold of food container**
- **Rubber mold**



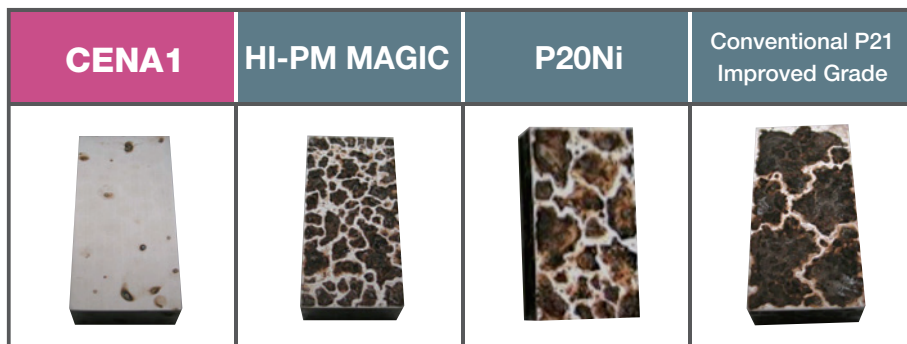
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Rust Resistivity

CENA1 has improved rust resistivity compared with conventional 40HRC prehardened grade.

- Improvement of corrosion problem on mold surface by resins.
- Decreased rust formation at cooling water hole makes cooling effect stable.
- Fewer rust problem in storage, transportation, or usage of mold
- Much less rust formation on WEDM surface

Rust Resistivity of Polished Surface



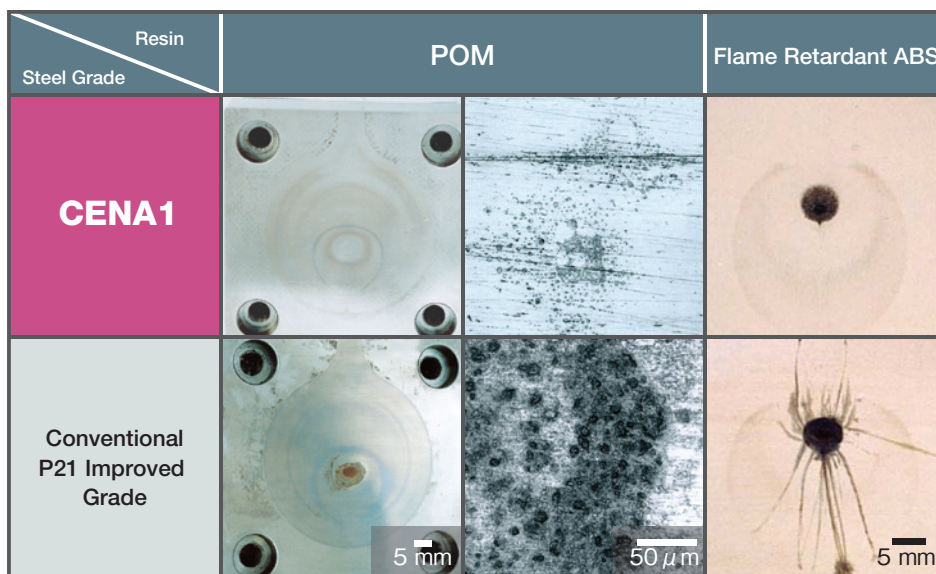
[Condition]
 Finished by #800 emery paper,
 Temperature: 80°C
 Humidity: 90%
 2 hour hold

CENA1 increases mold durability against corrosion by gas generated from resin.

Gas generated from resin often becomes high temperature by injection pressure and corrode the mold. It brings cloudiness of mirror surface and burr of injected parts. CENA1 improves above gas-corrosion resistance by alloy combination.

Accelerated Gas-corrosion Tests:

Change on Mirror-Finished Mold Surface after Injection Molding Tests



<Figure>
 Accelerated gas-corrosion tests by a mold that is made to shut gas intentionally.
 Observation results of mirror-finished mold surface after 3000 shots of POM and ABS flame retardant grade.



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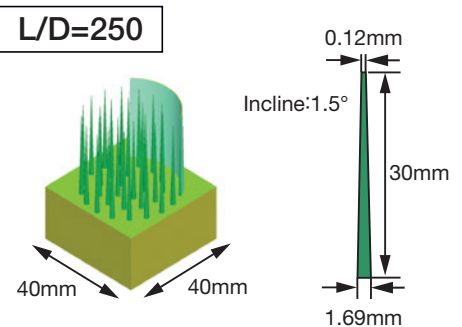
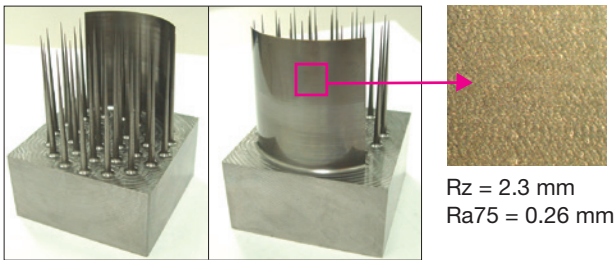
Machinability

CENA1 decrease tool wear in endmilling and promote cutting efficiency.

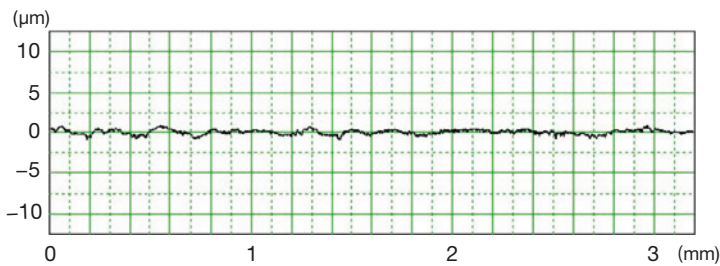
- CENA1 can promote cutting efficiency
- CENA1 can decrease tool-change frequency drastically.
- Smooth cut surface of CENA1 makes after-polishing easier.

Endmilling Example

This sample was machined by one endmill for 22 hours.
Machined surface roughness is very smooth.



