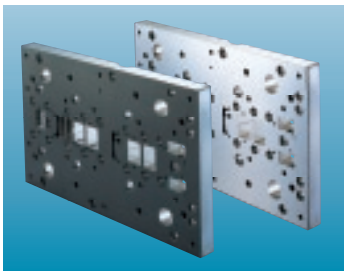
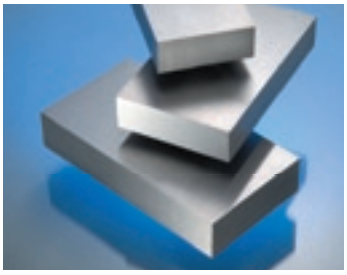
HITACHI

General Catalog of YSS TOOL STEELS

Hitachi Metals, Ltd.



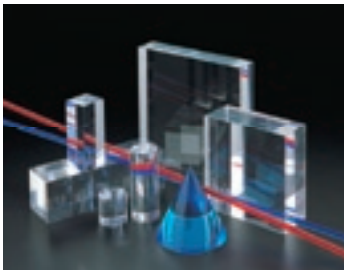
COLD WORKING TOOL STEELS



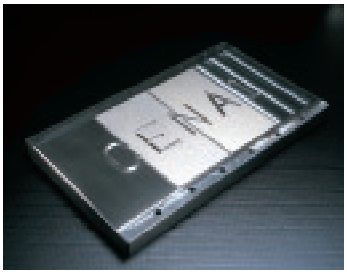
COLD WORKING TOOL STEELS
SLD MAGIC

HOT WORKING TOOL STEELS

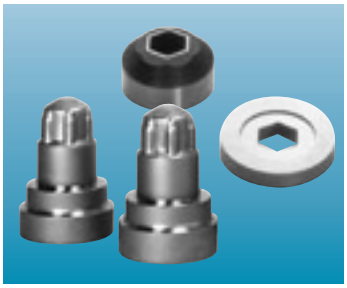
DIE STEELS FOR DIE CASTING
DAC Series



PLASTIC MOLD STEELS
HPM Series

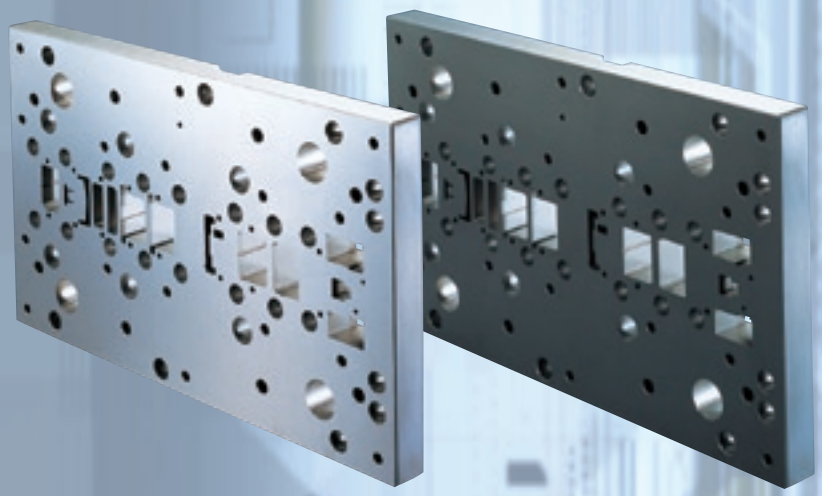


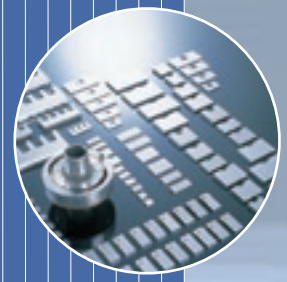
PLASTIC MOLD STEELS
CENA1

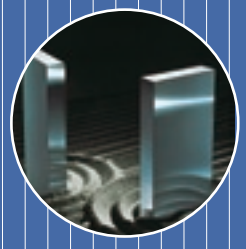


HIGH SPEED TOOL STEELS

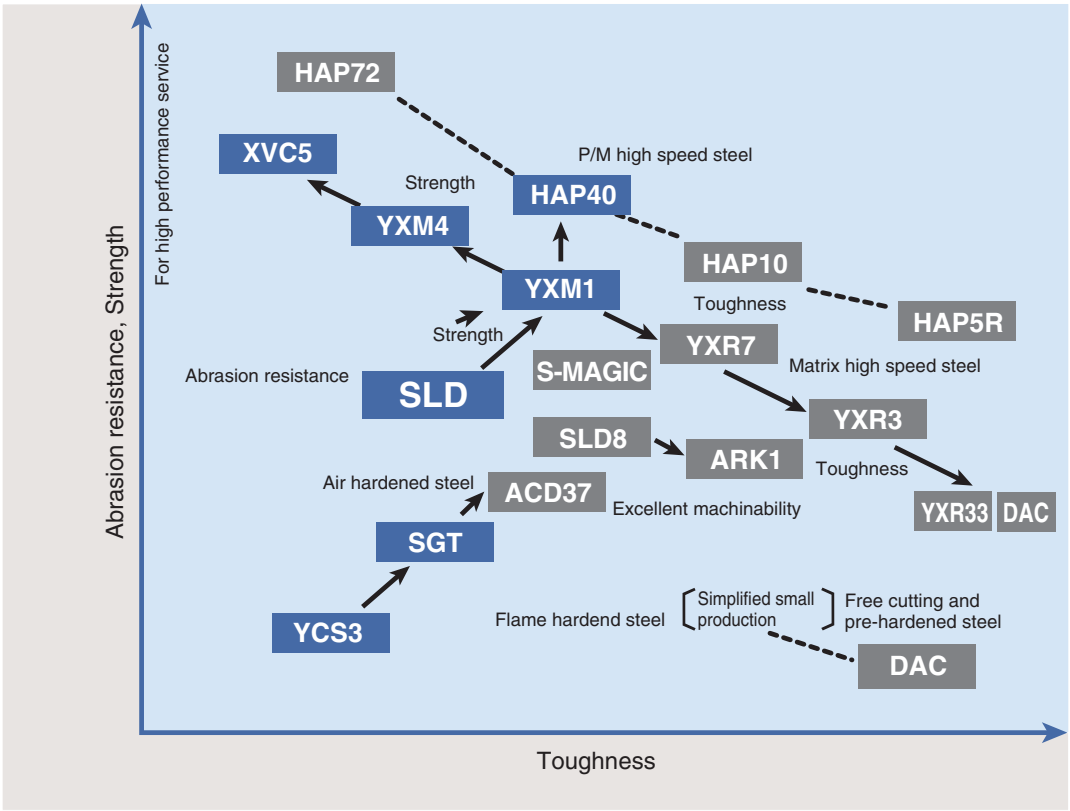
YSS
COLD WORKING TOOL STEELS







Characteristics of YSS Cold Work Tool Steels



●Comparison of charactistics

YSS grade	Abrasion resistance	Pressure resistance	Strength at elevated temperature	Toughness	Hardenability	Distortion by heat treatment	Machinability	Weldability	Standard hardness (HRC)
S-MAGIC	A	A	B	A^{-}	A^{+}	A^{+}	A^{-}	B	58~62
SLD	A	A	B	B	A^{+}	A^{+}	B	C	57~63
ARK1	B^{+}	A	B	A	A^{+}	A^{+}	A	B	58~60
SLD8	A^{-}	A	B^{+}	A^{-}	A^{+}	A	B^{+}	C	58~63
SLD10	A^{-}	A^{+}	A^{-}	A^{-}	A^{+}	A	B^{-}	C	59~65
CRD	A^{+}	A	C	C	B^{-}	B	C	D	57~63
YCS3	D	C	D	C	D	D	A^{+}	B	57~63
SGT	C	B^{+}	D	B	C	D	A	B	57~63
ACD37	B	A^{-}	C	B	A^{+}	A	A	B	55~60
HMD5 HMD1	C	B	D	B	—	—	A	A	55~60
HPM1 HPM2T	D^{-}	D	D	A^{-}	—	—	A^{-}	A	40
YXM1	A	A^{+}	A	A^{-}	B	B	B	C	58~64
YXM4	A^{++}	A^{+}	A^{+}	B	B	B	B^{-}	C	62~66
XVC5	A^{+++}	A^{++}	A^{++}	C	B	B^{-}	C	D	63~67
YXR7	A	A^{+}	A	A	A	B	B	C	61~65
YXR3	A^{-}	A	A	A^{+}	B	B	B^{+}	C^{+}	58~61
YXR33	B	B	A^{+}	A^{++}	A	B	B^{+}	C^{+}	54~58
HAP5R	A	A^{+}	A	A^{+}	A	A	B	C	58~62
HAP10	A^{+}	A^{+}	A	A	A	A	B^{-}	C	62~65
HAP40	A^{++}	A^{++}	A^{++}	A^{-}	B	A	C^{+}	C	64~67
HAP72	A^{+++}	A^{+++}	A^{+++}	C	A^{-}	A	C^{-}	D	68~71

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

Applications and YSS grade Features

YSS grade	Main applications	Features
S-MAGIC (NEW)	Cold work dies for high-tensile steels, SUS, mass production, and general use.	High performance cold work tool steel attaining both extended mold lifespan and outstandingly easy mold fabrication. 60~62 HRC with high temperature. tempering. Excellent wear & galling resistance.
SLD	Cold work dies for general use, forming roll, shear.	Cold work die steel with high abrasion resistance for general use, excellent harden-ability and minimal quench stress.
ARK1	Dies for printed circuit board, die plates, stripper plates.	Cold work die steel with high toughness and improved machinability. The same heat treatment conditions as SKD11.
SLD8	Rolling dies, cold forging dies.	62HRC or more with high temperature tempering, superior machinability and toughness.
SLD10	Rolling dies.	Extremely highest hardness in die steels. 62-64HRC, with excellent toughness.
CRD	Drawing dies, blanking dies for mass production, brick liner.	Cold work die steel with highest abrasion resistance.
YCS3	Press forming dies, jigs and tools.	Carbon tool steel for small production to be quenched in oil , easy to heat-treat.
SGT	Dies for deep drawing, gauges.	Cold work die steel with superior machinability for generaluse; Be careful with quenching large dies and wire electric discharge machining.
ACD37	Dies for deep drawing, gauges.	Vacuum quenched and air quenched steel, improved for SGT as to hardenability and wire electric discharge machinability.
HMD5 HMD1	Dies for deep drawing.	Steel for flame hardening, resulting in high hardness and small strain even with air quenched; good weldability.
HPM1	Press forming dies for small production, jigs and tools.	Free cutting and fully hardened steel, good nitriding characteristics.
YXM1	Cold forging dies, cold heading dies, slitter.	High speed steel with high abrasion resistance and toughness for general use.
YXM4 XVC5	Cold forging dies, drawing dies.	High speed steel to prevent from abrasion, seizure and deformation under high pressure.
YXR7	Rolling dies, cold forging dies, roll, cold forging panches, blanking panches.	Matrix high speed steel, extremely highest toughness in 62-65HRC. available to vacuum quenching.
YXR3	Dies to be used for cracking or chip breaking resistance.	Matrix high speed steel for general use, extremely highest toughness in 58-61HRC.
YXR33	Cold forging dies, warm forging dies.	Matrix high speed steel extremely highest toughness in high speed steels.
HAP5R	Cold forging dies, fine blanking dies.	Standard hardness 56-58HRC. Extremely tough Powder Metallurgy process high speed steel.
HAP10	Fine blanking dies.	Extremely tough Powder Metallurgy process high speed steel.
HAP40	Press forming dies for mass production, roll.	P/M high speed steel with high abrasion resistance and toughness for general use.
HAP72	Cold plastic working dies of long life, high performanced IC molds.	P/M high speed steel with high hardness and highest abrasion resistance.

Type and Chemical Compositions

Grade		Chemical Composition (%)										
YSS	JIS equivalent	C	Si	Mn	P	S	Ni	Cr	W	Mo	V	Co
S-MAGIC	Patent pending	High performance cold work tool steel										
SLD	SKD11	1.50	0.25	0.45	≤ 0.025	≤ 0.010	–	12.00	–	1.00	0.35	–
ARK1	Patented steel	High toughness cold work tool steel										
SLD8	Patented steel	High strength cold work tool steel										
CRD	SKD1	2.10	0.25	0.45	≤ 0.025	≤ 0.010	–	13.50	–	–	–	–
YCS3	SKS93	1.05	0.35	0.80	≤ 0.030	≤ 0.030	–	0.40	–	–	–	–
SGT	SKS3	0.95	0.25	1.05	≤ 0.025	≤ 0.010	–	0.75	0.75	–	–	–
ACD37		0.85	0.25	2.10	≤ 0.025	≤ 0.010	–	1.20	–	1.50	–	–
HMD5 HMD1	Original steel	Flame hardened tool steel										
HPM1	Patented steel	0.12	0.30	0.90	≤ 0.025	≤ 0.10	3.00	–	–	0.30	Cu2.2	Al1.0
YXM1	SKH51	0.85	0.25	0.35	≤ 0.025	≤ 0.010	–	4.15	6.50	5.30	2.05	–
YXM4	SKH55	0.85	0.25	0.35	≤ 0.025	≤ 0.010	–	4.15	6.50	5.30	2.05	5.00
XVC5	SKH57	1.25	0.25	0.35	≤ 0.025	≤ 0.010	–	4.15	10.00	3.50	3.45	10.00
YXR7 YXR3	Original steel	Matrix high speed steel										
YXR33	Patented steel	Extremely tough matrix high speed steel										
HAP5R	P/M high speed steels	Extremely tough P/M high speed steel										
HAP10		1.3	–	–	–	–	–	5.0	3.0	6.0	4.0	–
HAP40	SKH40	1.3	–	–	–	–	–	4.0	6.0	5.0	3.0	8.0
HAP72	Patented steel	2.1	–	–	–	–	–	4.0	9.5	8.2	5.0	9.5

Heat Treatment

(1)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 occured by cold working such as cold drawing, cold rolling or cutting and machining.
   • Heating temperature: 650-700°C
   • Holding time: 1h/25mm thickness

(2)Holding time at hardening temperature

● High speed tool steel

1. Preheating time 1st stage: 30 minutes for every 25 mm of the tool at 500-550°C
   2nd stage: (holding time X 2) at 850°C
   3nd stage: (holding time X 2) at 1,050°C

Preheating is (holding time X 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.

2. Holding time at hardening temperature (holding time)

Furnace type	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
	Thickness X multiple	X12	X9	X8	X8	X7	X7	X6.5	X6	X5.5	X5.5

Note: Use the holding time in the salt bath as the immersion time.

●Cold die steels, alloy tool steels and carbon tool steels

1. Preheating time 1st stage: (holding time X 2) at 500-550°C
   2nd stage: (holding time X 1) at 750-800°C
   (Unnecessary for SK, SKS)
   Except that preheating can be omitted wherever an electric furnace is used or for small tools (50mm or less thickness) and simple shape tools.

2. Holding time at hardening temperature (holding time)

Furnace type	Thickness (mm) / Time	≤ 15	25	50	75	100	125	150	200	300
Salt bath or electric furnace	Holding time (min)	15	25	40	50	60	65	70	80	100

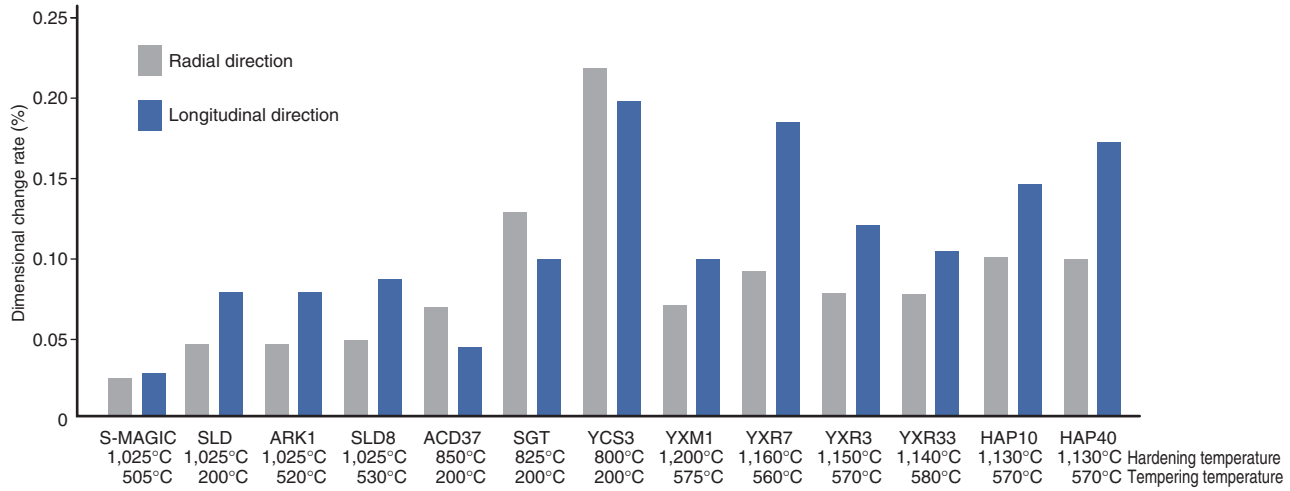
Note: Using salt bath needs preheating and the holding time used as the immersion time.

(3)Holding time at tempering temperature

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

Note: Apply this standard to tempering at 500°C or more, and increase elongate tempering time to tempering temperature X 1.5 for 250-500°C and holding time X 2 for tempering temperature less than 250°C

(4)Dimensional changes after heat treatment



Heat Treatment

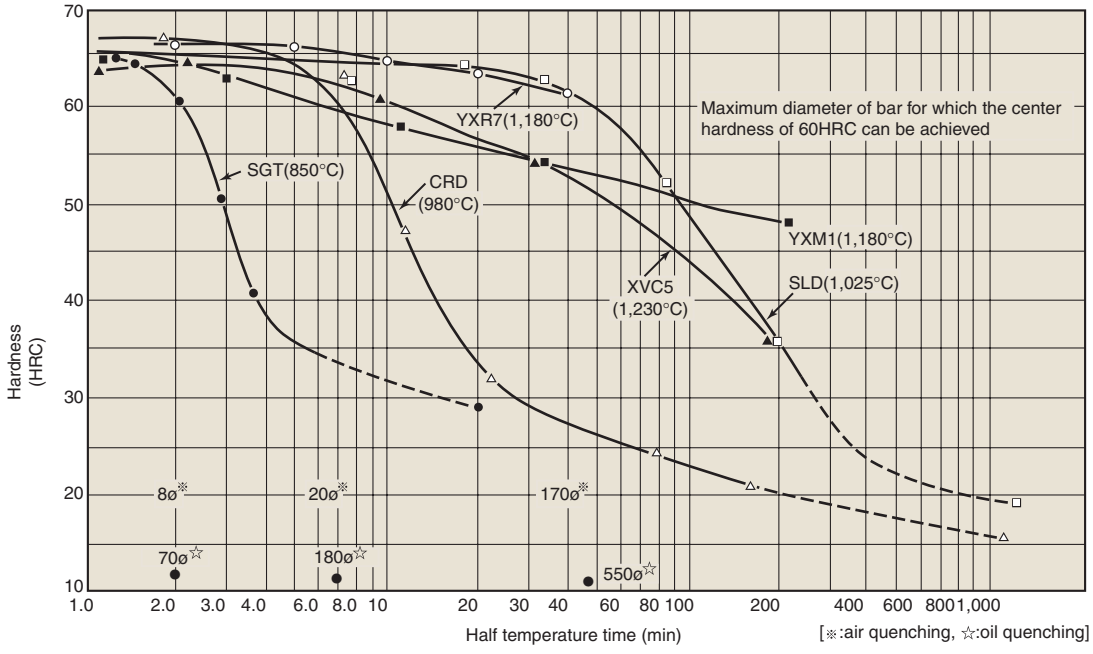
(5) Standard heat treatment conditions

YSS grade	Annealing		Hardening	Tempering	
	Temperature (°C)	Hardness (HBW)	Temperature (°C)	Temperature (°C)	Hardness (HRC)
S-MAGIC	830-880 Slow cooling	≤ 255	1010-1040 Air quenching	480~530 Air cooling	≥ 60
SLD	830-880 Slow cooling	≤ 248	1000-1050 (980-1030) Air quenching (Oil quenching)	150~200 Air cooling	≥ 58
ARK1	830-880 Slow cooling	≤ 248	1010-1040 Air quenching	480~530 Air cooling	≥ 58
SLD8	830-880 Slow cooling	≤ 248	1020-1040 Air quenching	520~550 Air cooling	≥ 60
CRD	830-880 Slow cooling	≤ 248	930-980 (950-1000) Oil quenching (Air quenching)	150~200 Air cooling	≥ 61
YCS3	750-780 Slow cooling	≤ 212	790-850 Oil quenching	150~200 Air cooling	≥ 63
SGT	750-780 Slow cooling	≤ 217	800-850 Oil quenching	150~200 Air cooling	≥ 60
ACD37	750-800 Slow cooling	≤ 235	830-870 Air quenching	150~200 Air cooling	≥ 58
HMD5/HMD1	825-875 Slow cooling	≤ 235	Flame hardening		
YXM1	800-880 Slow cooling	≤ 255	(1)1220-1240 (2)1200-1220 Oil quenching	550~570 Air cooling	≥ 63
YXM4	800-880 Slow cooling	≤ 277	(1)1230-1250 (2)1210-1230 Oil quenching	560~580 Air cooling	≥ 64
XVC5	820-880 Slow cooling	≤ 285	(1)1230-1250 (2)1210-1230 Oil quenching	550~580 Air cooling	≥ 64
YXR7	800-880 Slow cooling	≤ 241	(1)1160-1180 (2)1120-1160 Oil quenching	550~580 Air cooling	≥ 61
YXR3	800-880 Slow cooling	≤ 241	(1)1150-1170 (2)1130-1150 Oil quenching	560~590 Air cooling	≥ 58
YXR33	800-880 Slow cooling	≤ 241	1080-1160 Oil quenching	550~600 Air cooling	≥ 55
HAP5R	820-870 Slow cooling	≤ 269	1120-1160 Oil quenching	530~580 Air cooling	≤ 58
HAP10	820-870 Slow cooling	≤ 269	(1)1170-1190 (2)1120-1170 Oil quenching	530~580 Air cooling	≥ 61
HAP40	820-870 Slow cooling	≤ 277	(1)1190-1210 (2)1120-1190 Oil quenching	560~580 Air cooling	≥ 64
HAP72	820-870 Slow cooling	≤ 352	1180-1210 Oil quenching	560~580Air cooling	≥ 68

(1) Simple shape tools
(2) The others, especially needs toughness
*Sample size is 15mm square or round and 20mm length based on the JIS Standard hardness test.