Roughness curve (Longitudinal: × 2,000, Horizontal × 50)



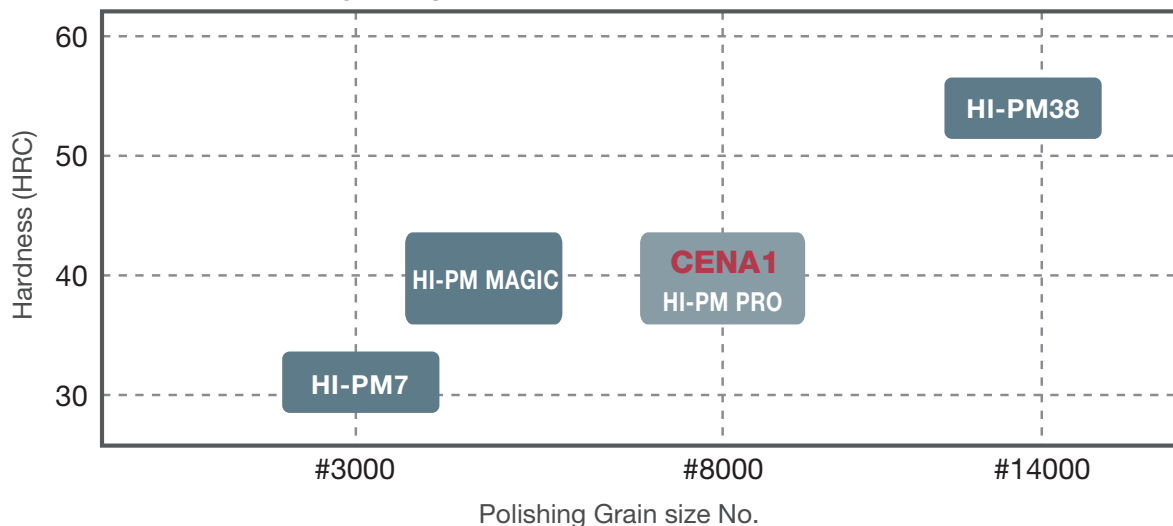
Tool: φ 3.0 2 teeth,
EPDR2030-30-05-TH (Hitachi Tool)
Machine: MAKINO V33
Cutting Verocity: 50 m/min (5300 min⁻¹)
Feed: 0.06 mm/tooth (640 mm/min)
Cutting Depth: 0.06 mm
Pick Feed: 0.12 mm
Dry (Air Blow)
Cutting time: 22 Hr
Number of tool use: 1

Same condition cutting on conventional P21 steel needs 2 endmills.

Mirror Polishability

CENA1 has very low non-metallic inclusion content and excellent mirror polishability.

Mirror Polishability Comparison



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Crepability

CENA1 has homogenized micro structure and good crepability. CENA1 is suitable for precise creping.

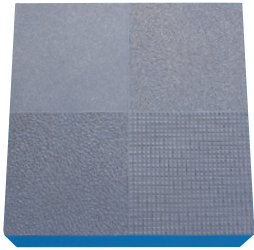
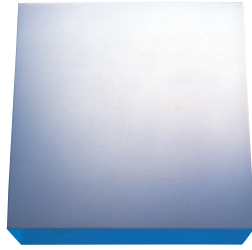


Photo Etching Sample



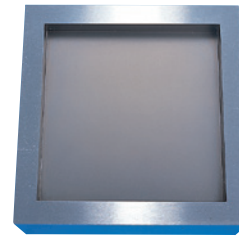
Non-glare Treatment Sample

*EDM surface Etching ... Sand blasting treatment is needed before etching.

*Welded Surface Etching ... Post-heating ($\geq 200^{\circ}\text{C}$) after welding is needed before etching.

EDM Finishability

CENA1 has good EDM Finishability. As surface hardened layer is much less than conventional grades, CENA1 is able to be polished easier after EDM machining.



CENA1
100×100×50 (mm)

EDM Finished

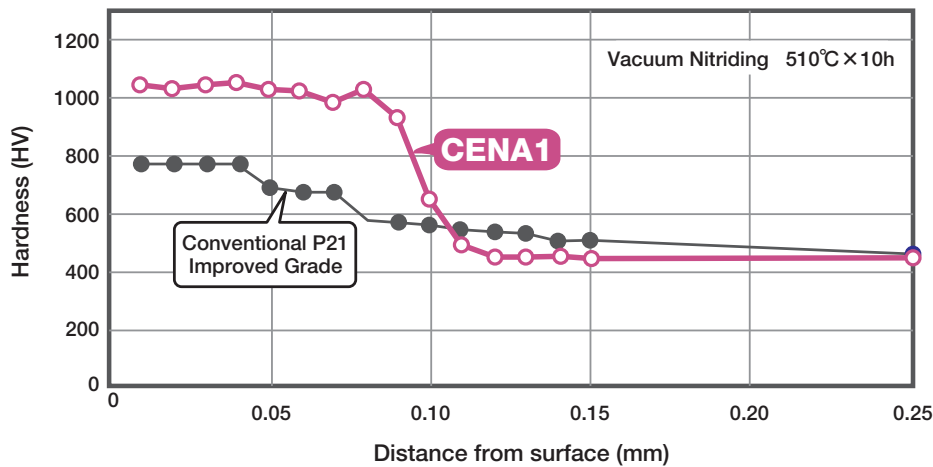
【Condition】

Machine : HQSF(MAKINO), EDGE2S #108
 Solution : Paraol 250
 Additive : μSC (0.8-1.0g/L)
 Electrode : Gr 78.0mm (EDM depth 1.0mm)
 Cu 79.2mm (EDM depth 0.4mm)
 Cu 79.7mm (EDM depth 0.15mm)

Nitriding Property

By nitriding, 1000HV surface hardness is obtained easily on CENA1, that is effective against wearing of slide core or reinforced resin mold.

Hardness Profile of Nitrided Cross-section



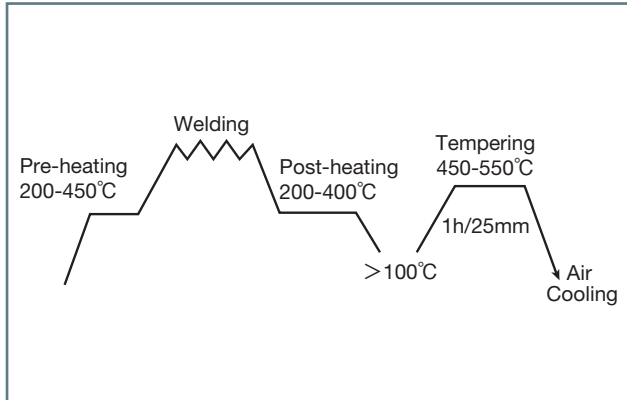
*The care is necessary to avoid breakage by over-hardening especially for small dia. pin or sharp edge part. It is recommended to apply lower nitriding temperature or weak nitriding condition.



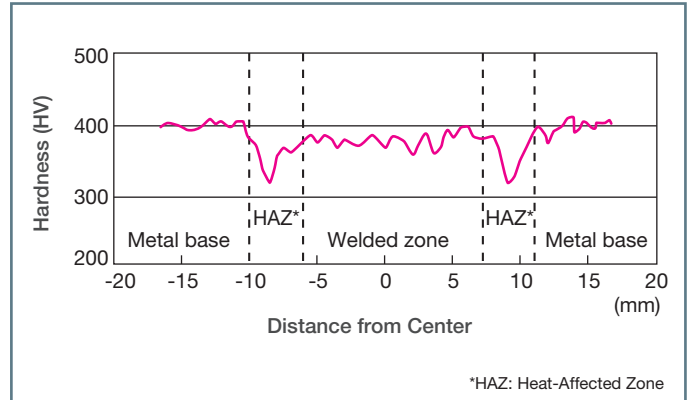
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Weldability

As welded area hardness variety of CENA1 is less than conventional grades, mold is able to be repaired and finished easily.



Welding Procedure Example



Measured Surface Hardness of Welded Area

Welding repair is recommended to be done by TIG welding with CENA1-W rod.

Mechanical Properties

Representative value of flat bar 50t×400W.

Grade	Hardness (HRC)	Tensile Strength (N/mm ²)	0.2%Yield Strength (N/mm ²)	Elongation (%)	Reduction of Area (%)	2U Charpy impact value (J/cm ²)
CENA1	40	1,225	1,150	15	50	20

Physical Properties

Specific Gravity 7.78

Thermal Conductivity

W/(m·K)

Grade	20°C	100°C	200°C	300°C	400°C
CENA1	20.5	22.9	25.9	28.2	30.5

Thermal Expansion Coefficient

Average value from 30°C, ×10⁻⁶/°C

Grade	100°C	200°C	300°C	400°C
CENA1	10.8	11.5	12.0	12.4

Young's Modulus 205GPa



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Actual Performance

Rust Resistivity

Application	Comparison of Actual Performance with Conventional Grade by Customers
Electronics Parts	Least rusting during WEDM for 1 week. Rust removing process becomes unnecessary.
Mechanical Parts	Resistant to corrosive gas generated by advanced engineering resins. Mold durability is improved.

Machinability and EDM Finishability

Acrylic Lens	<ul style="list-style-type: none"> • Carbide endmill tool life is doubled. • Easy to mirror polish EDM surface.
TV Speaker	<ul style="list-style-type: none"> • Many small pins were made by EDM machining. Better EDM surface has been obtained compared with conventional grade.
Auto Head-light Lens	<ul style="list-style-type: none"> • Good machinability in ball endmilling. • Smooth surface machined with 0.4R ball endmill makes polishing easy.

CENA1 and Weldless Molds

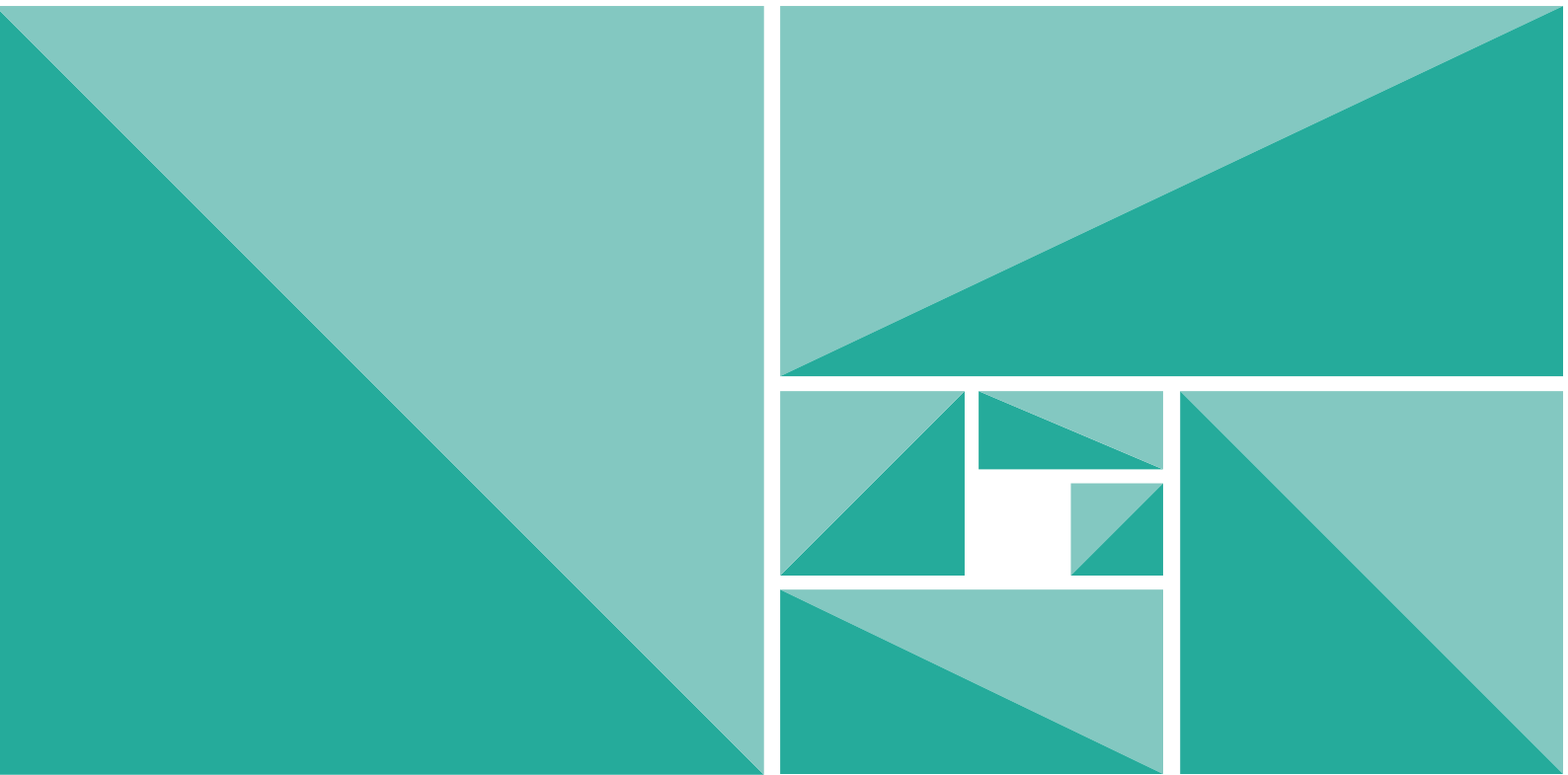
CENA1 is most suitable for weldless molds for which temperature control is required, because surface condition of heating and cooling holes comes to be less corrosive and more stable. **CENA1** is widely used for the products such as TV frame and video camera for better surface condition.



Weldless Molds



YSS High Speed Tool Steels



Chemical compositions of YSS High Speed Tool Steels

(mass%)