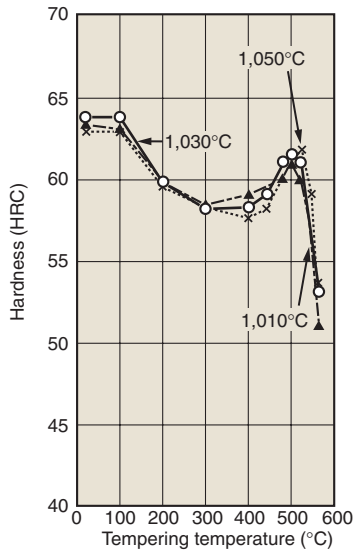
(6) Hardenability

(Half temperature time: time requred to cool from the austenitizing temperature to half that temperature) {(austenitizing temperature + room temperature) / 2}

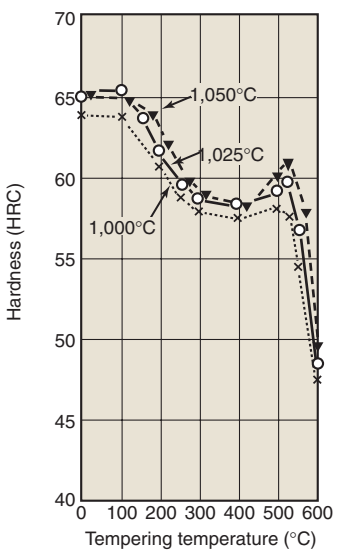


YSS Quenched and tempered hardness curve

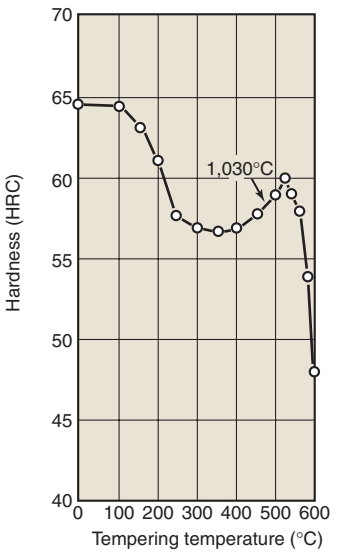
S-MAGIC



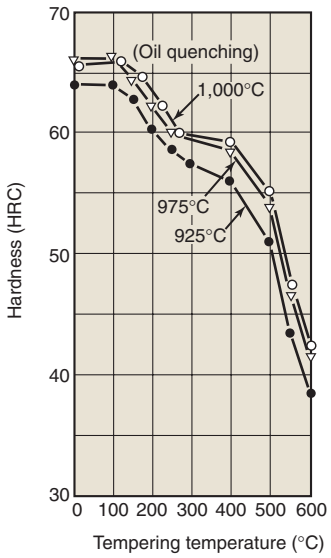
SLD



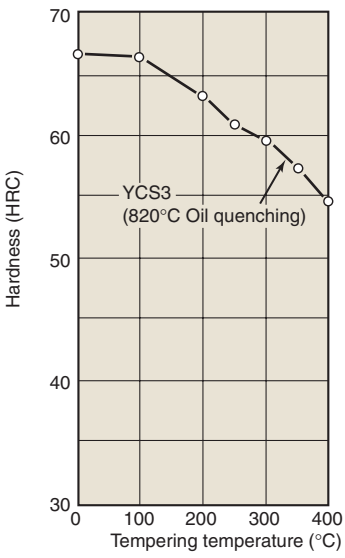
ARK1



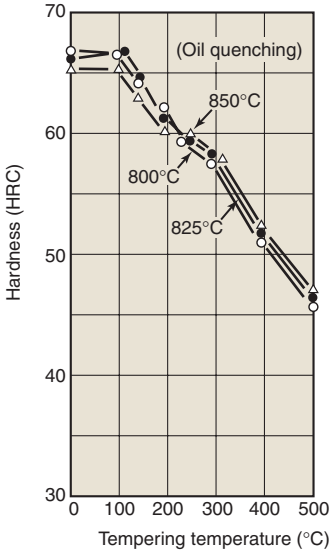
CRD



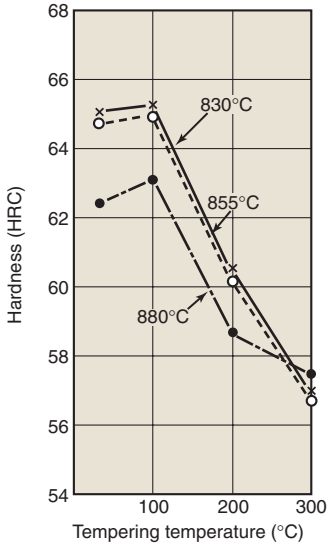
YCS3



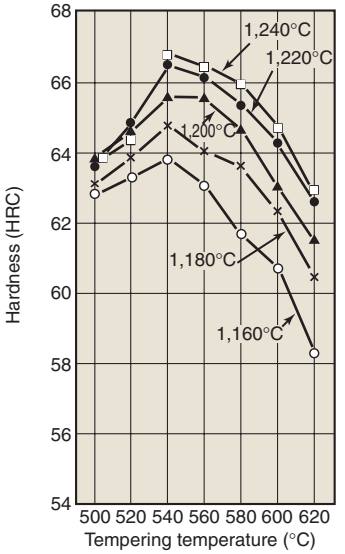
SGT



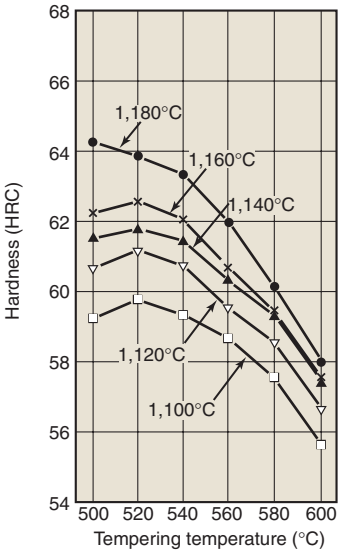
ACD37



YXM1

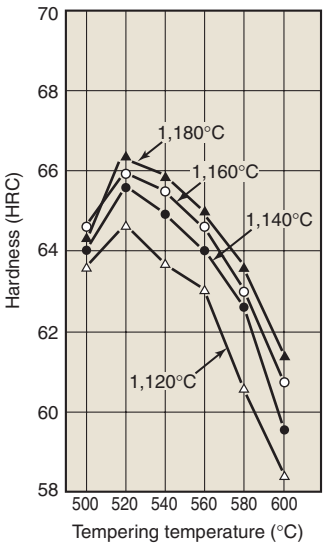


HAP5R

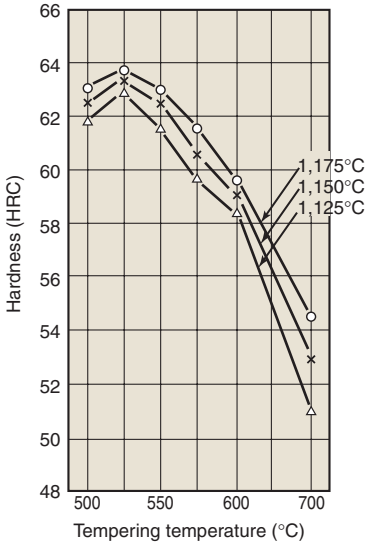


YSS Quenched and tempered hardness curve

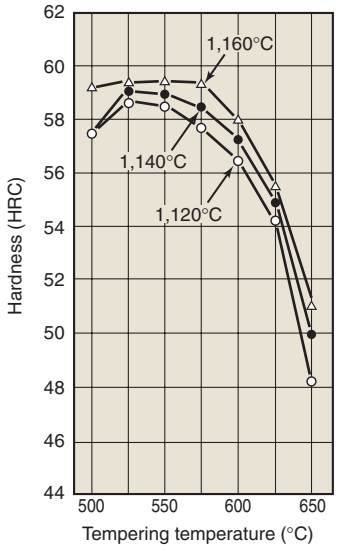
YXR7



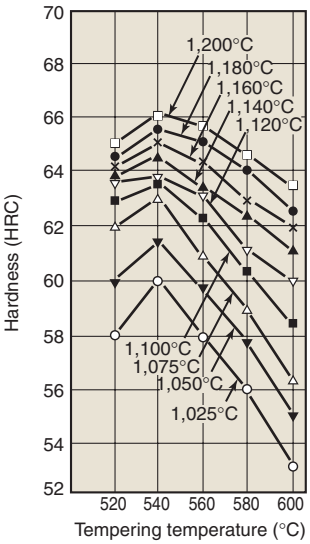
YXR3



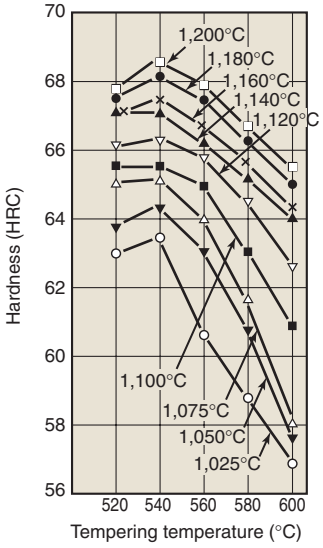
YXR33



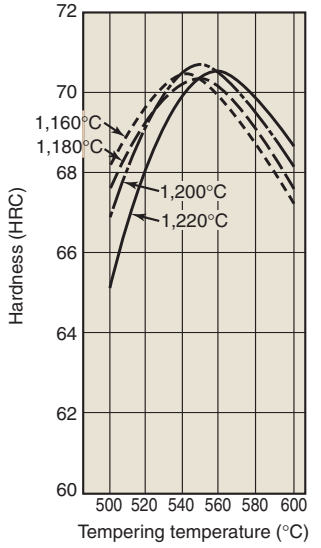
HAP10



HAP40



HAP72



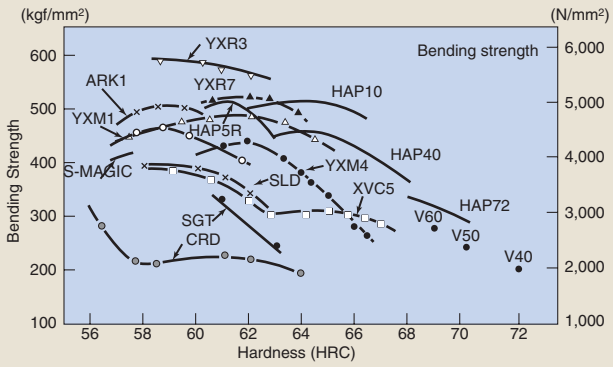
YSS Properties

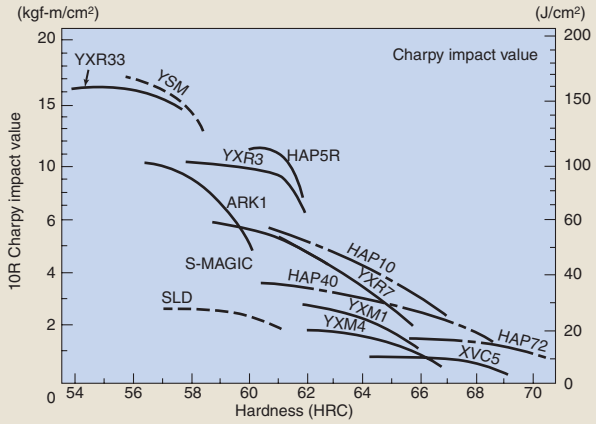
●Abrasion resistance

YSS grade	Hardness (HRC)	Specific abrasion volume($mm^3/mm^2 \cdot mm$)X10^{-7} 0.5 1.0 1.5 2.0
S-MAGIC	62.0	
SLD	60.0	
ARK1	59.0	
SLD8	62.5	
YCS3	60.0	
SGT	60.0	
ACD37	60.0	
YXM1	65.5	
XVC5	67.0	
YXR7	65.0	
YXR3	59.0	
YXR33	58.0	
HAP5R	60.0	
HAP10	64.0	
HAP40	67.0	
HAP72	70.0	

The Ogoshi type abrasion tester was used to determine abrasion resistance of matched SCM415 samples, tested under the following conditions: abrasion length of 400 mm, load of 67N, and friction speed of 0.78 m/sec.

●Toughness





Available Size Range (by Rolling)

●Round and Square Bars

(Unit: mm)

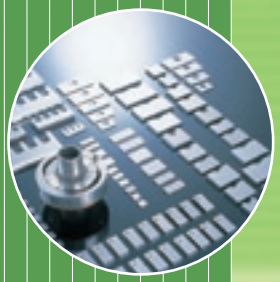
Shape / diameter or parallel side	Round bar																	Square bar										
Dimension	0	0.5	1	1.5	2	2.5	3	3.5	4	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	0	1	2	3	4	5	6	7	8	9	9.5
180	●																													
170	●																													
160	●																													
150	●																													
140	●																													
130	●																													
120	●									●																				
110	●									●																				
100	●									●															●					
90	●									●										●										
80	●									●																				
70	●									●															●					
60	●									●															●					
50	●									●										●										
40	●				●				●	●		●				●				●	●	●	●							
30	●				●				●			●				●				●	●	●	●	●	●	●	●	●	●	●
20	●		●		●		●		●	●		●		●		●				●	●	●	●	●	●	●	●	●	●	●
10	●	●	●	●	●	●	●	●	●	●		●		●		●		●		●	●	●	●	●	●	●	●	●	●	●
0										●	●	●	●	●	●	●	●	●	●								●	●	●	

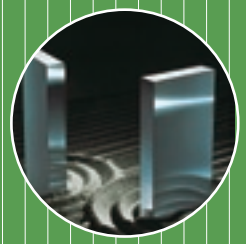
●Flat Bars

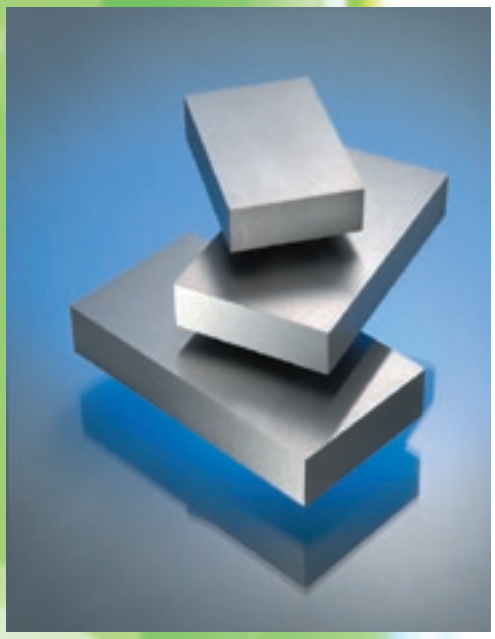
Width (mm) / Thickness (mm)	50	65	75	90	105	130	155	185	205	255	305	355	405	460
6	●	●	●											
10	●	●	●	●	●									
13	●	●	●	●	●	●	●		●					
16	●	●	●	●	●	●	●		●					
19	●	●	●	●	●	●	●	●	●	●	●			
25	●	●	●	●	●	●	●	●	●	●	●	●	●	
32	●	●	●	●	●	●	●	●	●	●	●	●	●	●
38	●	●	●	●	●	●	●	●	●	●	●	●	●	●
50		●	●	●	●	●	●	●	●	●	●	●	●	●
65			●	●	●	●	●	●	●	●	●	●	●	●
75					●	●	●	●	●	●	●	●	●	●
100						●	●	●	●	●	●	●	●	●
110								●	●	●	●	●	●	●
120								●	●	●	●	●	●	●
130								●	●	●	●	●	●	●
140								●	●	●	●	●	●	●

The BEST 10 New Prodacts Nippon Brand Prize of The Nikkan sinbunn.

YSS
COLD WORKING TOOL Steel SLD MAGIC







The arrival of a new die and mold material seeking longer mold lifespan and total cost reduction.

- Considerably prolongs lifespan of molds.
- Prevents scuffing of high-tensile steels during bendingand drawing.
- Reduces reworking man-hours through minimal heatand surface treatment deformations.
- Shortens mold processing time via enhancedmachinability.
- Lowers tool expenses by extending cutting tool lifespan.

Striving for the 21st century global standard.

Concept

SLD-MAGIC (S-MAGIC) is the revolutionary next-generation die steel attaining both extended mold lifespan and outstandingly easy mold fabrication.

SLD-MAGIC

M: Materials Magic
A: Advanced
G: Gratifying
I: Innovative
C: Cold work die steel

S-MAGIC Features

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

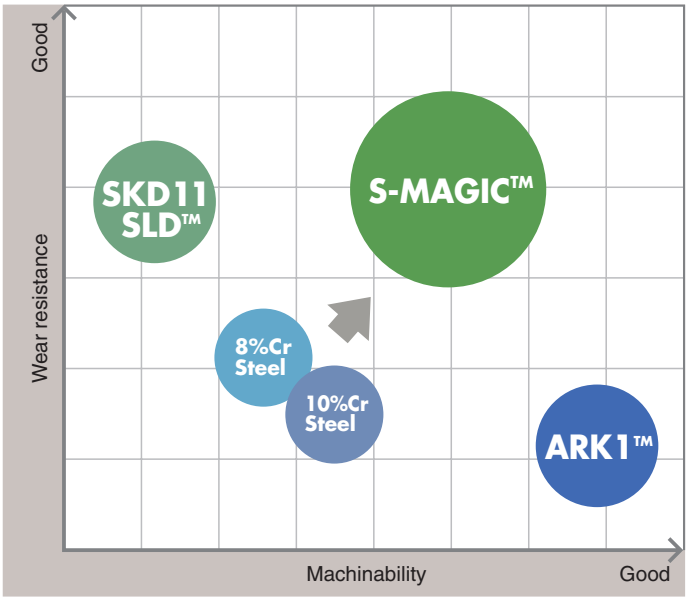
Surface treatment
Adherence between the coating layer and steel after surface treatment (CVD and other methods) is improved by approximately 30%*.

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.

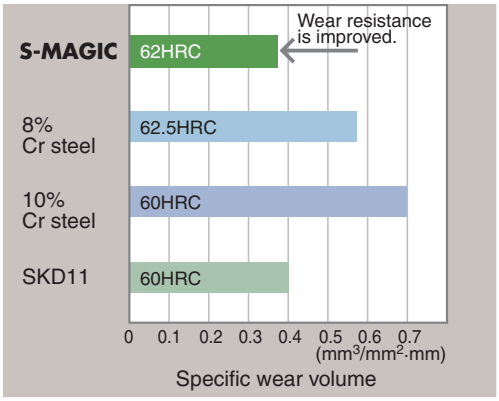
Relationship



Wear resistance

S-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

Comparison of Properties

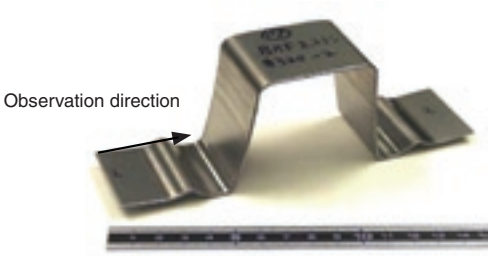
Grade	S-MAGIC	8% Cr Steel	10% Cr Steel	SKD11
Hardness (HRC)	60-62	61-63	59-61	58-60
Wear resistance	◎	○	○	◎
Surface treatment*	◎	△	△	○
Toughness	○	○	△	△
Machinability	○+	△	○	×
Dimensional change by heat treatment	◎	△	△	○
Weldability	○	○	△	△

◎ ○+ ○ △ ×
Excellent ← → Poor

*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.