		Grade	JIS equivalent	AISI/ASTM W.Nr DIN/ISO	C	Cr	W	Mo	V	Co
Conventional High Speed Tool Steels	Molybdenum HSS	YXM1	SKH51	$\frac{M2}{1.3343}$ HS6-5-2	0.80-0.90	3.80-4.50	6.00-7.00	4.80-5.80	1.80-2.30	–
		YXM4	SKH55	$\frac{-}{1.3243}$ HS6-5-2-5	0.85-0.95	3.80-4.50	6.00-7.00	4.80-5.80	1.80-2.30	4.50-5.50
		YXM27	–	–	1.15-1.25	3.80-4.50	4.80-5.80	5.80-6.80	2.60-2.80	–
		YXM42	SKH59	$\frac{M42}{1.3247}$ HS2-9-1-8	1.00-1.10	3.50-4.25	1.25-2.00	9.00-10.00	1.00-1.50	7.75-8.75
		YXM60	–	–	1.00-1.10	3.80-4.50	5.00-6.00	6.00-7.00	1.50-1.80	7.50-8.50
	Vanadium HSS	XVC5	SKH57	$\frac{-}{1.3207}$ HS10-4-3-10	1.20-1.30	3.80-4.50	9.00-11.00	3.00-4.00	3.20-3.70	9.50-10.50
	Tungsten HSS	YHX2	SKH2	$\frac{T1}{1.3355}$ HS18-0-1	0.73-0.83	3.80-4.50	17.00-18.00	–	0.80-1.20	–
	Matrix HSS	YXR3	Matrix HSS	–	0.6	4.3	–	2.9	1.8	–
		YXR33	Matrix HSS	–	0.5	4.2	1.6	2.0	1.2	1.0 or less
		YXR7	Matrix HSS	–	0.8	4.7	1.3	5.5	1.3	–
P/M High Speed Tool Steels	HAP10	–	–	1.30-1.40	4.50-5.50	2.50-3.50	5.50-6.50	3.60-4.00	–	
	HAP40	SKH40	$\frac{-}{-}$ HS6-5-3-8	1.27-1.37	3.70-4.70	5.60-6.40	4.60-5.40	2.80-3.30	7.50-8.50	
	HAP50	–	–	1.54-1.64	3.70-4.70	7.50-8.50	5.50-6.50	3.80-4.30	7.50-8.50	
	HAP72	–	–	2.02-2.32	3.70-4.70	9.00-10.00	8.00-8.50	4.80-5.10	9.00-10.00	
	HAP5R	–	–	0.9	4.3	2.0	3.0	3.0	–	

HSS: High Speed Tool Steel

Isotropy



Yasugi (Kaigan) Works

YSS High Speed Tool Steels are used not only for cutting tools but also various forming tools which require higher wear resistance and toughness. Along with conventional type steels, there are some grades made by powder metallurgy process (HAP series) that has superb wear resistance and toughness because of higher alloy content and uniform fine microstructure.



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Features of YSS High Speed Tool Steels

		Grade	Features
Conventional High Speed Tool Steels	Molybdenum HSS	YXM1	Standard Molybdenum high speed steel with superior toughness
		YXM4	Standard Cobalt alloyed Molybdenum high speed steel with superior heat resistance
		YXM27	High Vanadium high speed steel with good wear resistance and grindability
		YXM42	Super-hard high speed steel suitable for cutting for hard materials
		YXM60	High-performance high speed steel with superior durability, toughness and grindability
	Vanadium HSS	XVC5	High-performance Cobalt alloyed Vanadium high speed steel with wear/heat resistance
	Tungsten HSS	YHX2	Standard Tungsten high speed steel
	Matrix HSS	YXR3	Matrix high speed steel for forging tools with superior toughness
		YXR33	Matrix high speed steel for forging tools with most superior toughness
		YXR7	Matrix high speed steel for forging tools with superior strength/toughness
P/M High Speed Tool Steels	HAP10	Superior toughness effective to avoid chipping	
	HAP40	Most standard grade with good balance of hardness, toughness and wear resistance	
	HAP50	Higher hardness, good heat and wear resistance	
	HAP72	Good heat wear resistance and highest obtainable hardness of 70HRC	
	HAP5R	Toughest P/M high speed steel	

Outstanding Features;

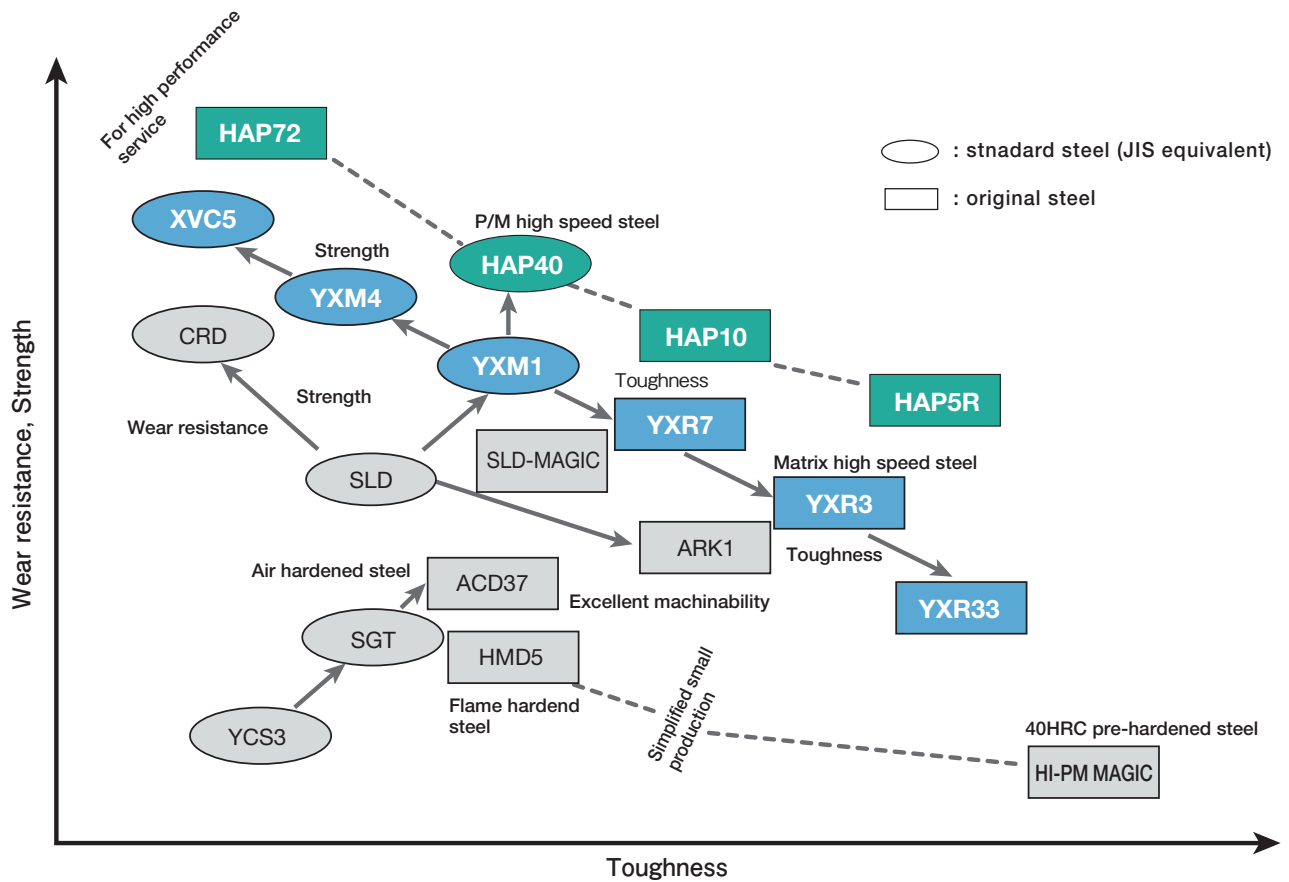
- High toughness
- High wear resistance
- Stabilized heat treatment property
- Stable performance due to uniform and fine carbide distribution
- Good mechanical properties coming from fine and uniform grain size
- High purity with least inclusions and gases



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Characteristics of YSS High Speed Tool Steels