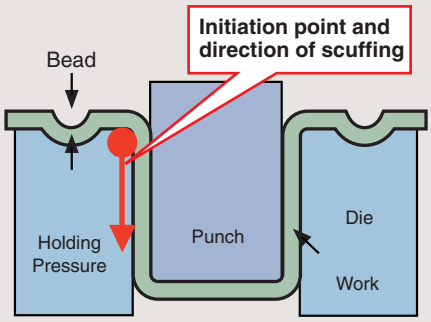
Scuffing resistance

S-MAGIC shows no scuffing on Hat Testing simulating practical mold wear phenomena.



Appearance of work Sample

Scuffing Test



Schematic of test conditions

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=0.04μm)

Scuffing Observation

S-MAGIC

Mold surface

No scuffing

Work Surface

SKD11

Mold surface

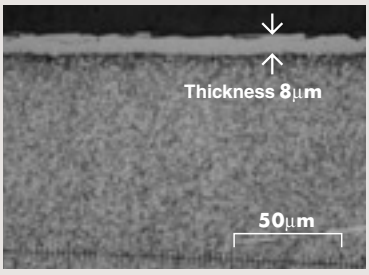
Scuffing

Work Surface

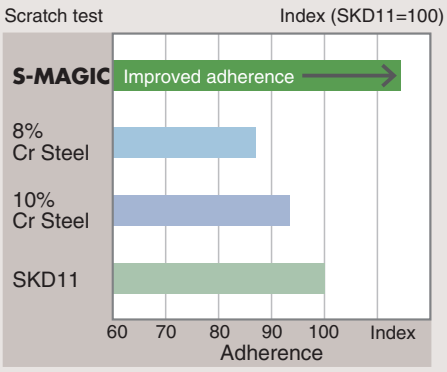
Surface treatment

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



Weldability

S-MAGIC shows lower susceptibility of cracking by welding compared with SKD11 and others.

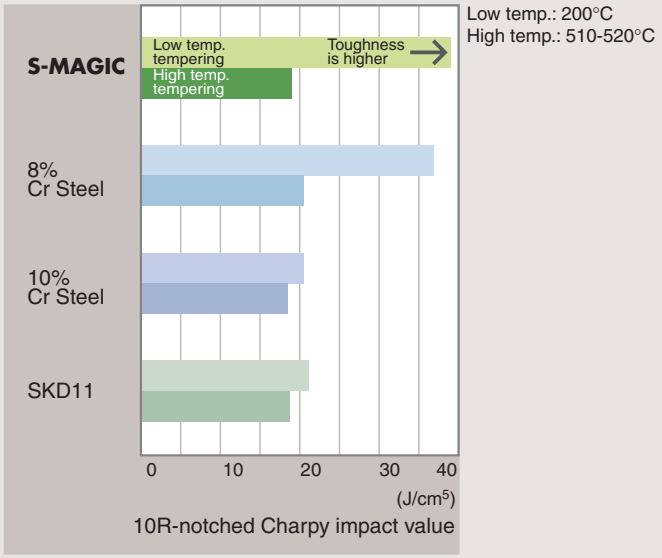
Pre-heating temperture	S-MAGIC	SKD11	8%Cr Steel	10Cr Steel
Under 100°C	××	××	××	××
100~200°C	○	××	××	××
200~300°C	○	××	○	××
Over 300°C	-	○	○	○
ranking of anti-cracking	1	3	2	3

Welding rod: SKD61 grade ϕ4.0mm
Welding current: 130A (AC)
××: Cracking occured at 3rd layer
○ : No cracking at 3rd laye

Toughness

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

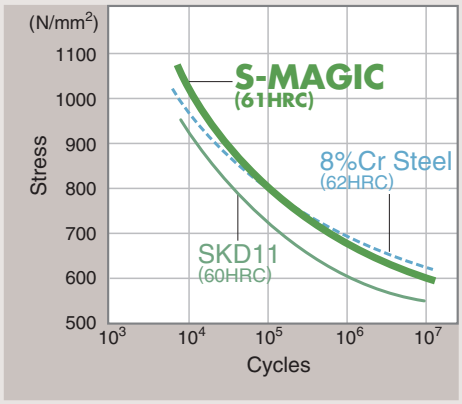
10R-notched Charpy impact value



Fatigue strength

S-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 X10^{-6}/°C	20~100°C	20~200°C
	11.7	12.3

Thermal conductivity W/m·K	Room temperature
	28.9

Specific gravity	Annealed	Quenched and tempered
	7.77	7.76

Young's modulus GPa	209

Transformation temperature	Ac1	Ms temperature
	850°C	166°C

Heat Treatment

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

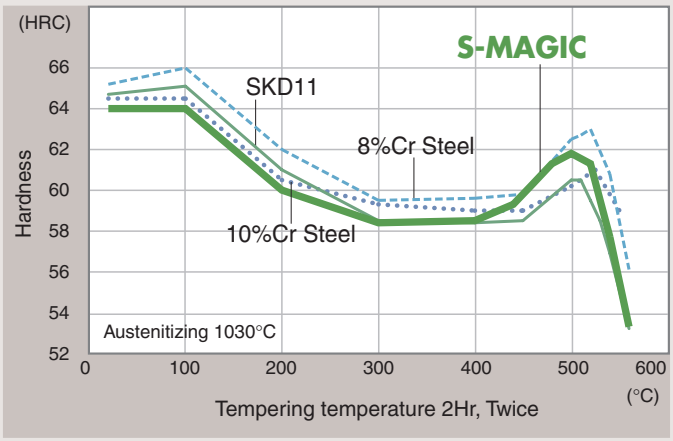
It is possible to obtain maximum hardness (60~62HRC) with tempering at around 500°C where dimensional change is near to zero, achieving both high hardness and less dimensional change.

Secular change of S-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, sub-zero treatment or stabilizing.

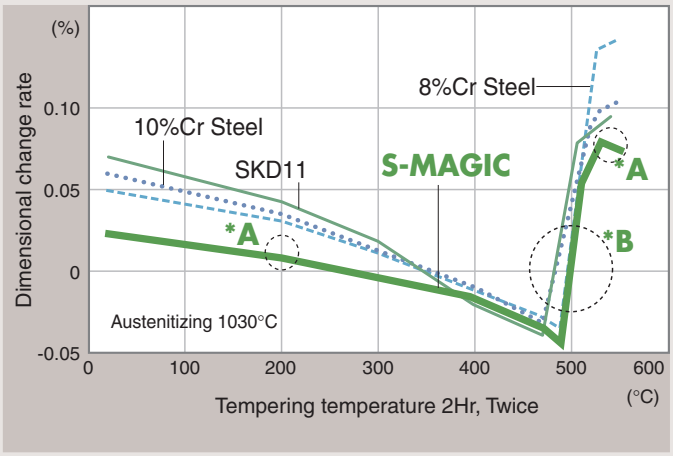
Standard Heat Treatment Conditions

Annealed Hardness	Austenitizing	Tempering	Hardness (HRC)
≤ 255HBW	1010~1040°C Air quenching	480~530°C Air cooling or 150~250°C Air cooling	≥ 60

Quenched and tempered hardness

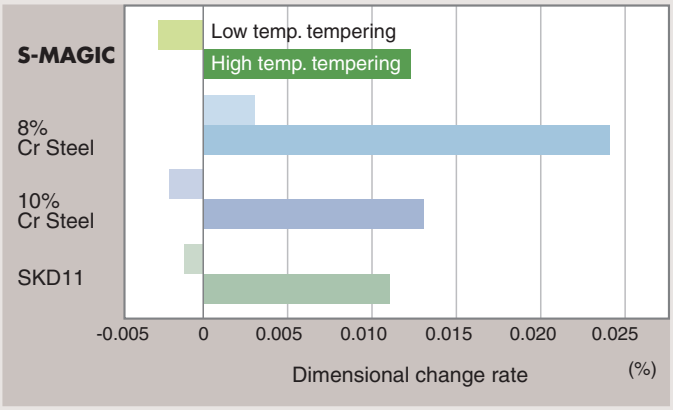


Dimensional change after heat treatment



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

Secular change / Dimensional growth

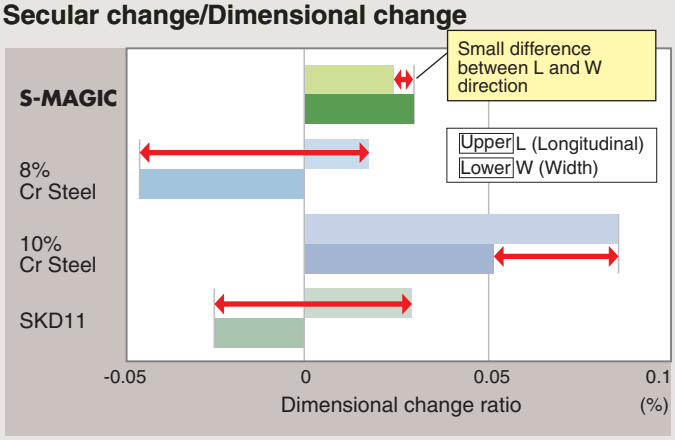


Size of test pieces: 45T X 90W X 200L
Austenitizing: 1030°C
Low temp. tempering: 180°C X 2times
High temp. tempering: 520°C X 2times
Measure: 200mm direction
Dimensional change after 6 months posterior heat treatment

Heat Treatment

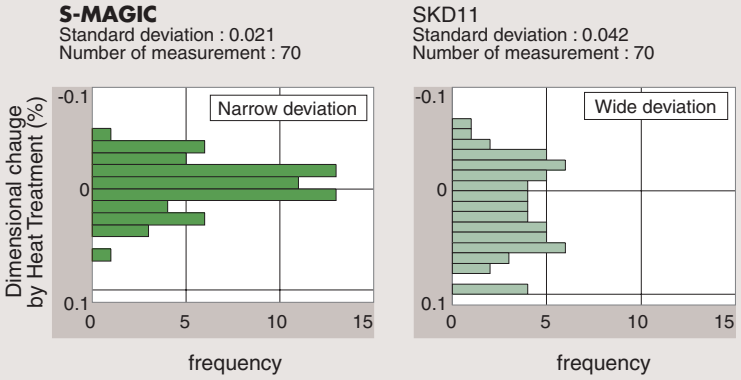
S-MAGIC shows smaller in dimentional change difference in the longitudinal, width and thickness directions, compared to SKD11 or 8% Cr steels.

Secular change/Dimensional change



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

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

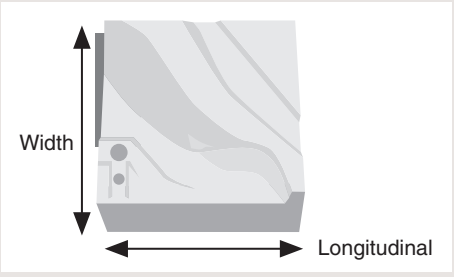


For example, in case of separation type molds, mold set up time was largely decreased because of narrow dimensional deviation.

Grade	Direction	(mm) Original Dimension	(mm) demensional Change	(%) demensional Change ratio	Mold set up time
S-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 ajusting time after heat treatment

Example of dimensional change for insert type mold.



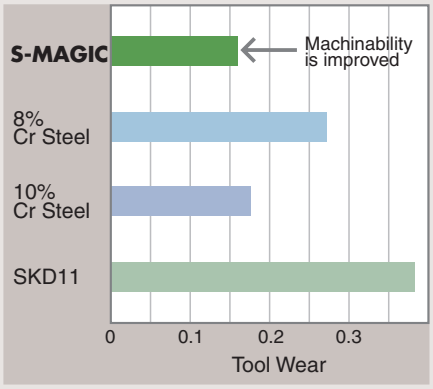
Machinability

S-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 shortened due to enhanced machinability.

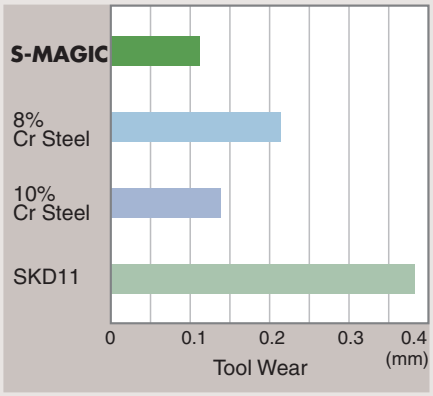
The lifespan of cutting tools is increased, thus reducing direct purchasing costs of tools.

ø125 Face Mill



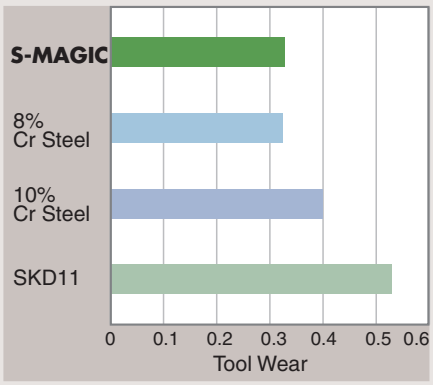
Work: Annealed condition
Tool: Coated carbide chip, 1chip only
Cutting speed: 120m/min, Dry
Feed: 0.13mm/blade
Depth of cut: 2^{Z} X 90^{W}mm,
Cutting distance: 4m

End Mill



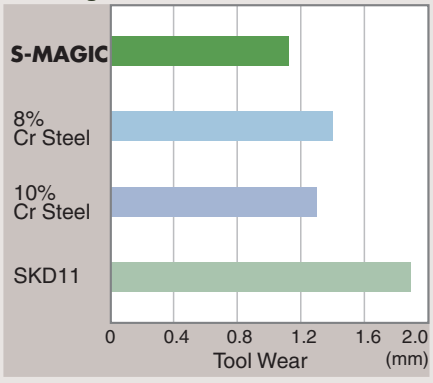
Work: Annealed condition
Tool: End mill ø8 (Co-HSS)
Cutting speed: 30m/min,Down-cut,Wet
Feed: 0.05mm/tooth
Depth of cut: 15^{Z} X 0.5^{W}mm,
Cutting distance: 5m

Drill



Work: Annealed condition
Tool: Drill ø5 (Co-HSS)
Cutting speed: 20m/min, Wet
Feed: 0.05mm/ev
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

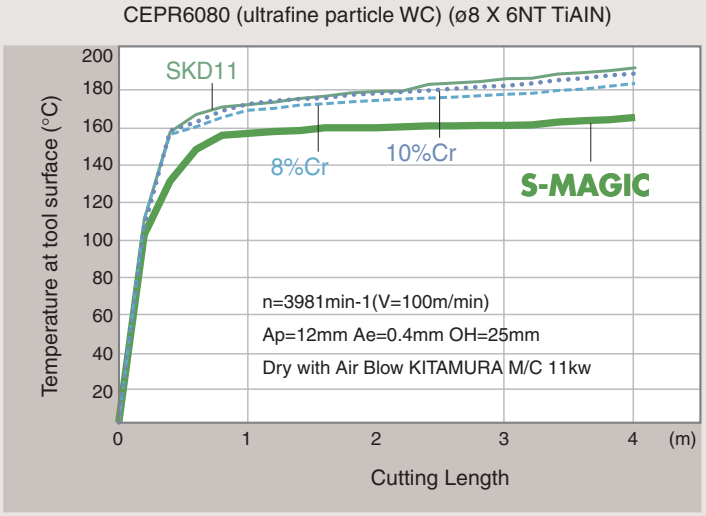
Machinability

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

S-MAGIC

SKD11
(Tempered color)

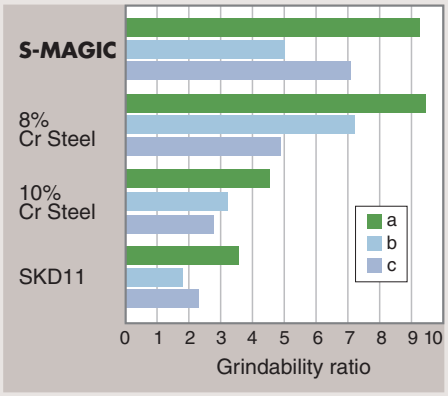
Cutting tool temperature comparison



Grindability

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

Grindability comparison as a function of diffenent grinding wheels



Grinding test conditions
- Work 50 X 90 X 200L
  (Heat treated condition)
- Machine: Reciprocal Type
- Grinding Wheel
  a: Alumina Single Crystal
  b: Alumina
  c: Alumina + Other ceramics

Grinding Conditions
- Wet Traverse Grinding
- Velocity of Wheel 33m/sec
- Table velocity 0.33m/sec
- Undercut 5µm/pass
- Cross Field 5mm/lap
- Spark out 1lap
- Total undercut 0.1mm

- Grinding ratio Ground off amount/wear of wheel
- Grinding ratio is higher the better

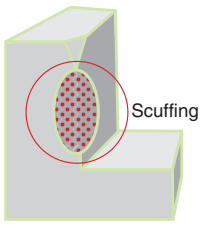
Application Examples

In addition to prolonging the lifespan of molds, S-MAGIC also enables remarkably easy mold fabrication, thereby contributing to total cost reduction and shorter processing times in the automobile and mold industries.

01 Bending die for automotive parts

Inner parts
Work 440MPa (t3.2)

	Present condition	Evaluation
Grade	SKD11	**S-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

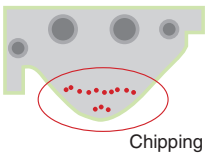


Mold lifespan significantly improved

02 Blanking die for automotive parts

Function parts
Work 590MPa (t7.0)

	Present condition	Evaluation
Grade	SKD11	**S~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

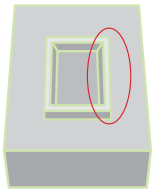


Mold lifespan more than doubles

03 Blanking die for electrical appliances

Electrical appliances
Work Film

	Present condition	Evaluation
Grade	SKD11	**S-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

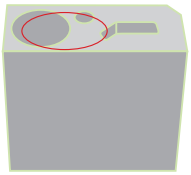


Mold lifespan 50% up

04 Blanking die for electrical appliances

Optical parts
Work SPCC (t0.8)

	Present condition	Evaluation
Grade	SKD11	**S-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

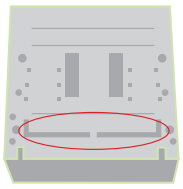


Mold lifespan doubles

05 Blanking die for electrical appliances

Liquid crystal panel parts
Work SUS304 (t0.3)

	Present condition	Evaluation
Grade	8%Cr Steel	**S-MAGIC**
Hardness	60-62HRC	60~62HRC
Heat treatment	505°C Tempering	480°C Tempering
Dimensional change	0.05%	-0.01-0.02%
Lifespan	30,000 pcs	40,000 pcs carrying on
Cause	Burr (Wear out)	Less wear



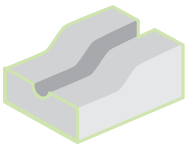
Mold lifespan 30% up

⚠ 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.

06 Die for hydroforming

Exhawst pipe
Work Steel tube

	Present condition	Evaluation
Grade	SKD11	**S-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 clue 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.

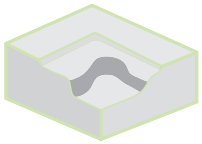


Mold adjusting time is reduced because of small dimension change of upper and lower die blocks by heat treatment

07 Die for cold press

Automobile parts
Work Hight-tensile
-strength steel

	Present condition	Evaluation
Grade	SKD11	**S-MAGIC**
Hardness	58~60HRC	60~62HRC
Heat treatment	High temp. Tempering Large dimensional ohange	High temp. Tempering Deviation is reduced to 1/2. Ajusting time is reduced
Surface treatment	TD	TD
Cause	Ball End Miuing Exchanging chips quite offen	The number of exchanged chips is reducedto 1/5~1/10 compared to SKD11. Feed rate is increased to 1.7 times.

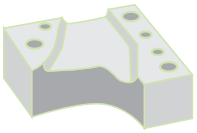


Small dimension deviation

08 Die for cold press

Inner parts
Work 440MPa (t2.3)

	Present condition	Evaluation
Grade	SKD11	**S-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	5500 pcs	Continuing beyond 15,000
Problem	Scuffing	



Mold lifespan is improved by almost 3 times.

09 Die for cold press

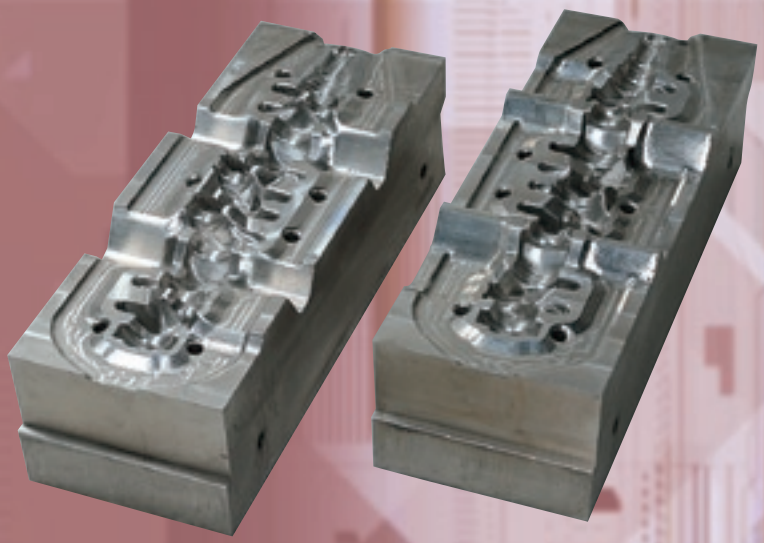
Inner parts
Work 780MPa (t2.3)

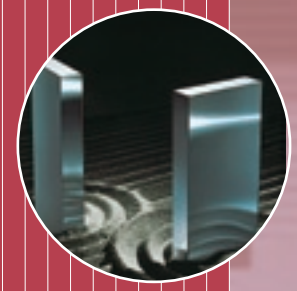
	Present condition	Evaluation
Grade	SKD11	**S-MAGIC**
Hardness	59~61HRC	60~62HRC
Heat treatment	High temp. Tempering	High temp. Tempering
Surface treatment	TD	Dimensional Changes by TD is small
Machinability	Bad	The life of chips used is 10 times longer than SKD11 cases.
Problem	Mochinabiliry and dimension change	

Small dimension changes after TD treatment

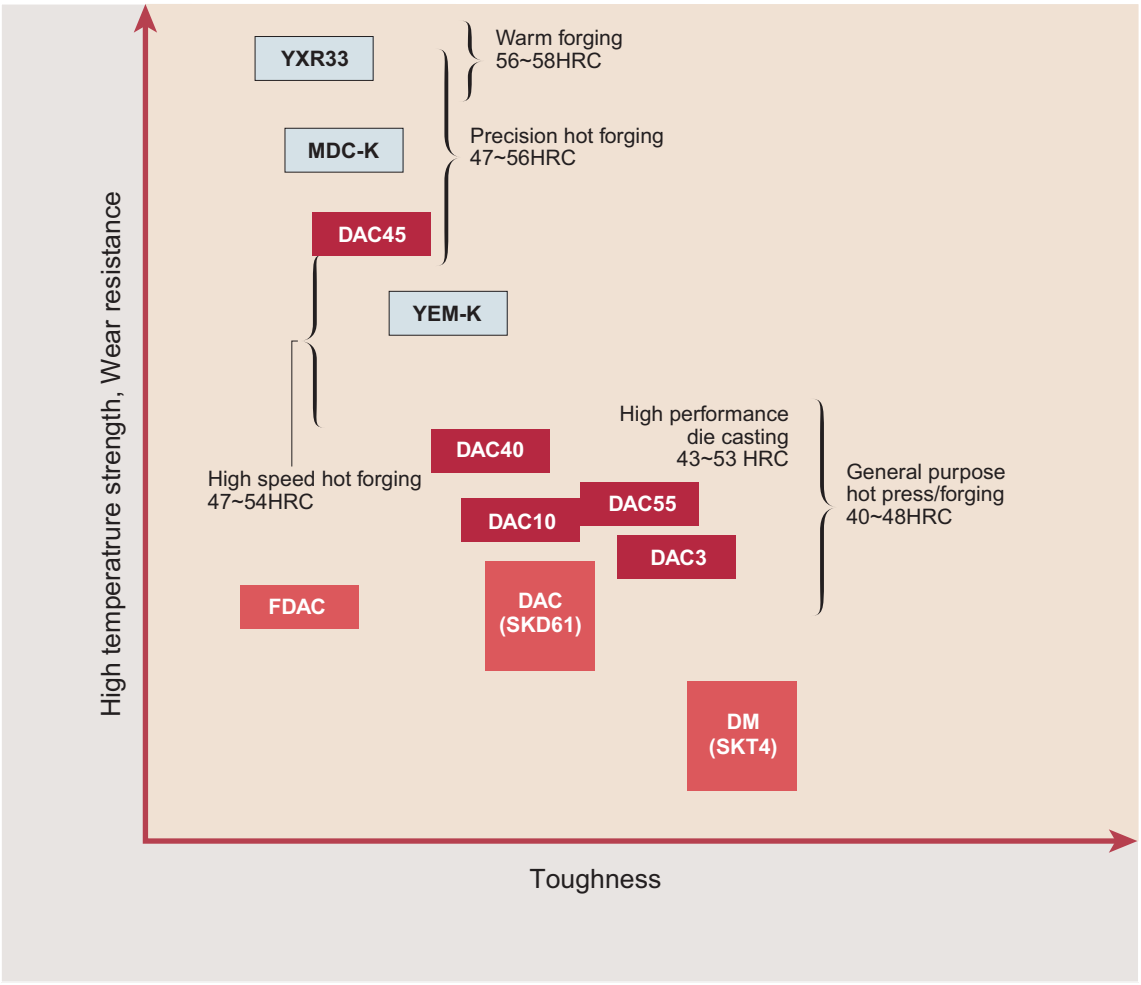
⚠ Note: The above-listed data is for application examples only and this data does not assure performance.
It is not suited for molds with EDM finished surface that require a high degree of mirror finish such as plastic molds.

YSS
HOT WORKING TOOL STEELS





Characteristics of YSS Hot Work Tool Steels



Applications and YSS grade Features

Grade		Applications	Features
YSS	JIS equivalent		
DAC	SKD61	Hot forging dies, Extrusion dise, Die casting dies.	General-purpose hot-working tool steel used in a wide range of applications.
DAC3	–	Hot forging dies, Extrusion dise.	A hot-working tool steel which has improved hardenability and greater toughness than DAC, and helps avoid cracking in hot-working press dies, high-hardened Al extrusion dies.
DAC10	–	Die casting dies, Extrusion dies.	Steel for precision die casting and hot-working press die which has excellent heat crack resistance and wear resistance.
DAC40	–	Extrusion dies.	Al extrusion die steel and hot-working press die steel which has better high-temperature strength and softening resistance than DAC.
DAC55	–	Die casting dies.	Tool steel for large or squeeze die casting moulds with excellent heat crack resistance.
YEM-K	–	Hot forging dies.	Hot-working tool steel with the improved high-temperature strength and toughness of JIS-SKD7 steel.
MDC-K	–	Hot forging dies.	Very high-strength hot working tool steel with the improved toughness of JIS-SKD8.
DAC45	–	Die casting dies, Hot forging dies.	Has great high-temperature strength and outstanding crack resistance, and is suited for hot-working press dies requiring wear resistance and high Si-Al die-cast molds requiring erosion resistance.
YXR3	–	Hot forging dies.	High-toughness matrix high speed steel.
YXR33	–	Hot forging dies, Anti-meltdown insert pin.	High-toughness matrix high speed steel for hot-working tools, and excellent wear resistance and crack resistance. Can withstand high-temperature loads such as in warm-and hot-working precision forging dies.
DM	SKT4	Hammer dies.	Tool steel for hammer dies.
FDAC	–	Dies for small lot, Simple dies Holding lock.	Free-cutting hot-working tool steel.

Chemical compositions of YSS hot-working tool steels

YSS	Grade	Chemical composition										
	JIS equivalent	C	Si	Mn	P	S	Ni	Cr	W	Mo	V	Co
DAC	SKD61	0.39	1.0	0.40	≤ 0.030	≤ 0.010	–	5.15	–	1.40	0.80	–
DAC3	(Original steel)	High toughness die steel										
DAC10	(Original steel)	High-strength die steel										
DAC40	(Original steel)	High-strength Al extrusion die steel										
DAC55	(Original steel)	High-strength and toughness die steel										
YEM-K	(Original steel)	High-strength die steel										
MDC-K	(Original steel)	High-strength die steel										
DAC45	(Original steel)	High-strength die steel										
YXR3	(Original steel)	Matrix high speed steel										
YXR33	(Original steel)	Matrix high speed steel										
DM	SKT4	0.55	0.25	0.85	0.030	≤ 0.010	1.65	1.20	–	0.35	0.15	–
FDAC	SKD61 Free cutting	0.39	1.00	0.65	0.030	0.130	–	5.15	–	1.40	0.55	–

*Harmful impurities such as S, Cu and Ni are restricted to below JIS levels using Hitachi Metals' own high-quality raw materials.

Heat Treatment

Standard heat treatment conditions for YSS hot-working tool steels

Grade	Annealing		Quenching	Tempering	
	Temperature	Hardness (HBW)	Temperature	Temperature	Hardness (HRC)
DAC	820-870 Slow cooling	≤ 229	1000-1050 Oil cooling(Air cooling)	550-650 Air cooling	≤ 53
DAC3	820-870 Slow cooling	≤ 229	1000-1050 Oil cooling(Air cooling)	550-650 Air cooling	≤ 53
DAC10	820-870 Slow cooling	≤ 229	1010-1030 Oil cooling(Air cooling)	550-650 Air cooling	≤ 53
DAC40	820-870 Slow cooling	≤ 229	1000-1050 Oil cooling	550-680 Air cooling	≤ 53
DAC55	820-870 Slow cooling	≤ 229	1010-1030 Oil cooling(Air cooling)	550-650 Air cooling	≤ 53
YEM-K	820-870 Slow cooling	≤ 229	1000-1050 Oil cooling(Air cooling)	550-650 Air cooling	≤ 53
MDC-K	820-870 Slow cooling	≤ 241	1050-1140 Oil cooling	600-700 Air cooling	≤ 55
DAC45	820-870 Slow cooling	≤ 241	1060-1080 Oil cooling	580-650 Air cooling	≤ 55
YXR3	800-880 Slow cooling	≤ 241	(1)1150-1170,(2)1130-1150 Oil cooling	560-590 Air cooling	≥ 57
YXR33	800-880 Slow cooling	≤ 241	1080-1160 Oil cooling	550-600 Air cooling	≥ 56
DM	750-800 Slow cooling	≤ 241	830-880 Oil cooling	400-650 Air cooling	≤ 50
FDAC	–	–	Delivery in prehardened condition		38-42

(1) Simple shape tools
(2) The others, especially needs toughness

Quenching and tempering time of YSS die steels

1.Holding time at hardening temperature

(1) Preheating time

First stage: 500~550°C hardening temperature holding time x 2
Second stage: 750~800°C hardening temperature holding time x 1
But preheating can be omittted when the electrical furnaces process is used or when workpieces are 50mm or under in thickness or a simple shape.

(2) Holding time at hardening temperature

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

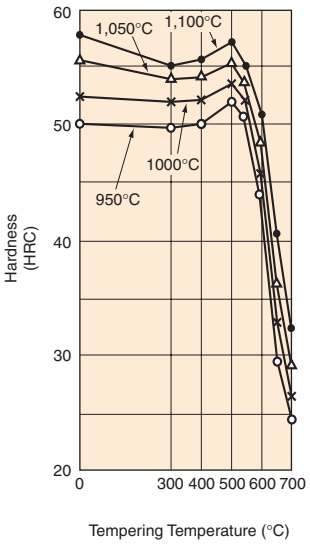
Caution: The salt bath needs preheating. Set the Soaking time same as the holding time.

2.Holding time at tempering temperature

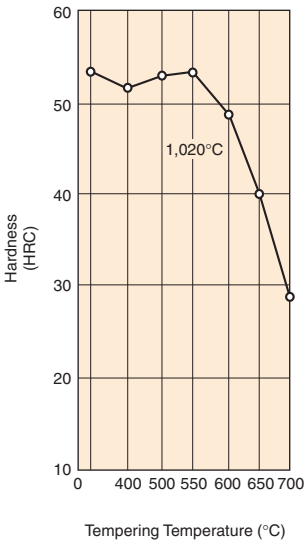
Thickness (mm)	≤ 25	26-35	36-64	65-84	85-124	125-174	175-249	250-349	350-499
Holding time (h)	1	1.5	2	3	4	5	6	7	8