Characteristics of steels



Properties Comparison Table

Grade	Strength at elevated temperature	Quench and tempered hardness	Wear resistance	Machinability	Toughness
YXM1	A	C	C	C	B
YXM4	A	C	B	C	B
YXM27	B	C	B	C	B
YXM42	A	B	A	B	C
YXM60	A	B	A	B	C
XVC5	A	C	A	D	D
YHX2	A	C	C	B	C
YXR3	D	D	D	A	A
YXR33	C	D	D	A	A
YXR7	D	C	C	C	B
HAP10	D	C	A	B	B
HAP40	B	B	A	C	B
HAP50	B	B	A	B	B
HAP72	B	A	A	D	D
HAP5R	D	D	C	B	A

Excellent "A" → Ordinary "C" → Poor "E"



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Characteristics of YSS High Speed Tool Steels

Wear resistance (Ogoshi method)

Grade	Hardness (HRC)	Specific wear ($\text{mm}^3/(\text{mm}^2 \cdot \text{mm}) \times 10^{-7}$)	
		0.5	1.0
YXM1	65.5	~0.5	~0.5
YXM4	66.0	~0.5	~0.5
YXM27	66.0	~0.5	~0.5
XVC5	67.0	~0.5	~0.5
YXR33	58.0	~0.5	~0.5
YXR3	59.0	~0.5	~0.5
YXR7	65.0	~0.5	~0.5
HAP5R	60.7	~0.5	~0.5
HAP10	64.0	~0.5	~0.5
HAP40	67.2	~0.5	~0.5
HAP72	70.0	~0.5	~0.5
SKD11	60.5	~0.5	~0.5
SKD61	55.5	~0.5	~1.85

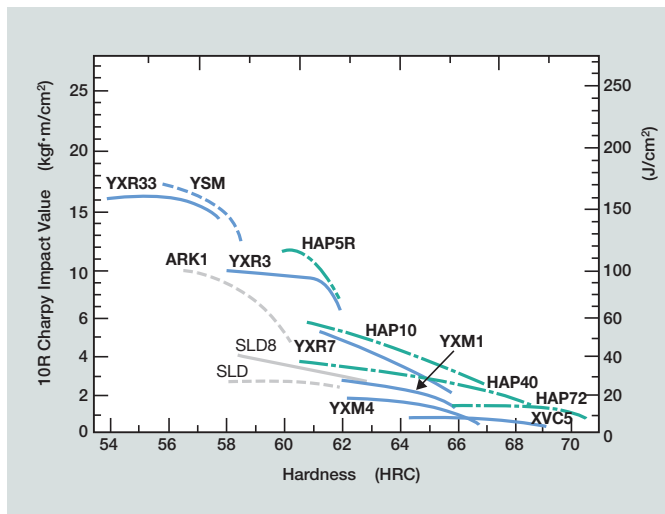
Test condition
 Co-friction material: SCM415 Friction length: 400m
 Load: 67N (6.8kgf) Friction speed: 0.78m/sec

Wear resistance (Abrasive Wear)

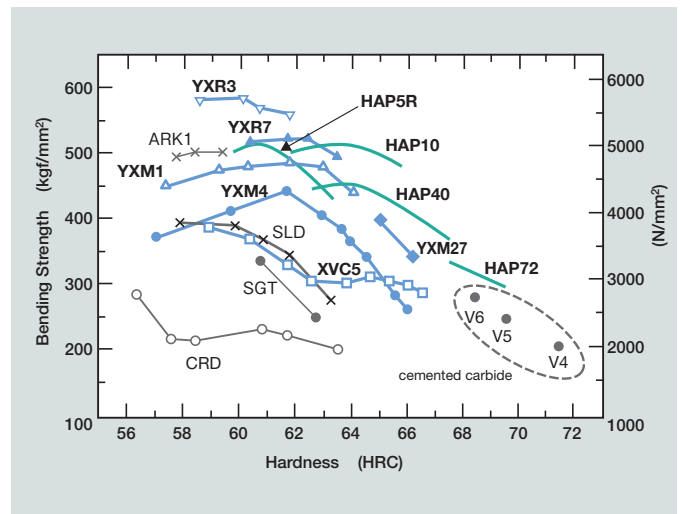
Grade	Hardness (HRC)	Wear (Volume loss; YXM1=1)		
		1.0	2.0	3.0
YXM1	65	1.0	1.0	1.0
YXM4	65	~1.0	~1.0	~1.0
XVC5	67	~1.0	~1.0	~1.0
YXR3	61	~1.0	~1.0	~1.0
YXR33	58	~1.0	~1.0	~1.0
HAP10	65	~1.0	~1.0	~1.0
HAP72	70	~1.0	~1.0	~1.0
SKD11	59	~1.0	~1.0	~1.0

Test condition
 Sandpaper: Al₂O₃ # 500 Revolution: 980rpm Friction length: 1000mm
 Lubricant: dry Load: 49N (5kgf)

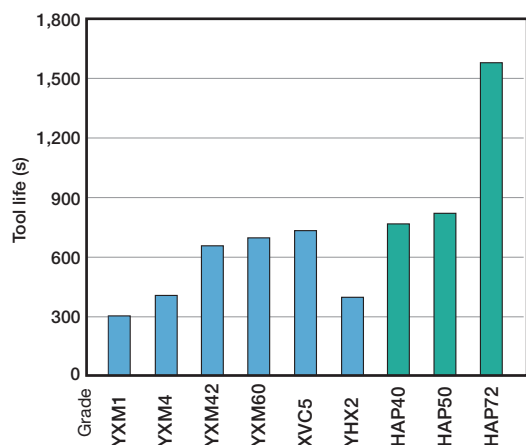
Charpy impact value



Bending strength

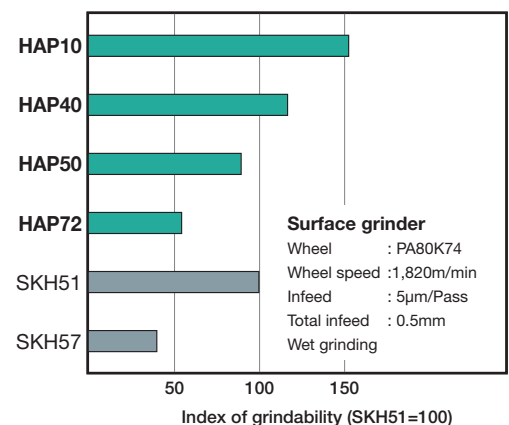


Continuous Cutting test by turning tool



Cutting condition
 Work : SKT4(357HB)
 Machine : Automatic lathe
 Tool tip shape : 8-15-6-6-20-15-0.5R
 Cutting speed : 25m/min
 Depth of cut : 1mm
 Feed : 0.3mm/rev
 Dry cutting

Grindability



Surface grinder
 Wheel : PA80K74
 Wheel speed : 1,820m/min
 Infeed : 5μm/Pass
 Total infeed : 0.5mm
 Wet grinding



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Recommended grade by application of YSS High Speed Tool Steels

Cutting tools

() shows standard employed hardness/HRC.