YSS Quenched and tempered hardness curve

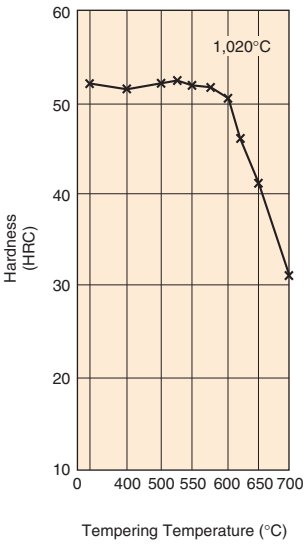
DAC



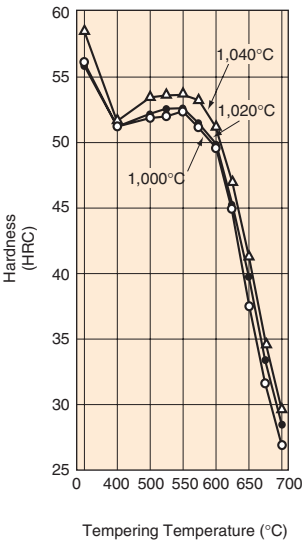
DAC3



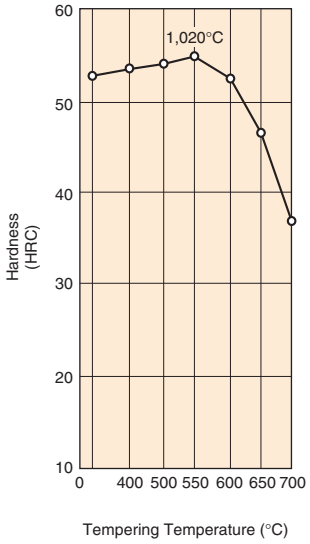
DAC10



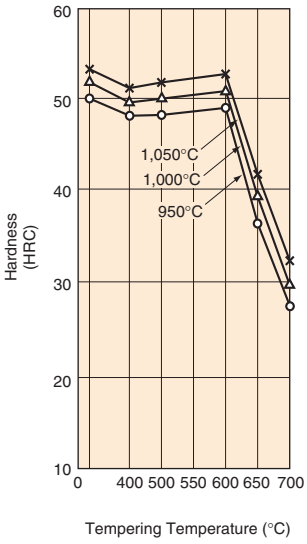
DAC55



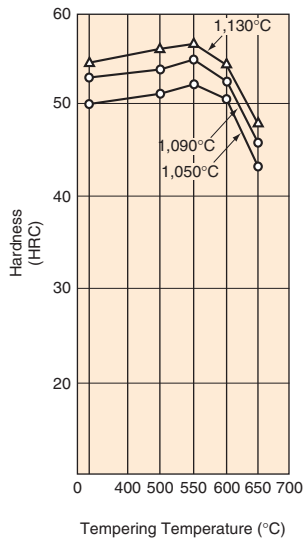
DAC40



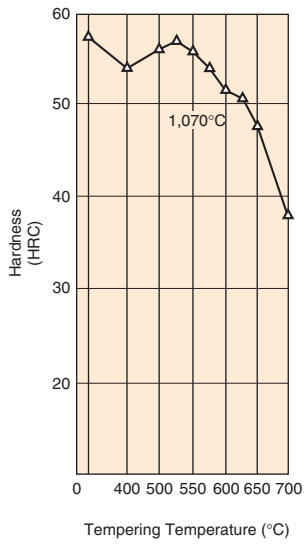
YEM-K



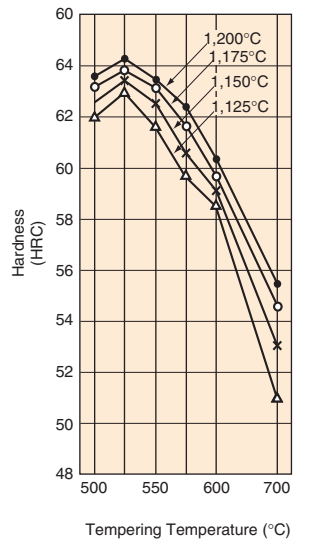
MDC-K



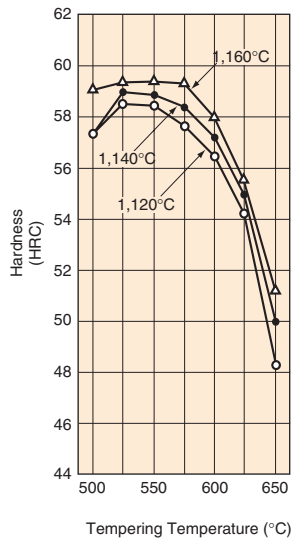
DAC45



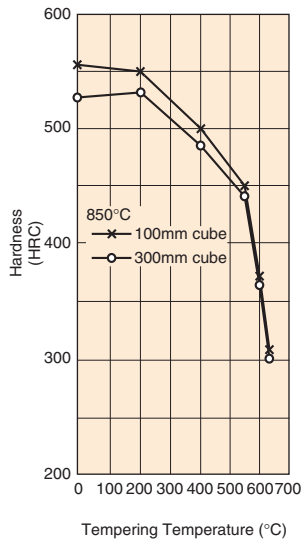
YXR3



YXR33

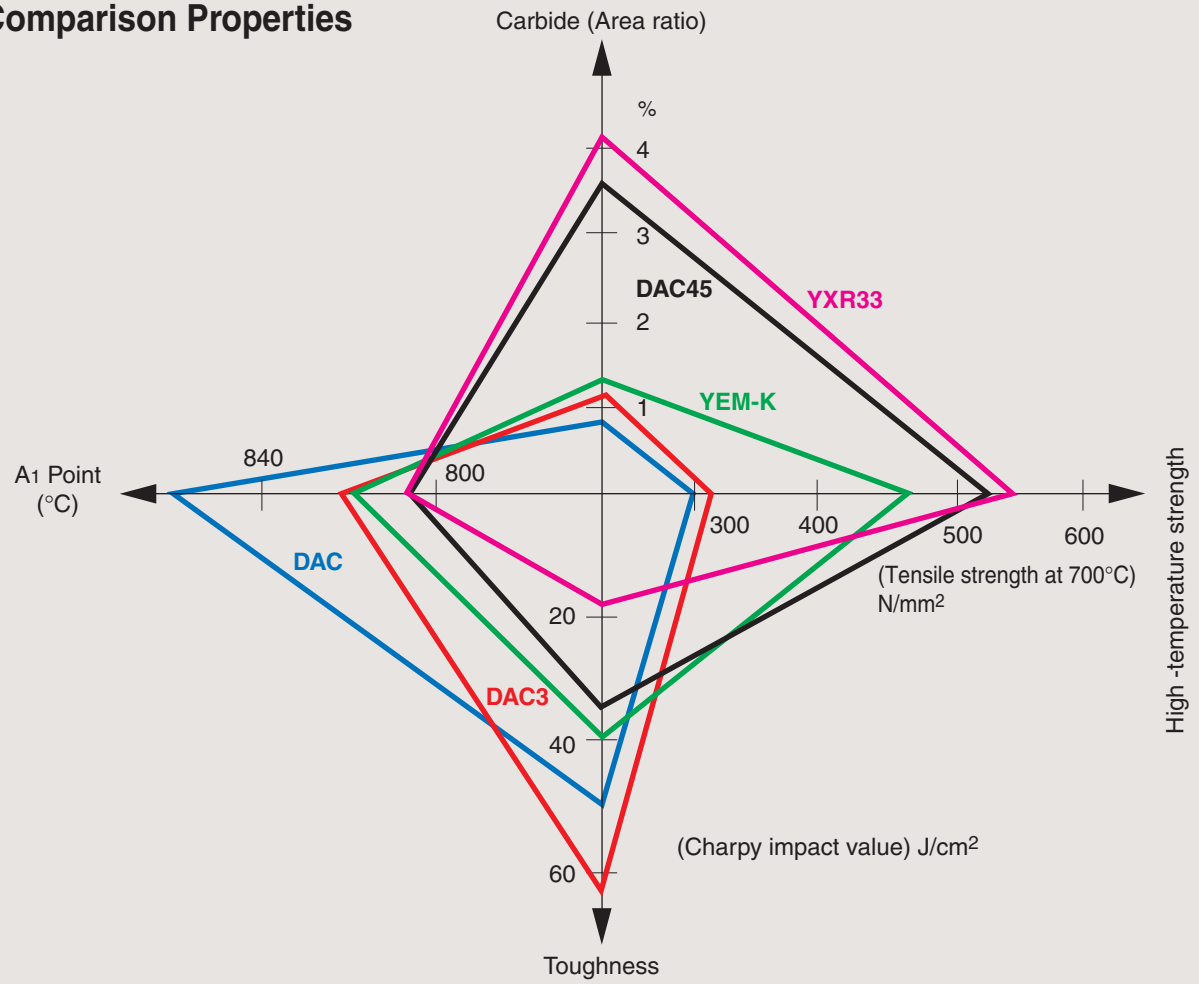


DM

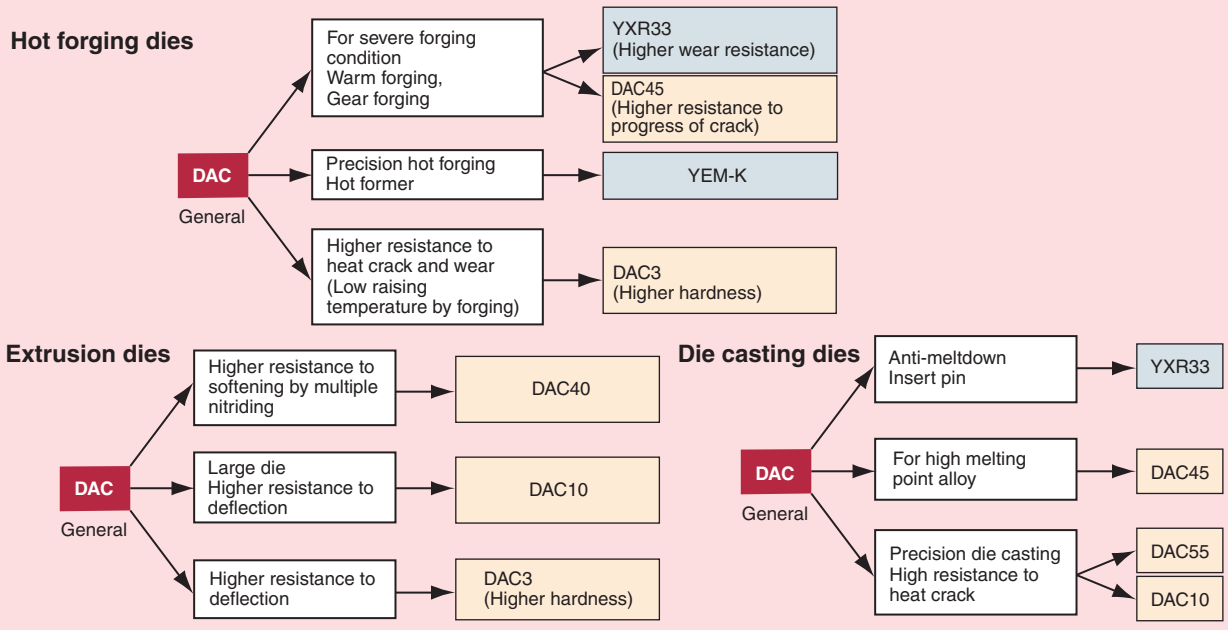


Properties

Comparison Properties

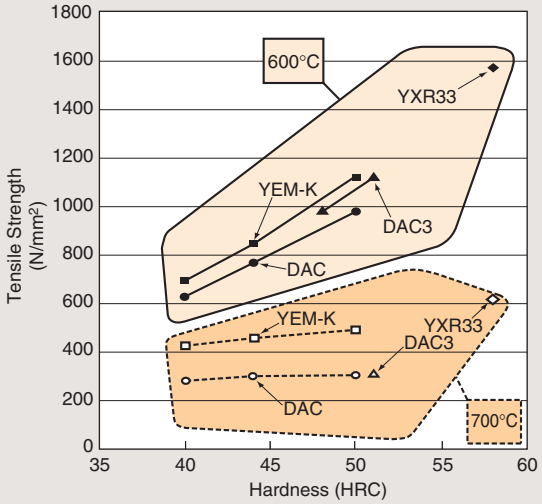


Guide for selecting die materials (example)

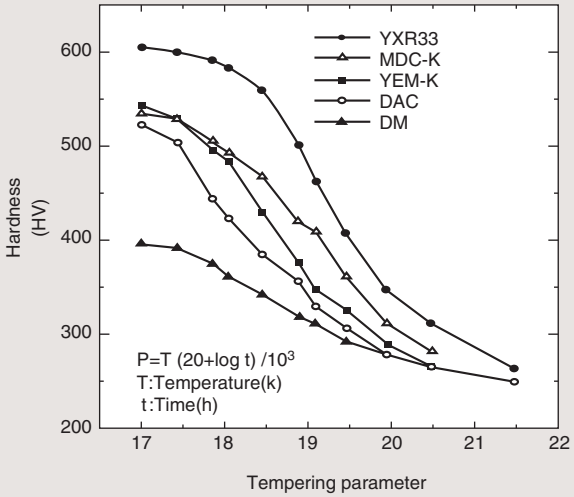


Properties

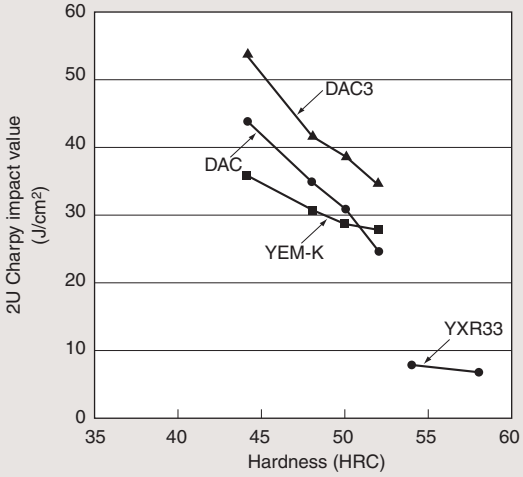
Tensile strength at elevated temperature



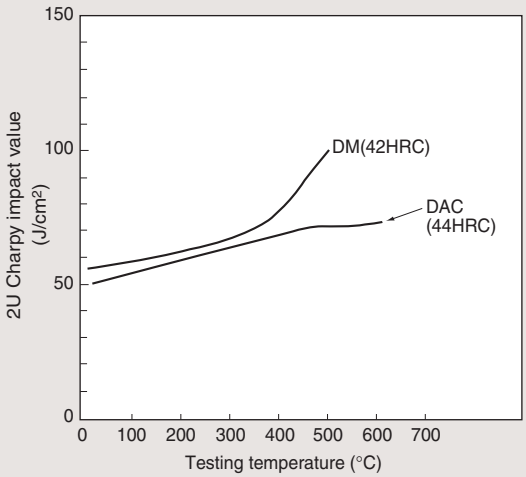
Tempering parameter



Charpy impact value at room temperature

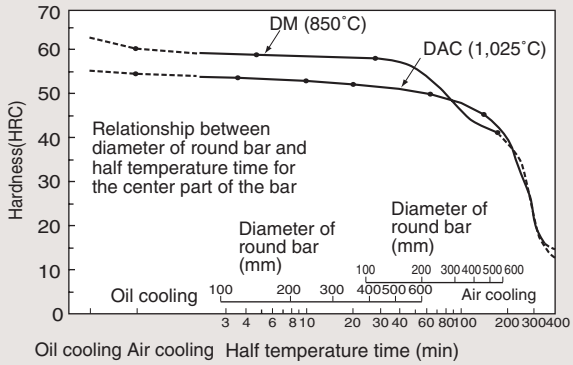


Charpy impact value at elevated temperature



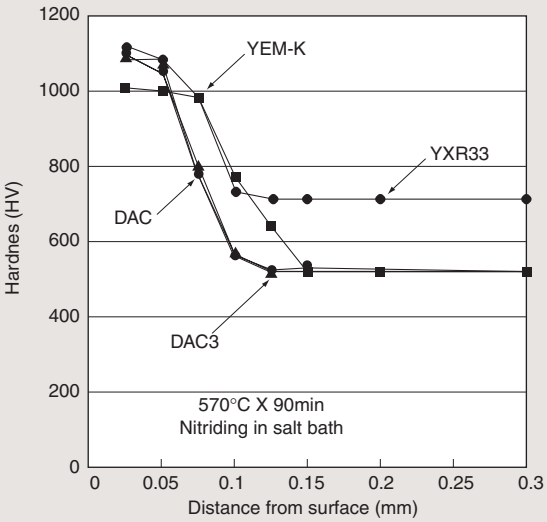
Hardenability

Half temperature time=Time required for cooling from quenching temperature to (Quenching temperature+Room temperature) /2



Relationship between half temperature time and quench hardness of hot working steels

Nitriding property



Properties

1.Coefficient of thermal expansion

[X10^{-6}/°C]

Grade	200°C	400°C	600°C	700°C
YXR33	11.6	12.1	13.0	13.2
DAC45	10.5	12.4	13.3	13.6
DAC10	11.1	12.3	13.8	13.2
DAC	12.5	13.2	13.8	14.0
DM	12.1	13.1	13.5	13.8

2. Thermal conductivity

[W/(m·k)]

Grade	20°C	200°C	400°C	600°C	700°C
YXR33	27.2	28.1	29.3	29.7	29.7
DAC45	26.4	27.6	28.9	28.1	27.6
DAC10	32.2	31.4	30.6	29.3	28.5
DAC	30.6	30.1	29.3	29.5	28.5
DM	36.0	39.4	37.7	36.0	35.2

1.Modulus of elasticity

[GPa]

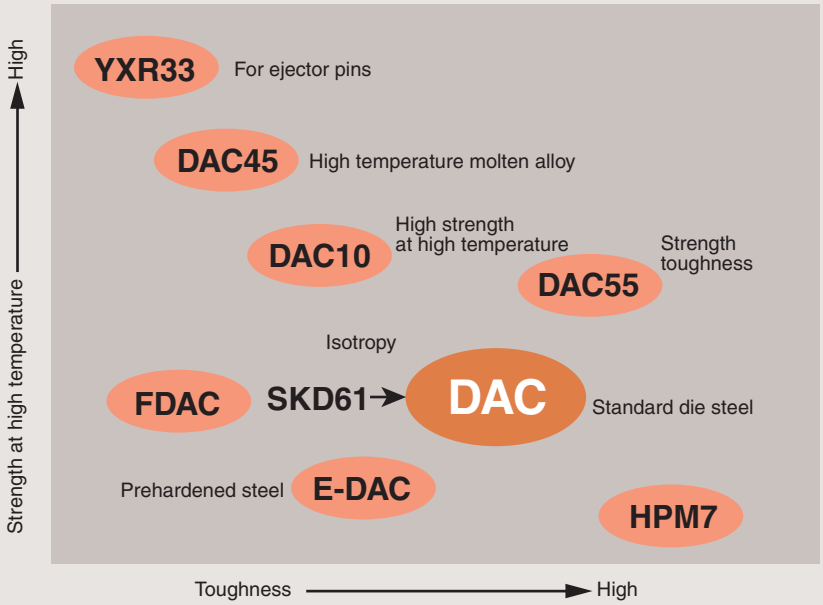
Grade	20°C	200°C	400°C	600°C
DAC	206	196	178	132
DM	211	204	190	141

YSS
DIE STEELS FOR DIE CASTING DAC Series

In compliance with changes of die casting technology

YSS Correlation for Diecasting Die steels

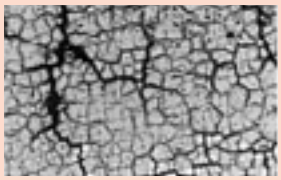
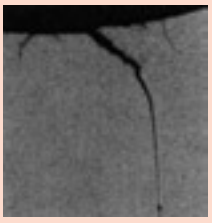
In compliance with diversification of diecasting technology, variety of steel grade is prepared in order to best fit for each individual application.



Die Steel for Diecasting Die-Kind and Features

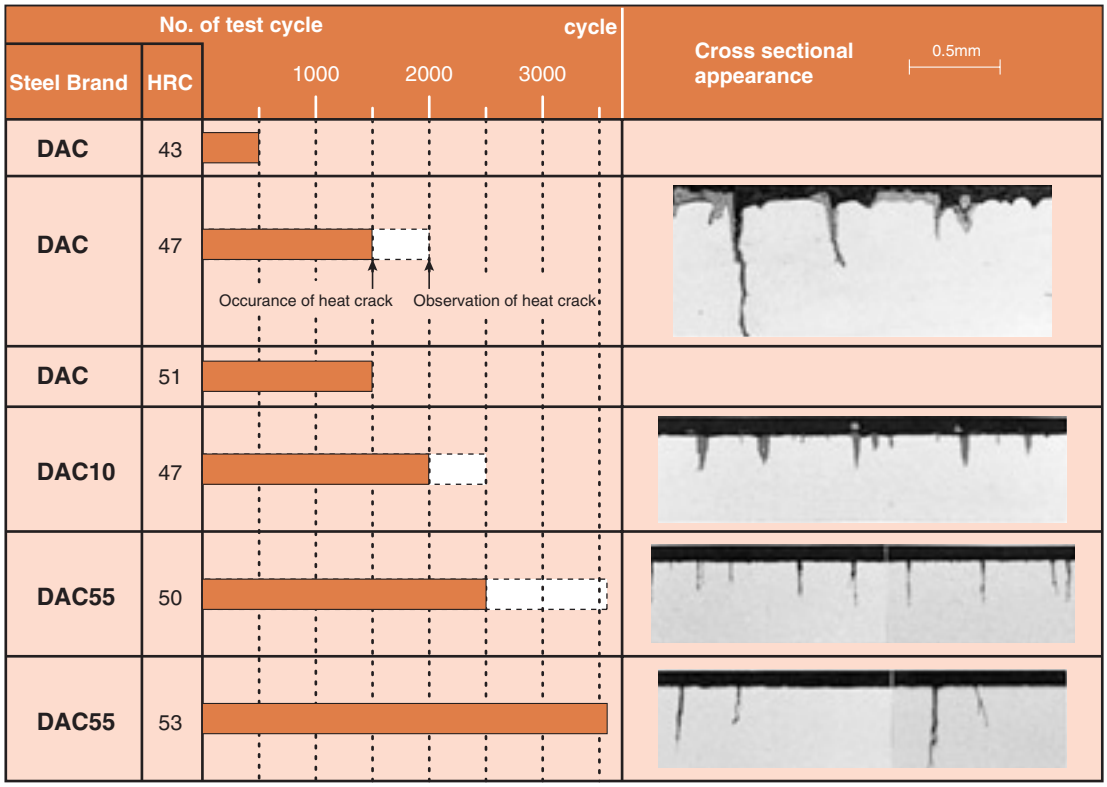
Applications	Steel Brand	Features
Die for Aluminium/Zinc Alloy in general use	**DAC** equivalent to JIS SKD61 0.38C-5Cr-1.3Mo-1V	Strength at elevated temperature and toughness are well balanced. Good machinability and less deformation after heat treatment.
High efficiency die, Squeeze die	**DAC55** 5Cr-Mo-V-Ni-Co	Superior heat crack resistance. Higher toughness enables initial hardness of dies much higher.
Precision Die Cast Die	**DAC10** 5Cr-2.5Mo-V	Higher strength at elevated temperature and good heat crack resistance.
Die for high melting point aluminium alloy and copper alloy	**DAC45** 3.5Cr-W-Mo-V	Higher strength at elevated temperature. Good crack development resistance.
Longer life pin, insert die parts	**YXR33** Matrix HSS	Highest strength at elevated temperature. Best erosion resistance.
Die for small lot, Simple die	**FDAC** SKD61+S Sulphurized DAC	Standard hardness is 40HRC. Delivered prehardened.
Simple die Core, Backblock	**HPM7** Mn-Cr-Mo	Prehardened to 32HRC.Good machinability & Toughness. Least difference of hardness between surface and center of large mold.

Appearance of Heat Crack and Test Result

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

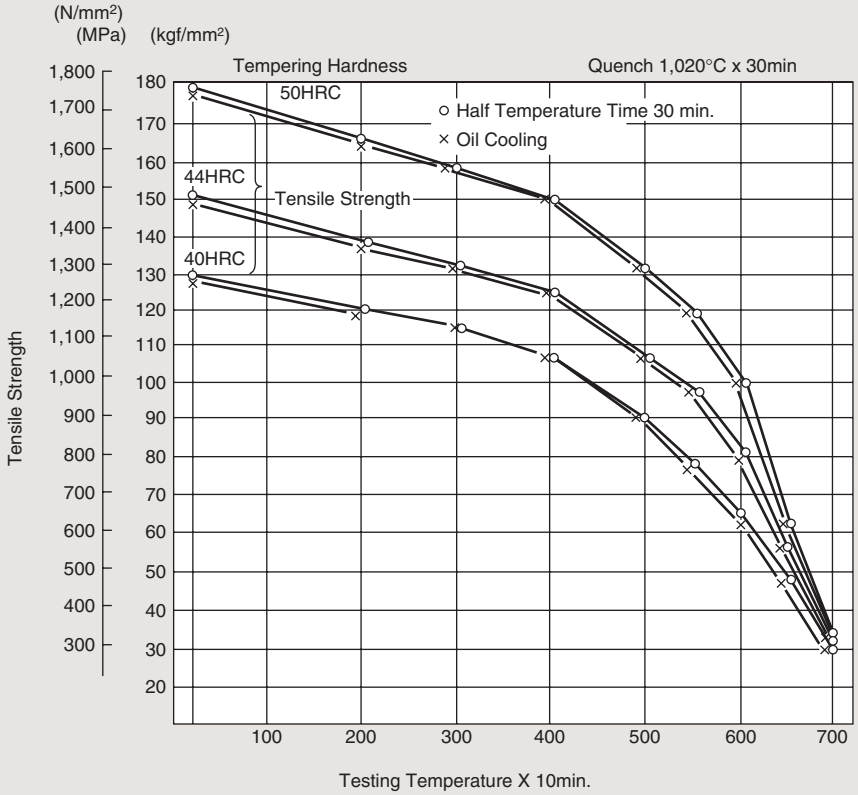
Number of cycles of heat crack initiation and cross sectional appearance

Test: Repetition of Heating upto 600°C by high frequency and Cooling by spray water. Specimen used is one end of dia 90mm bar.

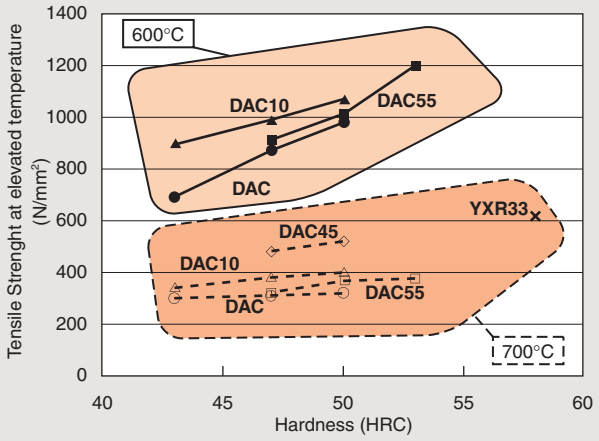


Mechanical Properties

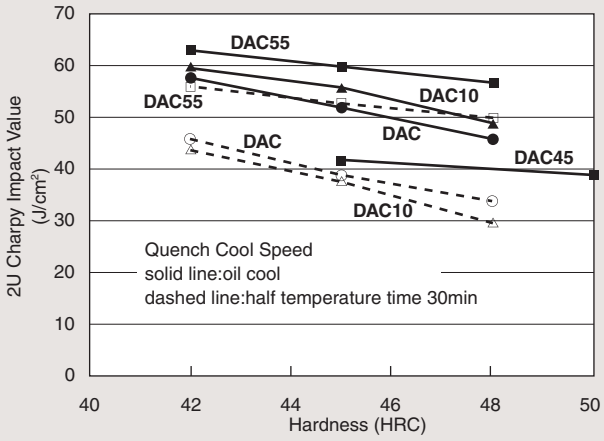
Tensile Strength at elevated temperature



Tempered hardness vs Tensile Strength at elevated temperature



Tempered hardness vs Charpy I - Value



Physical Properties

	Temperature	DAC	DAC10	DAC55	DAC45	YXR33
Thermal Expansion Coefficient X 10^{-6}/°C	100°C	11.7	10.7	11.6	10.5	11.6
	700°C	14.0	13.2	13.7	13.6	13.2
Thermal Conductivity W/m·K[cal/cm·s·°C]	20°C	30.5 [0.073]	32.2 [0.077]	34.5 [0.082]	26.4 [0.063]	27.2 [0.065]
	700°C	28.0 [0.067]	28.5 [0.068]	28.0 [0.067]	27.6 [0.066]	29.7 [0.071]

DAC

DAC Standard Quality for Aluminium Diecasting

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 Isotoropy 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 deformation 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 with prehardened condition of 30-40HRC.