Application	Recommended Grade		
	For general use	For hard material cutting	For high speed heavy duty cutting
Tool bit	XVC5 (65-68) , HAP72 (69-71)		
Drill	YXM1 (63-66)	YXM60, YXM42 (66-68) HAP50 (66-68) , HAP72 (68-70)	HAP40, HAP50 (66-68)
Tap	YXM1 (63-66)	YXM27 (65-67) , HAP10 HAP40 (65-67) , HAP72 (68-70)	YXM27 (65-67) , HAP40 (65-67)
Reamer	YXM1 (63-66)	YXM4, YXM60 (65-67)	YXM4 (64-67)
Milling cutter	YXM1 (63-66)	YXM42, YXM60 (65-67) HAP40 (66-68)	YXM4, XVC5 (65-67) HAP40, HAP50 (66-68)
End mill	YXM1, YXM4 (64-66) YXM60 (67-69)	YXM60 (67-69) , HAP72 (69-71)	XVC5 (66-68) , HAP50 (66-69) HAP72 (69-71)
Broach	YXM1 (63-66) , YXM4 (64-67)	YXM60 (66-68) , HAP10 HAP40, HAP50 (66-68)	YXM27 (65-67) , HAP10 HAP40, HAP50 (66-68)
Hob	YXM4, YXM1 (64-66)	YXM60 (67-69) , HAP50 (67-69)	HAP40, HAP50 (66-68)
Pinion cutter	YXM1, YXM4 (63-65)	HAP40 (65-67)	HAP10, HAP40 (64-66)
Shaving cutter	YXM1 (64-66)	YXM27 (65-67) YXM42, YXM60 (66-68)	
Rack cutter	YXR7, YXM1 (63-66)	YXM4 (65-67)	YXM4 (65-67)
Chaser	YXM1 (62-65)	YXM27 (65-67) , HAP10 (65-67)	YXM4, YXM27 (65-67)
Metal saw	YXM1 (63-66)		
Hack saw	YXM1 (62-65)	YXM42 (66-68) , HAP40 (66-68)	YXM42 (66-68) , HAP40 (66-68)
Metal band saw		YXM42 (66-68)	HAP50 (66-68)
Wood cutter	YXR3 (58-61) YXM1, YHX2 (62-65)	YXM42 (66-68)	YXM4 (65-67)



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Recommended grade by application of YSS High Speed Tool Steels

Cold working tools

() shows standard employed hardness/HRC.

Application		Required hardness range (HRC)	Recommended Grade			
			For general use	For mass production use		
				For abrasion resistance	For impact resistance	
Die for cold press	Blanking die		58 - 62	SLD, SLD-MAGIC, ARK1	HAP10, HAP40	YXM1, YXR7, HAP5R
	Blanking die	Sheet use	55 - 60	HMD5 (flame hardening type)	SLD, SLD-MAGIC	ARK1
		Heavy plate, high-tensile steel	58 - 62	SLD, SLD-MAGIC, ARK1	HAP10, HAP40	YXM1, YXR7, HAP5R
	Bender swaging dies	Sheet use	58 - 62	SLD	SLD-MAGIC	ARK1
		Heavy plate, high-tensile steel	58 - 62	SLD, SLD-MAGIC	XVC5	YXM1
Cold working dies	Cold working dies	Male die	58 - 63	SLD, SLD-MAGIC	YXM1, HAP40	YXR7, YXR3, HAP10
		Female die	55 - 60	SLD, SLD-MAGIC, ARK1	YXM1, HAP10	YXR3, YXR7, HAP5R
	Cold heading dies	Male die	58 - 62	SLD, SLD-MAGIC	HAP40	YXM1, YXR7, YXR3
		Female die	55 - 60	YSM	SLD, SLD-MAGIC	YXM1, YXR7, YXR3
Thread rolling dies		58 - 64	SLD, SLD-MAGIC	YXR7, YXM1, SLD10		
Rolls	Cold rolling mill rolls		80HS Min	SLD, SLD-MAGIC	YXM1, HAP50, HAP40	
Other	Triming dies	Thin material (under 3 mm)	55 - 60	SLD, SLD-MAGIC, ARK1	YXM1, HAP40	YXR3, YXR7
		Thick material (3 mm or over)	50 - 55	DAC, DM		
Drawing dies		57 - 62	YXM1, CRD	XVC5		
Cold hobbing dies		55 - 60	SLD, SLD-MAGIC	YXM1		
Machine cutlery	Shearing blades (Straight blades)	Thin material plate (under 3mm)	55 - 60	SLD, SLD-MAGIC, ARK1	YXM1, YXR7	YXR3
		Medium material plate (3mm to 9mm)	53 - 58	SLD, SLD-MAGIC, ARK1		YXR33
		Heavy material plate (10 mm or over)	48 - 53	DM		
	Rotary shear, slitters		54 - 60	SLD, SLD-MAGIC, ARK1	YXM1, HAP40	



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Standard heat treatment conditions of YSS High Speed Tool Steels

Grade	Temperature (°C)			Hardness		
	Annealing	Quenching	Tempering	Annealed (HBW)	Quenched and tempered (HRC)	
Conventional High Speed Tool Steels	YXM1	800-880 Slow cooling	(1)1,220-1,240 (2)1,200-1,220 Oil(hot bath)	550-570 Air cooling	255 Max	63 Min
	YXM4	800-880 Slow cooling	(1)1,230-1,250 (2)1,210-1,230 Oil(hot bath)	560-580 Air cooling	277 Max	64 Min
	YXM27	800-880 Slow cooling	1,180-1,210 Oil(hot bath)	550-580 Air cooling	255 Max	64 Min
	YXM42	820-880 Slow cooling	(1)1,190-1,210 (2)1,170-1,190 Oil(hot bath)	520-590 Air cooling	285 Max	66 Min
	YXM60	820-880 Slow cooling	(1)1,190-1,210 (2)1,170-1,190 Oil(hot bath)	560-590 Air cooling	285 Max	66 Min
	XVC5	820-880 Slow cooling	(1)1,230-1,250 (2)1,210-1,230 Oil(hot bath)	550-580 Air cooling	285 Max	64 Min
	YHX2	820-880 Slow cooling	(1)1,270-1,290 (2)1,250-1,270 Oil(hot bath)	560-580 Air cooling	248 Max	62 Min
	YXR3	800-880 Slow cooling	(1)1,150-1,170 (2)1,130-1,150 Oil(hot bath)	560-590 Air cooling	241 Max	57 Min
	YXR33	800-880 Slow cooling	1,080-1,140 Oil(hot bath)	550-600 Air cooling	241 Max	56 Min
	YXR7	800-880 Slow cooling	(1)1,160-1,180 (2)1,130-1,150 Oil(hot bath)	540-580 Air cooling	241 Max	62 Min
P/M High Speed Tool Steels	HAP10	820-880 Slow cooling	(1)1,170-1,190 (2)1,050-1,170 Oil(hot bath)	550-580 Air cooling	269 Max	(1) 65-66 (2) 58-65
	HAP40	820-880 Slow cooling	(1)1,180-1,210 (2)1,120-1,190 Oil(hot bath)	560-580 Air cooling	277 Max	(1) 66-68 (2) 64-66
	HAP50	820-880 Slow cooling	(1)1,200-1,220 (2)1,180-1,200 Oil(hot bath)	560-580 Air cooling	293 Max	(1) 67-69 (2) 66-67
	HAP72	820-880 Slow cooling	1,180-1,210 Oil(hot bath)	560-580 Air cooling	352 Max	68-70
	HAP5R	820-880 Slow cooling	1,120-1,160 Oil(hot bath)	530-580 Air cooling	269 Max	58-62