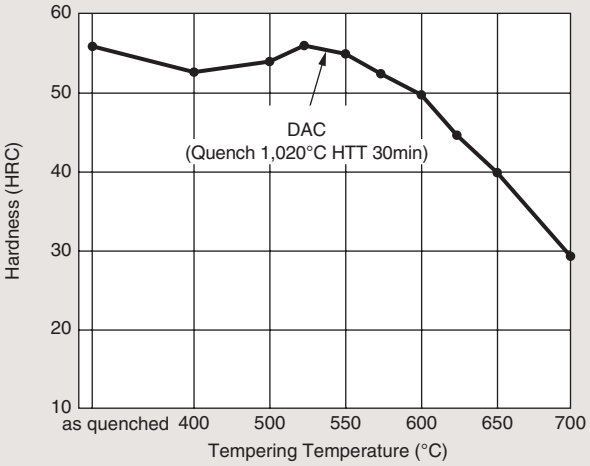
Hardend hardness

45~48HRC general size dies.
43~46HRC big size dies.

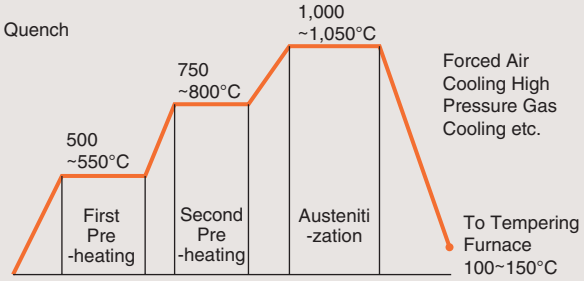
Quench cooling speed and Microstructure (X400)

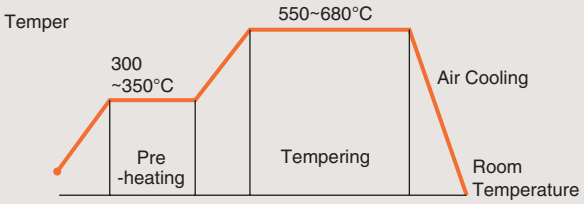
Oil cool	Half Temperature Time (30min.)
	
Half Temperature Time (60min.)	
	Quench Temperature 1020°C Hardness 44HRC

Quenched & tempered hardness



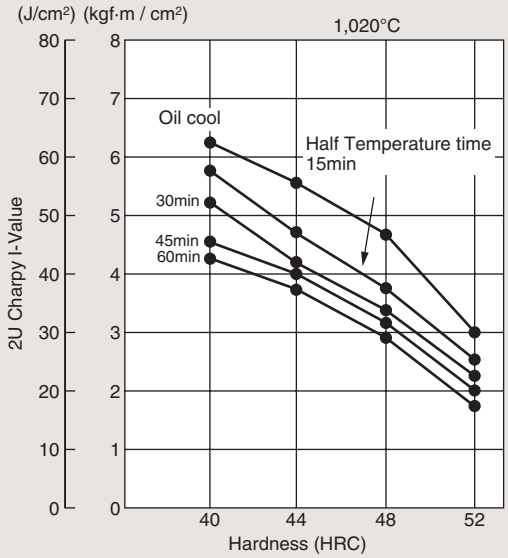
Standard Heat Treatment Process





Tempering is required at least two times or more.

Tempered hardness vs Charpy I-Value



DAC55

DAC55 For High Performance Diecasting

DAC55 has been developed in responding to the needs for a longer die life or a steel with good hardenablity 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 development.
*Higher strength at elevated temperature.
*Good hardenability.

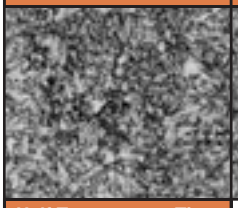
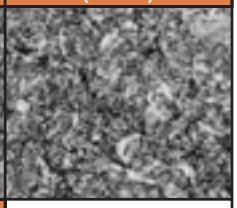
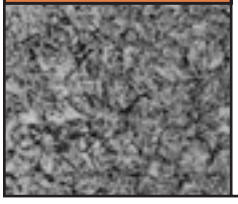
Applications

*Precision diecasting die.
*Big and medium dies for diecasting.
*Squeeze diecasting die.

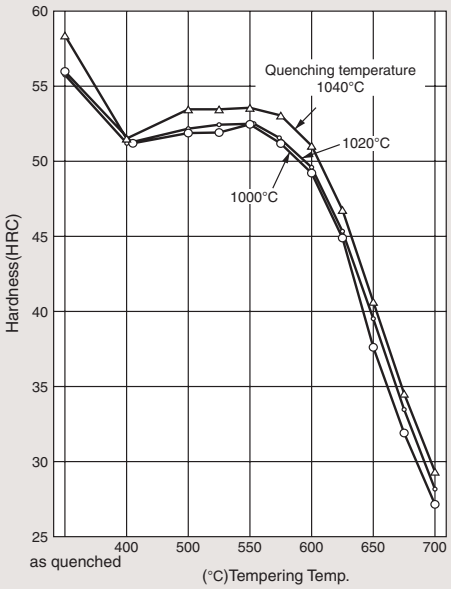
Standard Heat Treatment

Quench 1010-1030°C quick cool
Temper 550°C-640°C
Hardness 43-53 HRC

Quench cooling speed and Microstructure (X 400)

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

Quenched & tempered hardness

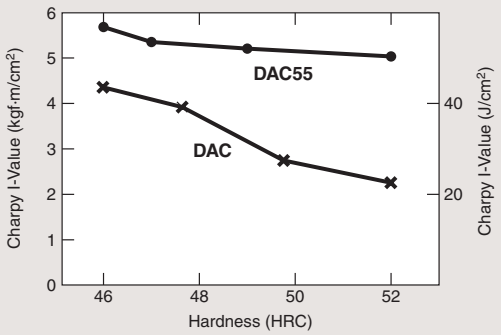


Recommended hardness

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

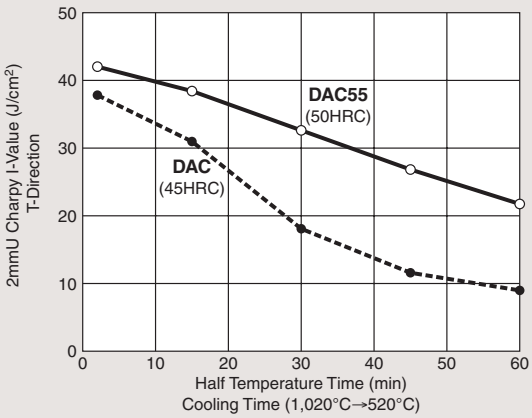
(Remarks) Recommended hardness may not apply depending on projection or casting conditions

Tempered hardness vs Charpy I-Value



Quench Cool Speed vs Charpy I-Value

(Test Result of 250mm Qubic Block)



DAC10

DAC10 For Precision Diecasting

As material of die for diecast products required higher level of surface, and 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 good heat crack resistance.
*Good erosion resistance.

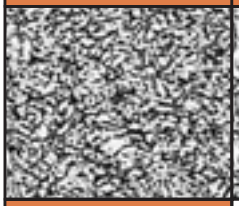
Applications

*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 VTR parts or OA components which require erosion resistance.

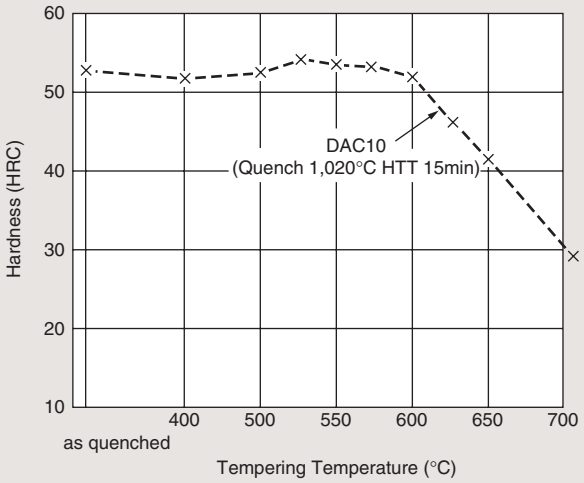
Standard Heat Treatment

Quench 1010-1030°C quick cool
Temper 570°C-610°C
Hardness 44-51 HRC

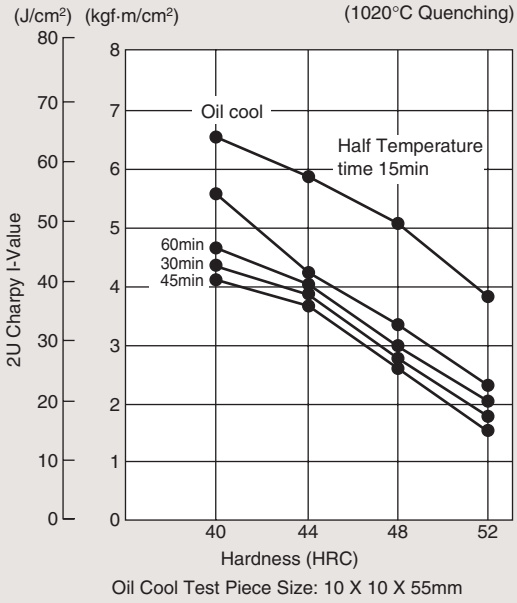
Quench cooling speed and Microstructure (X 400)

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

Quenched & tempered hardness

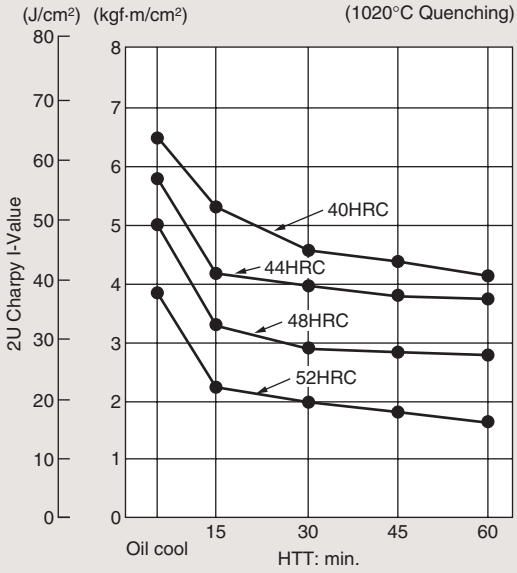


Tempered hardness vs Charpy I-Value



Oil Cool Test Piece Size: 10 X 10 X 55mm

Quench Cool Speed vs Charpy I-Value



DAC45

DAC45 For Diecasting Al-Alloy containing high Silicon

Exclusively developed for dies used in elevated temperature casting of 750°C molten steel. Superb erosion resistance.

Features

*Exceptional high strength at elevated temperature.
*Higher resistant to crack development.

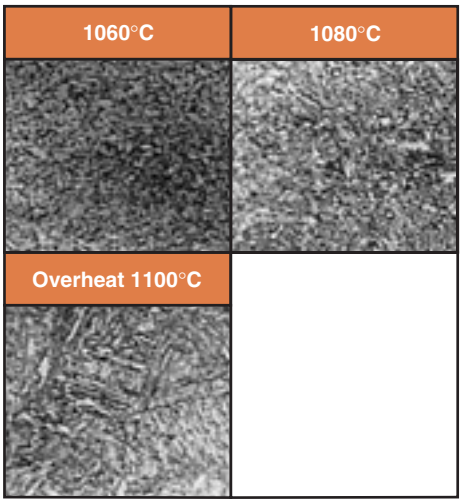
Applications

*Die for High Silicon Aluminium Diecasting like ADC14.
*Die for Copper Alloy Diecasting.
*Erosion resistant pin, insert die parts.

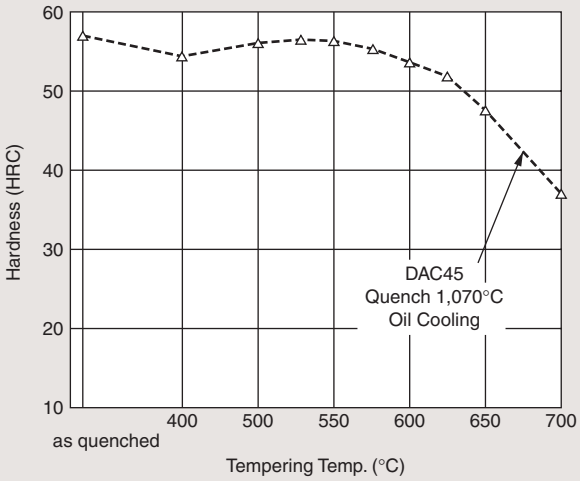
Standard Heat Treatment

Quench 1060-1070°C oil cool
Temper 570°C-610°C
Hardness 47-51 HRC

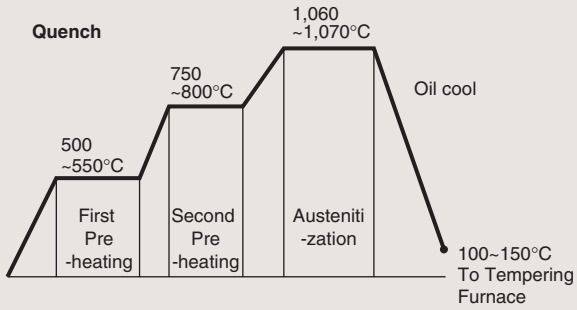
Quench temperature and Microstructure (X 400)

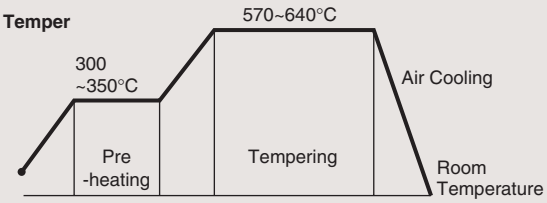


Quenched & tempered hardness



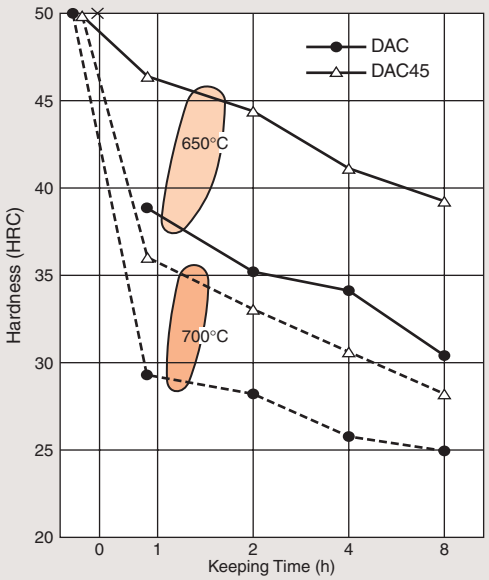
Standard Heat Treatment Process





Tempering is requuired at least two times or more.

Softening Resistance



YXR33

YXR33 For High quality Insert Pin

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.

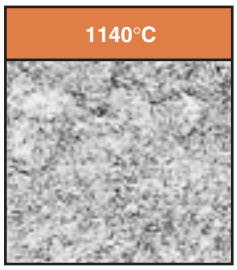
Applications

*Erosion resistant insert pin.
*Insert die parts.

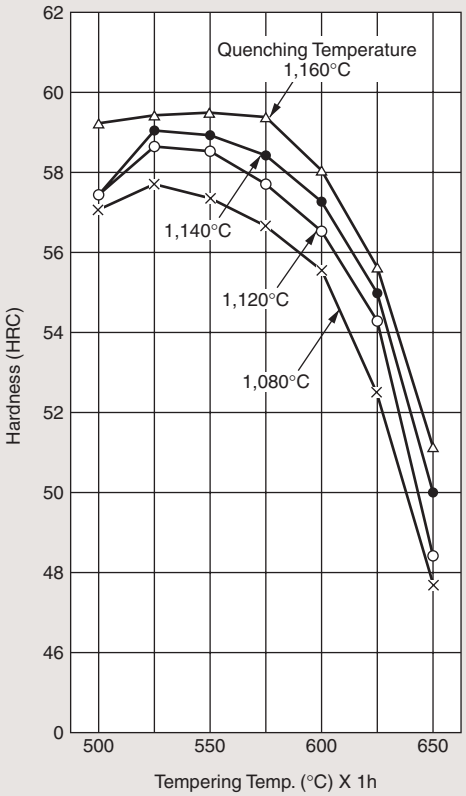
Standard Heat Treatment

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

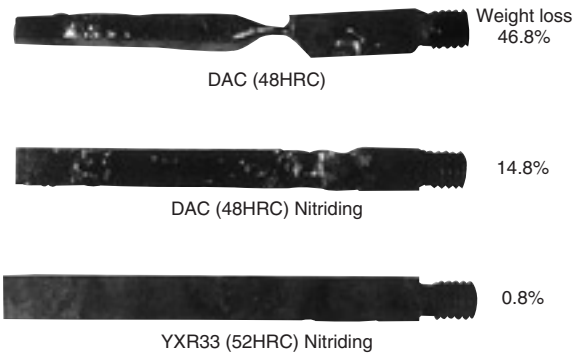
Microstructure as quenched & tempered (X 400)



Quenched & tempered hardness

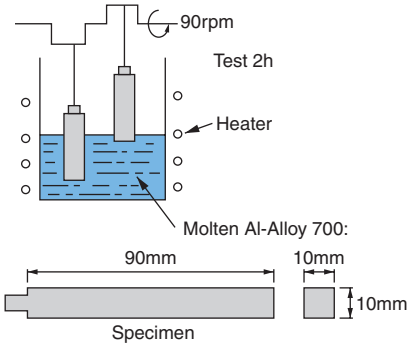


Specimen after Meltdown Damage Test



Meltdown Damage Test

(Specimen and Testing Condition)



FDAC/HPM7

Prehardened free machining die steel

FDAC

FDAC is based on DAC for main components with addition of Sulphur for machinability. As delivered pre-hardened to 38-42HRC, direct cavity making is possible.

HPM7

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

Features

*Good machinability.
*As delivered prehardened, no futher heat treatment is necessary.
→Possible to reduce manufacturing time and total cost.

Applications

Die for small lot , simple die, plain die, holding lock.
FDAC•••priority strength.
HPM7•••priority & toughness machinability.