Remarks (1) Tools required for high strength at elevated temperature
(2) Tools required for higher toughness



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Standard heat treatment conditions of YSS High Speed Tool Steels

Annealing

1. All material is delivered as spheroidized annealed condition.
2. When used after reforging, spheroidized annealing is to be done before hardening.
3. Stress relief annealing is to be done in order to remove stress occurred by cold working such as cold drawing, cold rolling or cutting and machining.
 - Heating temperature : 650-750°C
(to aim higher temperature when softening is required)
 - Holding time :1h/25mm thickness

Holding time of austenitizing

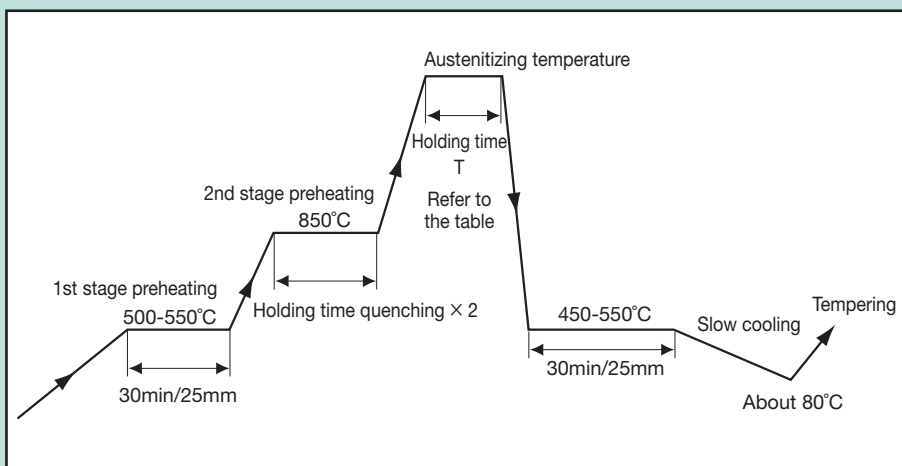
Preheating time 1st stage : 30 minutes for every 25 mm of the tool at 500-550°C

2nd stage: (Ta × 2) at 850°C

3rd stage: (Ta × 2) at 1,050°C

} Preheating is (Ta × 2) at 900°C for small thickness (50 mm max.) and simple shape tools, and wherever facilities are limited.
The first stage can be omitted for small tools.

Tools of ordinary shape



(Remarks) As for simple figure tools, 1st stage preheating can be skipped and oil quenching can be applied instead of hot salt bath quenching. For complex figure tools, 3rd stage preheat (1,050°C) applying is preferable.

Holding time at austenitizing temperature (Ta)

Heating furnace	Time	Thickness (mm)									
		5	10	20	30	40	50	60	70	80	90
Salt bath	Holding time (sec)	60	90	160	240	280	350	390	420	440	495
	Magnification(Holding time/Thickness)	×12	×9	×8	×8	×7	×7	×6.5	×6	×5.5	×5.5

(Remarks) Holding time in salt bath = dipping time

Holding time at tempering temperature (Tt)

Thickness (mm)	≤ 25	26 - 35	36 - 64	65 - 84	85 - 124	125 - 174	175 - 249	250 - 349	350 - 499
Tempering holding time (hour)	1	1.5	2	3	4	5	6	7	8

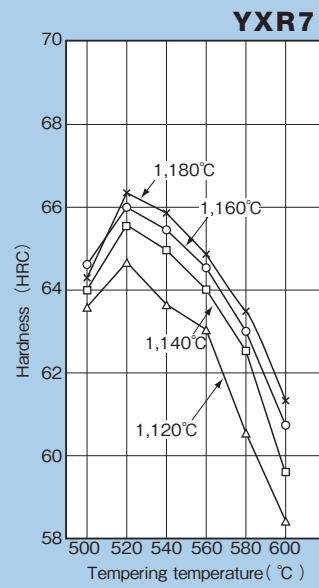
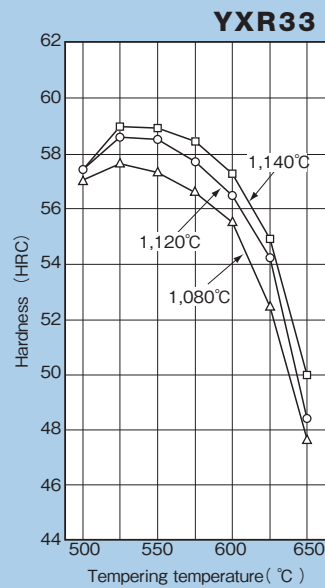
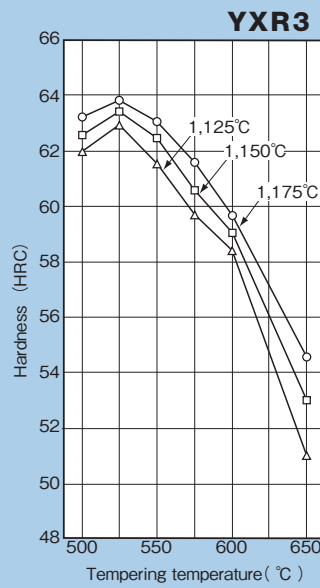
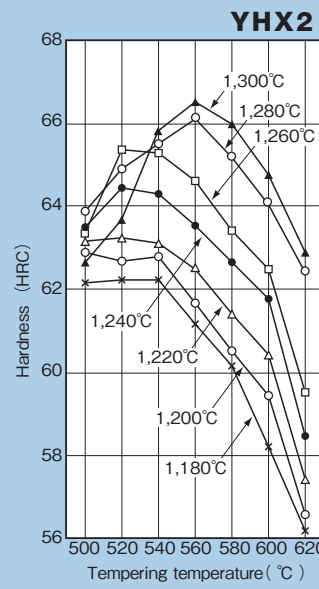
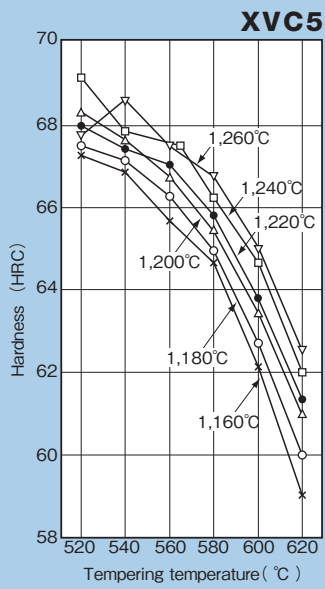
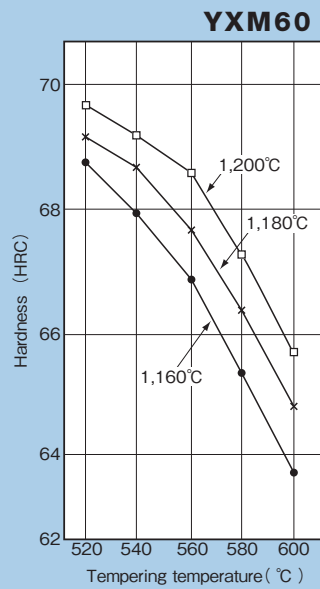
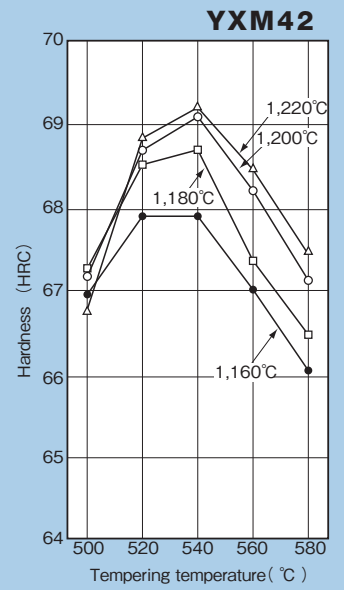
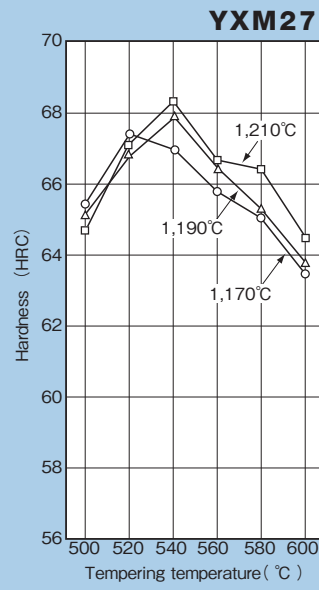
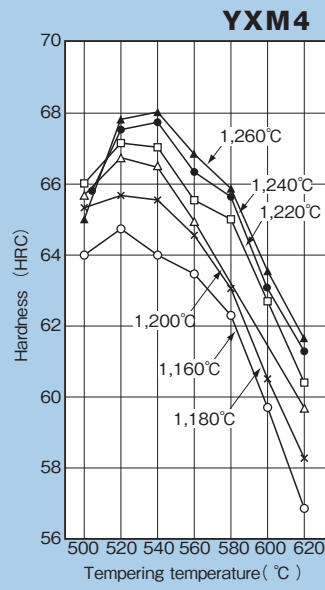
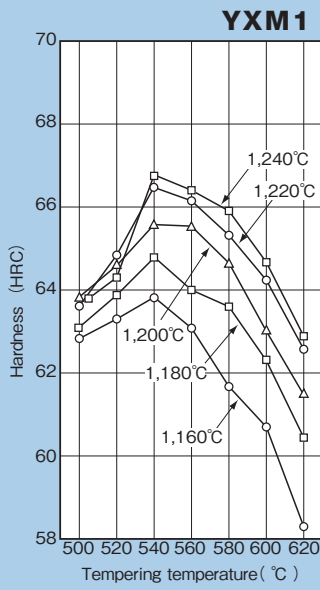
(Remarks) Tempering is needed more than 2 times for grades containing no cobalt and needed more than 3 times for grades cobalt alloyed in order to make it tough enough.



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Standard heat treatment conditions of YSS High Speed Tool Steels

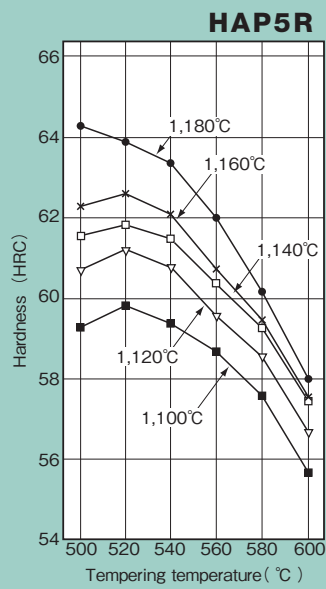
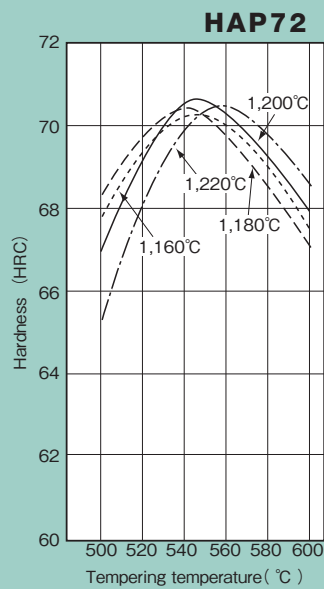
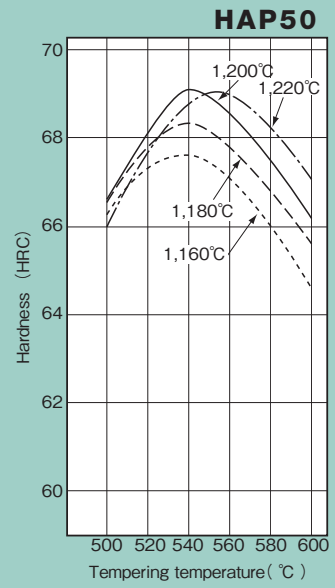
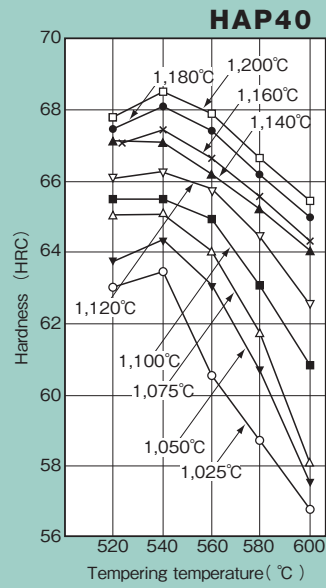
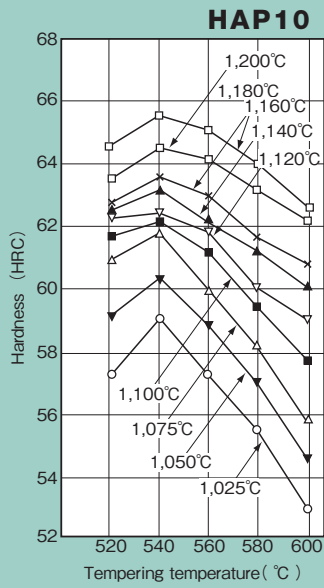
Conventional High Speed Tool Steels



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Standard heat treatment conditions of YSS High Speed Tool Steels

P/M High Speed Tool Steels



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- Please contact a representative of our Specialty Steel Division if there are any questions or problems.

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