Mechanical Properties (Reference)

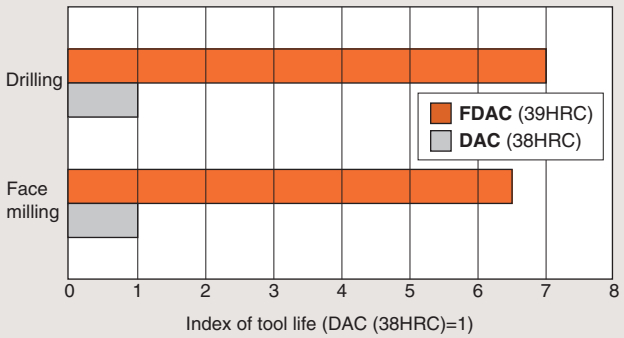
	Hardness (HRC)	0.2% Yielding Strength (MPa)	Tensile Strength (MPa)	Elongation (%)	Reduction of Area (%)
DAC	40	1070	1250	12	58
FDAC	40	1060	1240	11	20
HPM7	32	860	980	20	55

Charpy I - Value (Reference)

	Hardness (HRC)	Longitudinal direction (J/cm^2)	Transverse direction (J/cm^2)
DAC	40	58	39
FDAC	40	19	10
HPM7	32	67	61

Size of Raw Material: 280 X 640
Position of Specimen: w/2 X t/4

Machinability



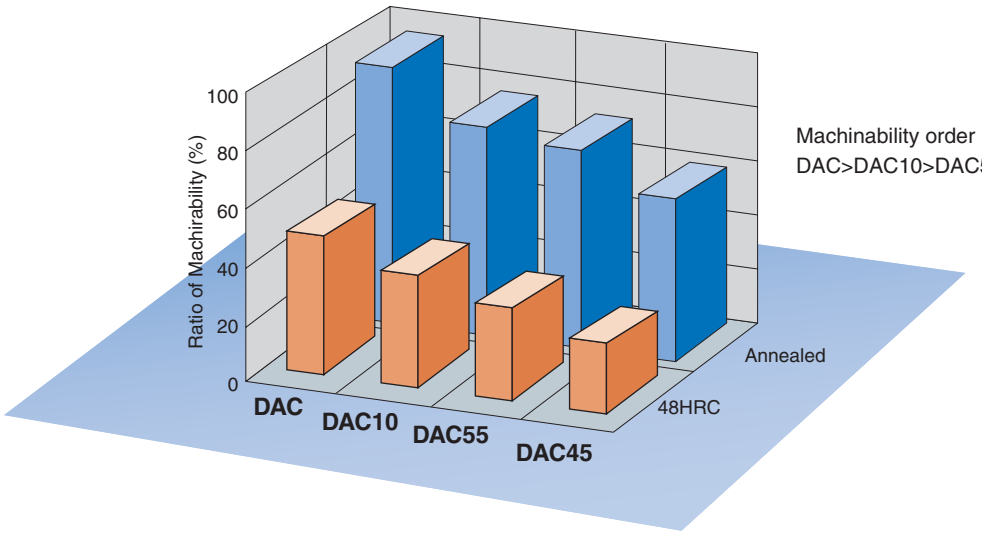
Cutting condition

Face milling	
Cutter	f63
Insert	Coated cemented carbide
Number of inserts	1
Cutting speed	130m/min
Feed	0.15mm/Tooth
Depth	0.5mm
Coolant	dry
Life	VB=0.3mm

Drilling	
Tool	HSS Co ϕ4
Cutting speed	20m/min
Feed	0.1mm/rev
Depth	40mm (Blind)
Coolant	Water-Soluble
Life	Number of cutting hole

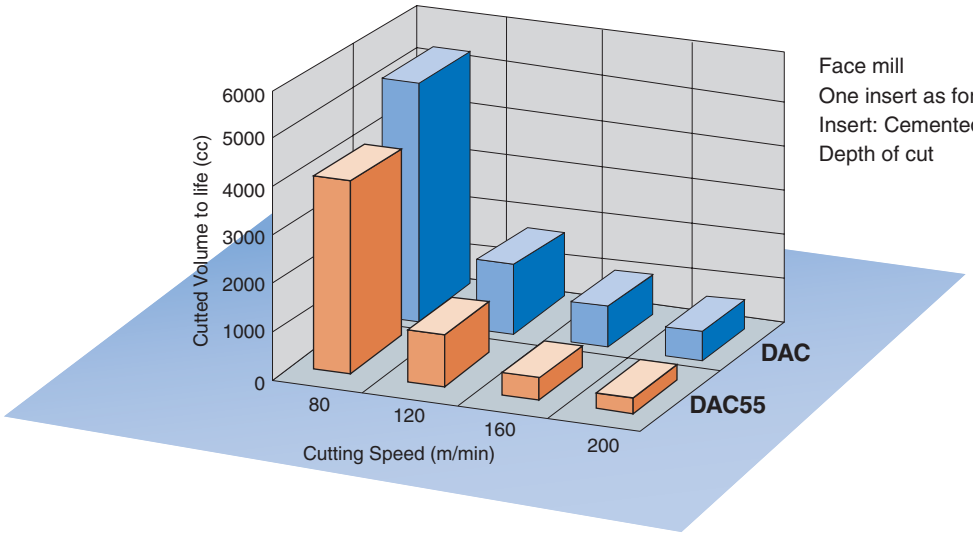
Machinability

Comparison of machinability by Endmill machining



Machinability order
DAC>DAC10>DAC55>DAC45

Comparison of machinability by Facemill machining



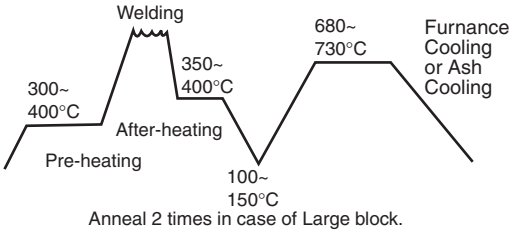
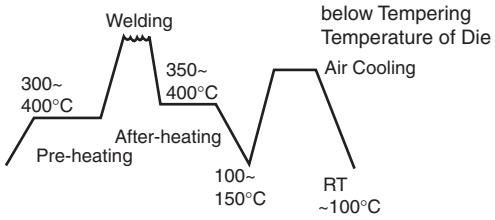
Face mill
One insert as for test purpose
Insert: Cemented Carbide+Coating (TiN)
Depth of cut

Cutting condition by Endmill (Reference)

Tool Material	DAC			DAC10		DAC55		
	Annealed condition	43HRC	48HRC	Annealed condition	48HRC	Annealed condition	48HRC	51HRC
Powder HSS	V=25 f=0.07	V=20 f=0.05	n. a.	V=15 f=0.07	n. a.	V=15 f=0.07	n. a.	n. a.
Powder HSS+Coating	V=30 f=0.07	V=25 f=0.05	n. a.	V=20 f=0.07	n. a.	V=20 f=0.07	n. a.	n. a.
Cemented Carbide+Coating Standard edge	V=45 f=0.05	V=35 f=0.03	V=25 f=0.03	V=35 f=0.05	V=15 f=0.03	V=35 f=0.05	V=17 f=0.03	V=15 f=0.03
Cemented Carbide+Coating Hi-speed edge	V=50 f=0.08	V=40 f=0.05	V=30 f=0.05	V=50 f=0.08	V=25 f=0.05	V=50 f=0.08	V=30 f=0.05	V=25 f=0.05

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, DAC55, DAC10, DAC45, FDAC, E-DAC.

State of Die	Welding Rod	Welding Method	Welding Condition	Welding Process Chart	Temp. between weldlayers
Annealed State	DAC or same steel	TIG	Welding bar 1.6~4.0ϕ Current 80~200A Flux of Ar gas 8-15R/min	 Anneal 2 times in case of Large block.	250: Above
Hardened State	YAG				250: 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.

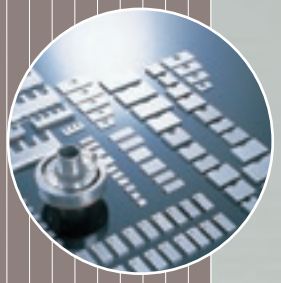
4. Keeping time of Temper and Anneal after welding should be 1h/25mm in thickness.

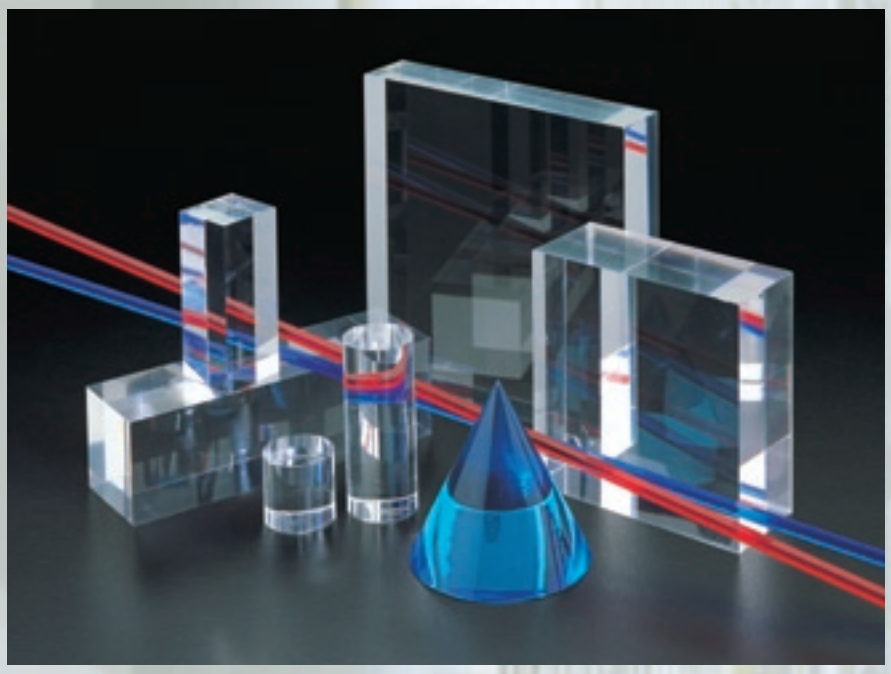
5. A careful attention is to be paid of crack during grinding.

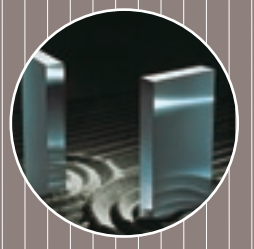
Actual Performance by Customers

Diecast Products Brand	Machine Capa (die size mm)	Comparision of Actural Performance by Customers		Effect
		Current	Application	
Autoparts surface priority	800ton 120X210X300	DAC (44HRC) 37K shot 1st heat crack	DAC (48HRC) 50K shot 1st heat crack	1.35 times
OA Components (precision die)	250 ton 80X200X300	DAC15K shot 1st heat crack 30K shot repair. 80K shot scrap	DAC10 24K shot 1st heat crack. No grinding repair. 120K shot scrap	1.6 times min.
OA Components (precision die)	650 ton 90X215X380	DAC 1K shot 1st bite 30K shot scrap	DAC10 10K shot no bite	3 times min
Autoparts surface priority	2000 ton	DAC (47HRC) 60K shot heat crack	100K shot still on service	1.6times min.
Autoparts	2500 ton	DAC (43HRC) heat crack	DAC55 (48HRC) later heat crack	4 times
Autoparts (thin insert)	n.a.	DAC 20K shot breakage	DAC55 40K shot and more	2 times
Wheel	1800 ton	DAC/DAC4 heat crack	2 times shot of DAC/DAC4 before crack	2 times
P/Computer Case (Mg)	n.a.	DAC 5K shot heat crack	DAC55 25K shot no repair	5 times min
High melting point Al-alloy autoparts	320 ton 90X200X300	DAC 5K shot 1st heat crack	DAC45 10K shot 1st heat crack but still in service	2 times
High melting point Al-alloy autoparts	Insert	DAC (52HRC) 3.5K shot meltdown	DAC45 (52HRC) 13K shot meltdown	4 times
Autoparts	Insert Pin	DAC 3K shot meltdown & galling	YXR33 10K shot still on service	3 times
High melting point Al-alloy autoparts	Insert Pin	SKH51 (60HRC) 2K shot breakage	YXR33 (54HRC)+TiN 20K shot meltdown	10 times

YSS
PLASTIC MOLD STEELS
HPM Series







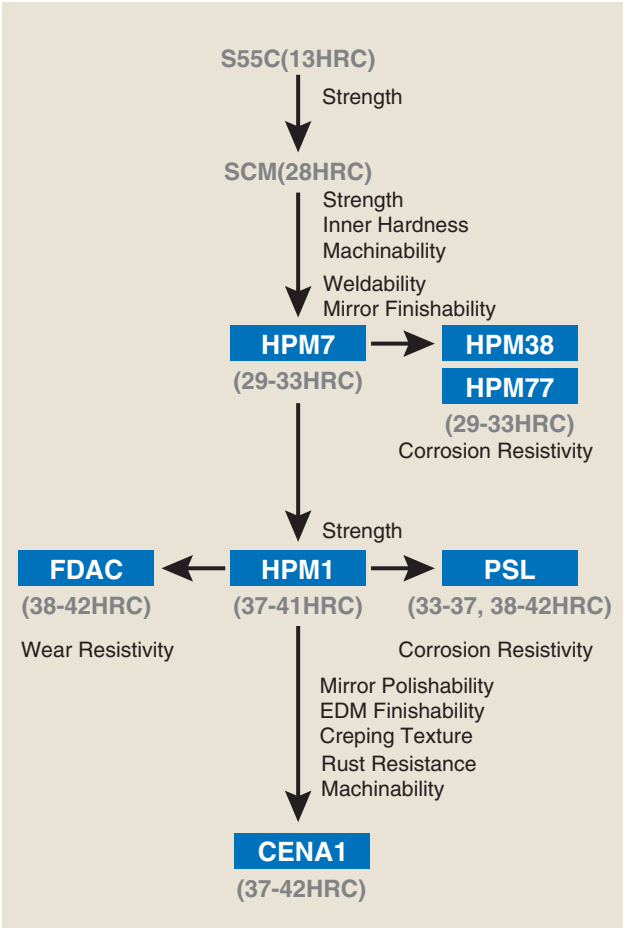
In compliance with advanced plastic molding technology

YSS plastic mold steels "HPM" series are increasing popularity in compliance with advanced plastic molding technology. "HPM" series are fulfilling demands of plastic industry for molds that provide crepe-and mirror-finishability and mold durability for corrosive gas generating and reinforced resins.

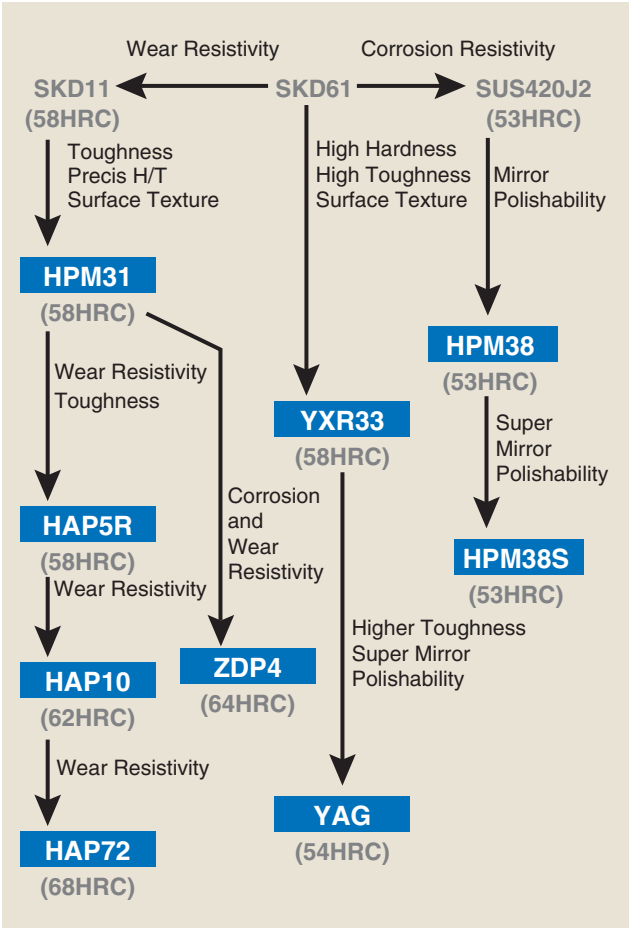
Mold Material and Application

Group	Hardness Employed (HRC)	Grade	Material Type	Application Example
Prehardened	29~33	**HPM7**	P20 improved	Mold required good weldability & machinability (Autoparts, Home electronics, House equipment)
		HPM38	420 improved	Flame retardant resin, Transparent parts, Rubber
		HPM77	420 improved & resulpherized	Corrosion resistant mold plates, 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 (OA electronics, Transparent case etc)
	37~41	**HPM1**	P21 improved & resulpherized	Mold for general use (Home electronics etc), Plate & holder
	38~42	**FDAC**	H13 improved & resulpherized	Engineering resin, Slide core
	50~55	**HPM38**	420 improved	Mold for Anti-corrosion / Mirror polish (Floppy, Casette, Medical instruments, Food container, etc)
		HPM38S	420 improved	Mold for super mirror polish (Optical disc / Lense)
For Quench and Temper	56~60	**HPM31**	A2 improved	Wear resistant mold for engineering resin (Gear, Connector, IC)
		YXR33	Matrix HSS	Mold required high toughness & high hardness (Core pin, Thin wall)
	60~63	**ZCD-M**	D2 improved	IC mold
	60~65	**HAP10**	P/M HSS	Reinforced engineering resin, IC mold
		ZDP4	P/M Cold Die Steel	Reinforced and flame retardant engineering resin, IC mold, Slide parts, Cutter required exceptional wear resistance
For Aging	40~45	**HPM75**	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 lense)

Sequence by Technical Needs



General Mold (Prehardened Steel)



Precise Mold (Steel for Hardening)

Properties Comparison Table

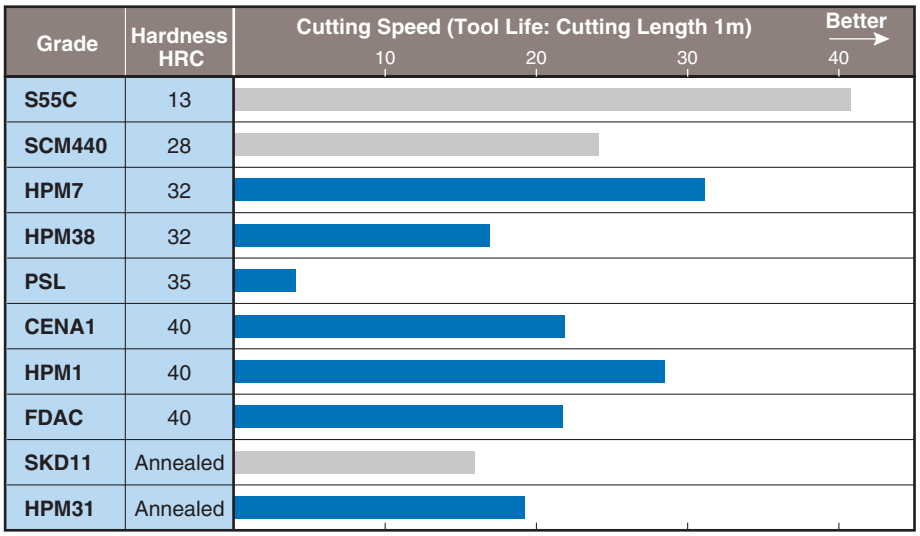
Material	Machinability	Heat deformation	EDM/Creping texture	Mirror polishability	Weldability	Rust resistance	Wear resistance	Toughness	Cost
HPM7	4	–	3	3	5	2	2	4	4
HPM38	3	4	5	4	3	4	3	3	2
HPM77	4	–	2	2	3	4	2	3	3
PSL	2	–	4	3	5	5	2	4	2
CENA1	4	–	5	4	4	3	2	3	3
HPM1	4	–	3	3	3	2	2	2	3
FDAC	3	–	2	2	3	3	3	3	3
HPM38S	3	4	5	5	3	4	3	3	1
HPM31	3	4	5	4	2	3	4	3	2
YXR33	3	3	5	4	3	3	4	4	2
ZCD-M	2	3	5	2	1	4	4	2	2
HAP10	2	3	4	3	1	2	5	2	1
ZDP4	1	3	4	4	1	4	5	2	1
HPM75	1	3	2	2	3	3	3	3	2
YAG	2	4	5	5	5	3	3	5	1
S55C	5	–	3	2	3	1	1	3	5
SCM440	3	–	3	2	3	2	1	3	4

Ratings: 5-Best 3-Ordinary 2,1-Poor
(Remarks) Please refer above as general concept.

Properties Comparison

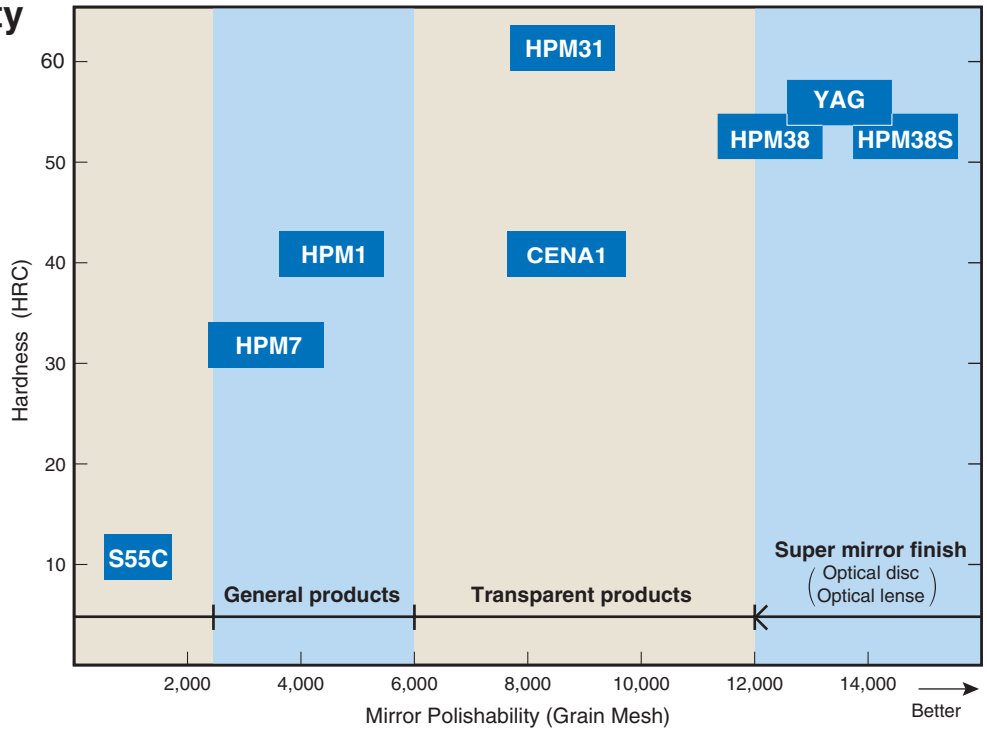
Machinability

Drilling
Tool: SKH51ø10
Feed: 0.15mm / rev
Depth: 30mm (brind hole)Dry



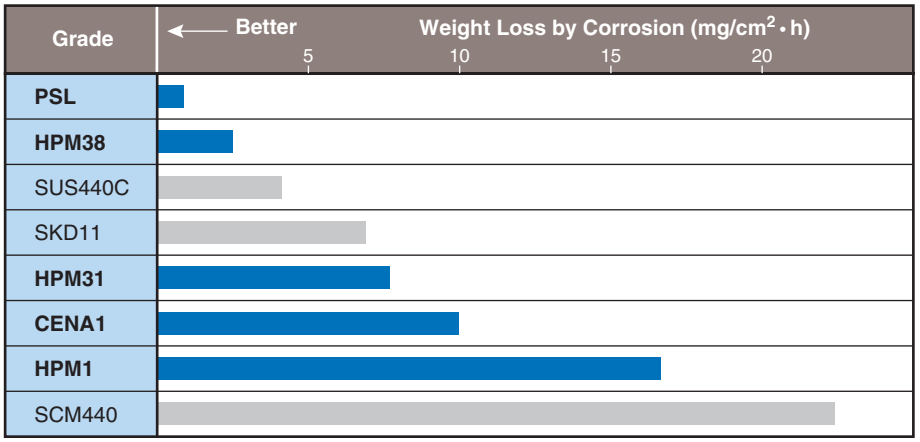
Polishing Property

(Schematic Diagram)



Corrosion Resistance

(5%Sulfuric Acid Solution)

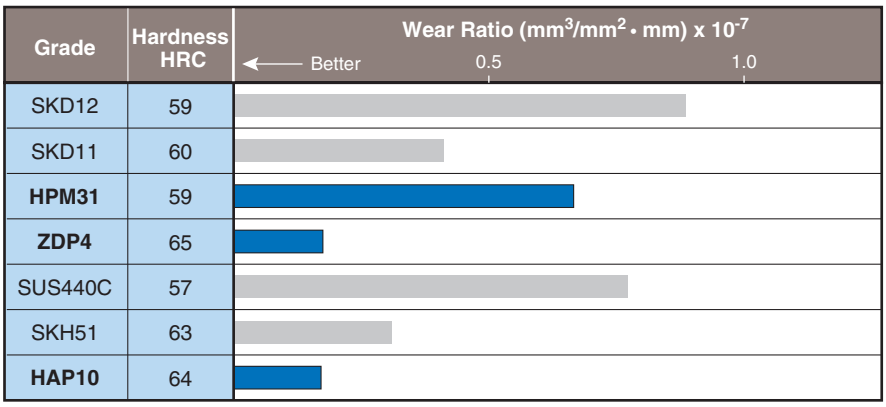


Properties Comparison

Wear Resistance

Ohgoshi Wear Test
Work Material SMC415
Load 6.8kg
Total Friction Length 400m
Friction Speed 0.78m/sec

Grade	Hardness HRC	Wear Ratio ($mm^3/mm^2 \cdot mm$) x 10^{-7} (← Better; 0.5; 1.0)
SKD12	59	
SKD11	60	
HPM31	59	
ZDP4	65	
SUS440C	57	
SKH51	63	
HAP10	64	



Mechanical Properties

Grade	Hardness HRC		Tensile Strength N/mm²	0.2%Yield Strength N/mm²	Elongation %	Reduction of Area %
HPM7	32			854	20	55
HPM38	52		1,912	1,618	13	35
HPM77	32		990	843	16	41
PSL	39		1,167	1,098	11	34
CENA1	40		1,225	1,150	15	50
HPM1	40	L	1,225	1,029	18	40
		T	1,216	1,010	10	25
HPM75	42		1,304	1,108	11	28
YAG	53		2,010	1,912	10	48

Physical Properties

Grade	Thermal Expantion Coef. (x 10^{-6} °C)				Thermal Conductivity (W/m • K)				
	100°C	200°C	300°C	400°C	20°C	100°C	200°C	300°C	400°C
HPM7	11.8	12.2	13.0	13.4	34.3	37.7	39.8	40.6	40.6
HPM2	11.5	11.9	12.5	12.9	37.2	37.6	38.0	39.3	38.0
HPM38	11.5	11.9	12.3	12.5	25.1		27.2		27.6
HPM77	10.7	11.1			17.9	18.8	20.9		
PSL	10.6	11.1	11.9	12.1	16.3	17.1	18.8		21.3
CENA1	11.0	11.4	12.0	12.5	28.6	28.3	28.8	30.1	
HPM1	11.4	11.8	12.3	11.8	32.6	33.0	33.4	34.7	34.7
HPM31	11.9	12.3	12.6	12.7	28.4		28.8		28.3
HAP10	10.6	10.8	11.1	11.4	19.2	20.0	20.9	21.3	22.5
HPM75	16.9	17.6	17.0		15.8		17.9		21.3
YAG		10.8			20.9		25.5		27.6

Resin Types and Grade Selection

Resin		Required Life and Grade Recommended				
		Required Properties for Mold	SHORT >10 milliom	MEDIUM > 50 milliom	LONG >100 milliom	MASS PRODUCTION >100 milliom
Thermo -plastic	General	Machinability	**HPM7**	**HPM7** **HPM2**	**CENA1** **HPM1, 50** **FDAC**	**CENA1** **FDAC** + Nitriding
	Engineering Resin	Wear Resistivity	**HPM7**	**HPM7+** Nitriding	**CENA1** **FDAC** + Nitriding	**HPM38** **HPM31**
	Reinforced	High Wear Resistivity	**FDAC** **CENA1** **HPM1**	**CENA1** **FDAC** + Nitriding, Plating	**HPM31**	**ZDP4** **HAP10**
	Flame Retardant	Corrosion Resistivity	**HPM38** **CENA1**	**HPM38** **PSL**	**HPM38**	**HPM38**
	Transparent	Mirror Polishability	**CENA1** **HPM38**	**CENA1** **HPM38**	**HPM38**	**HPM38** **ZDP282**
Thermo-set	eneral	Wear Resistivity	**CENA1** **HPM1** **FDAC**	**CENA1** **HPM1, 50** **FDAC** + Plating	**HPM31**	**HPM31**
	Reinforced	High Wear Resistivity	**CENA1** **FDAC** +Nitriding	**HPM31**	**HPM31**	**HAP10** **ZDP4**

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.

40HRC Prehardened Grade

CENA1

Prehardened: 37~ 42HRC Precipitation Hardening, Rust-Resisting Grade for Precise Mold

CENA1 is new concept grade breaking through with rust resistivity and excellent machinability. CENA1 is manufactured by consumable electrode remelting method, having exceptional high purity and suit for critical surface finish.

Features

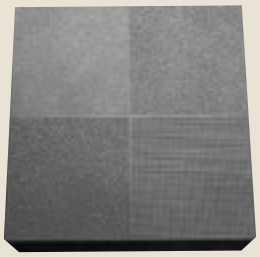
- No heat treatment is necessary. Uniform hardness distribution. (37~42HRC)
- Higher rust resistivity compared with P21 type grade.
- Excellent machinability makes machined surface better.
- Excellent mirror polishability, crepe- and EDM finishability.
- Good weldability with least hardness elevation.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

Application

- Critical surface finish mold for transparent parts, etc.
- Engineering resin products.

Mobile Telephone

Video Camera



Creping Sample

Non-glare Treatment Sample

EDM Sample

CENA1 100X100X50 (mm)

40HRC Prehardened Grade

HPM1

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

HPM1 is free machining plastic mold steel prehardened to 40HRC . With superb machinability, HPM1 is fitted for genaral applications.

Features

- No heat treatment is necessary. (37~41HRC)
- Excellent machinability among 40HRC prehardened grades.
- Uniform hardness even in large crosssection and less wear of parting.

Application

- General plastic products.
- Home electronics, auto parts.
- Daily goods for mass production.
- Precision mold for rubber.
- High hardness die plate, holders.

FDAC

Prehardened: 38~42HRC
Free Machining
Hot Working Die Steel

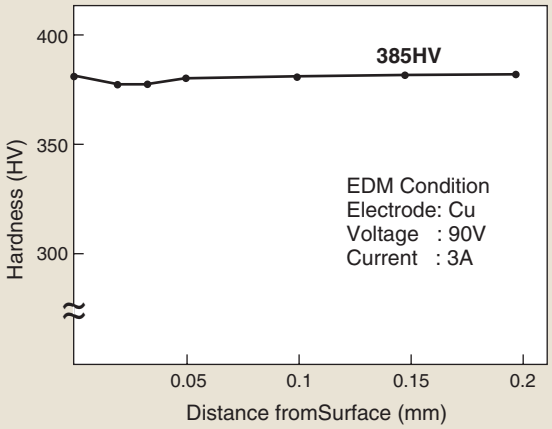
Features

- No heat treatment is necessary. (38~42HRC)
- High wear resistance and toughness.
- High abrasion resistance.
- High hardness obtained by nitriding.

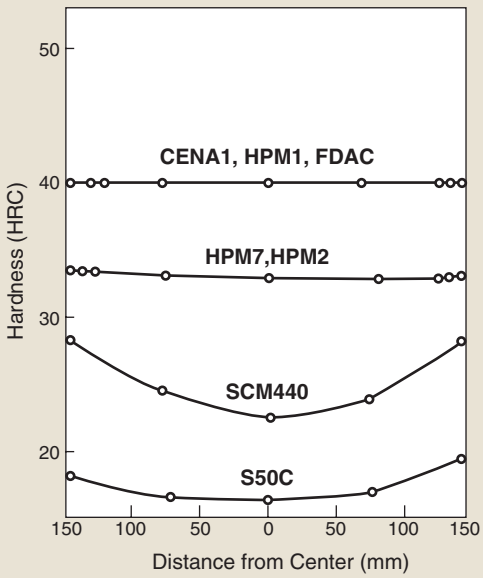
Application

- Slide parts, Pin.
- Engineering resin products.

Personal Computer



Hardness Distribution of EDMachined Surface in Depth (HPM1)



Cross Section Hardness Distribution (300mm Square Size)

32HRC Prehardened Grade

HPM7

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

HPM7 is 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 EDMachinability to make itself one of the best steel among P20 improved grades.

Features

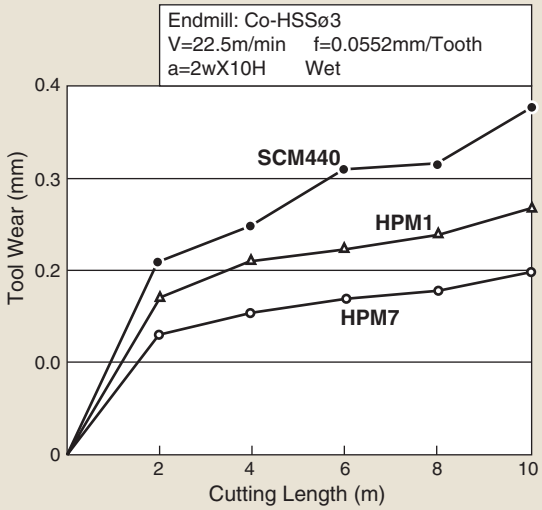
- Uniform hardness distribution even in large crosssection. (29-33HRC)
- Machinability is better than P20 or free machining carbon steel.
- Excellent weldability with least hardness elevation.
- Good mirror polishability.
- Less streak texture and least hardness elevation on EDM surface makes finishing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

Application

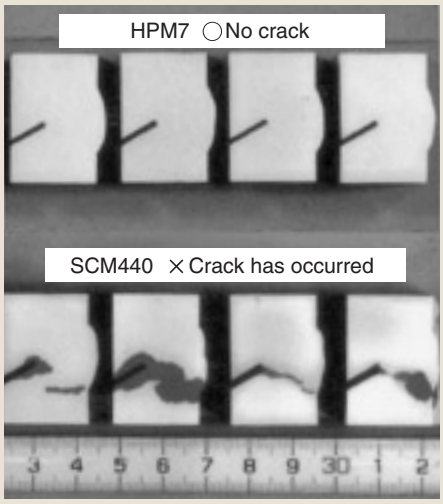
- Auto parts ex.Headlight lense, Taillamp, Inner panel etc.
- Home electronics, House equipment ex. TV cabinet, Air conditioner housing etc.
- Others large daily goods, Large container, Pipe, Rubber.

Inner Panel

Tail Lamp



Machinability Comparison



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

Prehardened Stainless Grade

HPM38

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

HPM38 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 HPM38 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 saving plating: Food container,Medical instruments.

Heat Treatment

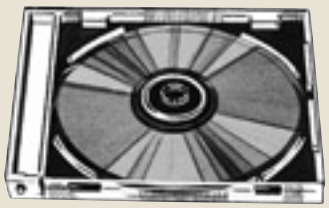
- Quenching: 1,000~1,050˚C Air Cooling.
- Tempering: 200~500˚C Air Cooling.

HPM38S

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

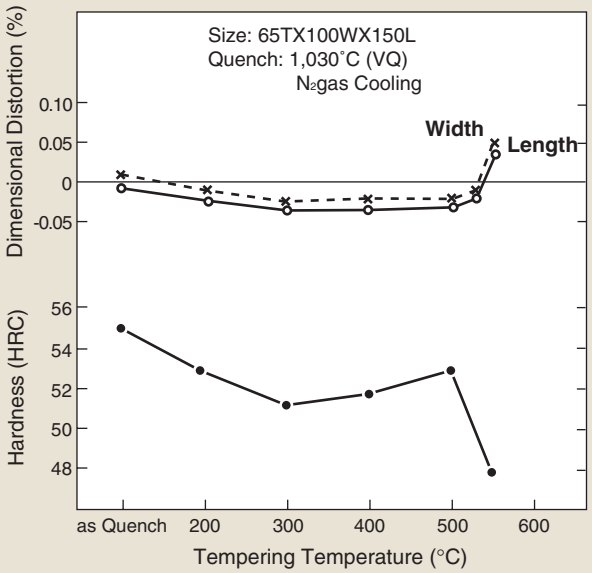
Features

- Superior mirror polishability to below 0.01μ m surface roughness.
- Other features are same as HPM38.
- CD, DVD, MO, and optical lense.

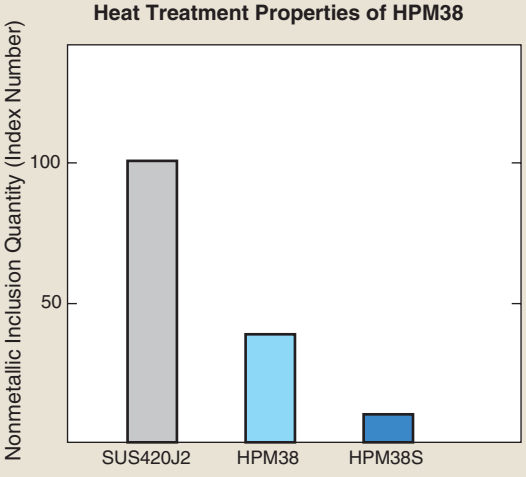


Compact Disc

Food Container



Heat Treatment Properties of HPM38



Purity of HPM38S

Prehardened Stainless Grade

PSL

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

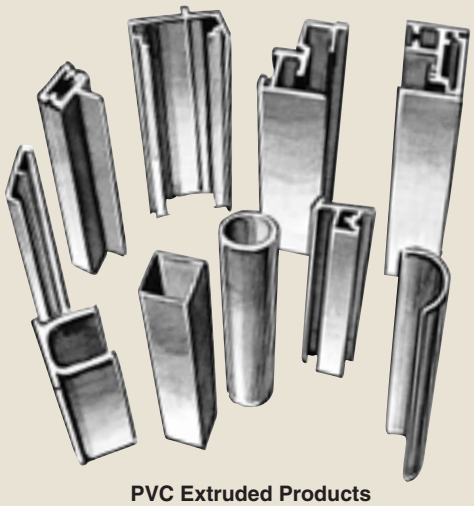
PSL is precipitation hardening stainless steel which shows superior corrosion resistance as used for corrosive gas yielding resins or resins with flame retardant additives without plating.

Features

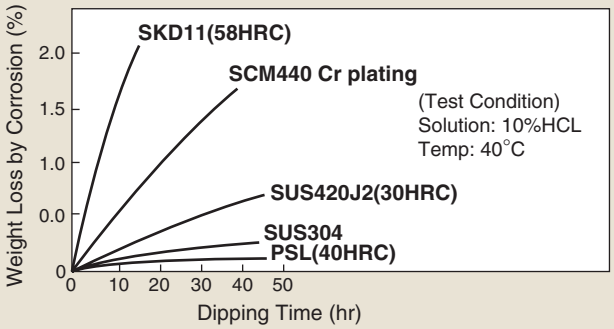
- Best corrosion resistance among plastic mold steels. Plating is not needed.
- Least hardness elevation on EDM or welded surface and easier finishing jobs.

Application

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



PVC Extruded Products



Corrosion Resistivity Comparison

HPM77

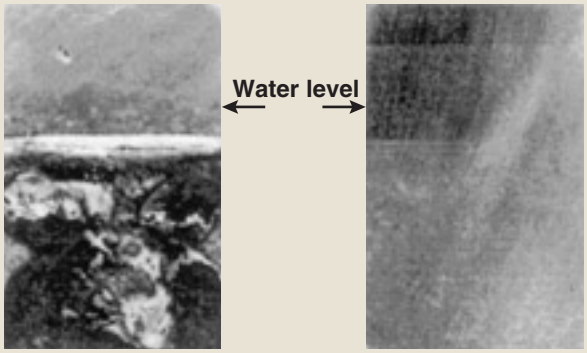
Prehardened : 29~33HRC
Free Machining Martensitic Stainless Grade for Mold Base

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



S55C HPM77

Rust after 1month dipping in water

High Wear Resistance Grade

HPM31

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

HPM31 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

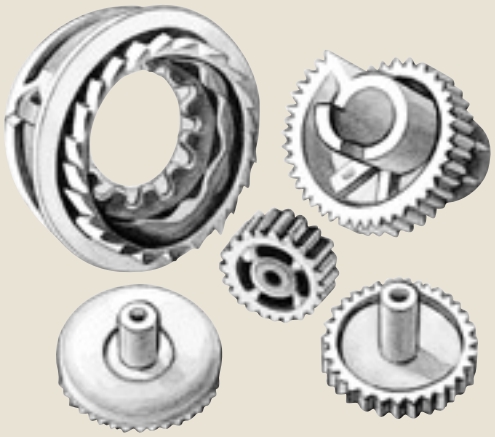
- High wear resistance as same as D2.
- Much better machinability and grindability than D2.
- Least heat treatment deformation, best fitted for precise mold.
- Good mirror polishability, crepe- and EDM finishability
- High hardness and toughness.

Application

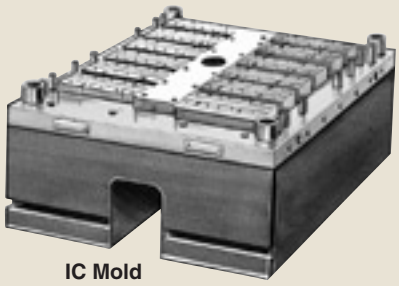
- Engineering resin products and thermosetting resin products.
- Precise mold: IC mold, Connector, Watch parts, Camera parts.

Heat Treatment

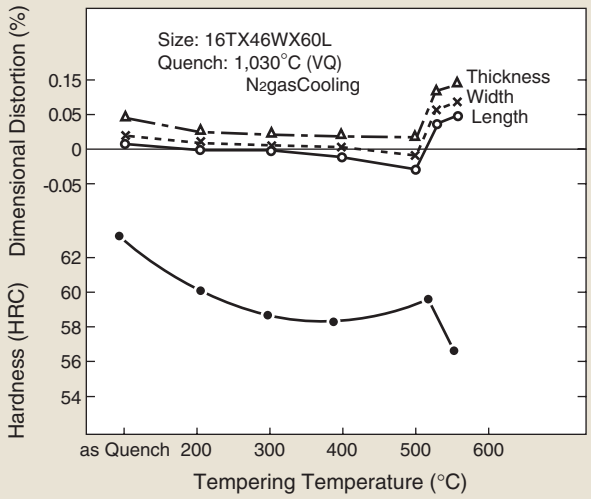
- Quenching: 1,000~1,050°C Air Cooling.
- Tempering: 200~550°C Air Cooling.



Engineering Resin Gear



IC Mold



Heat Treatment Properties of HPM31

Aging Grade

YAG

Hardenable to: 50~57HRC
Super High Toughness Maraging Steel

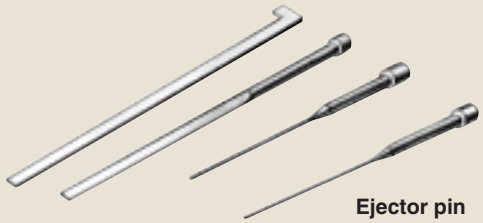
As YAG is delivered as solution heat treated condition, you are advised to conduct aging at 480-520°C in order to get hardness between 50-57HRC after engraving cavity.

Features

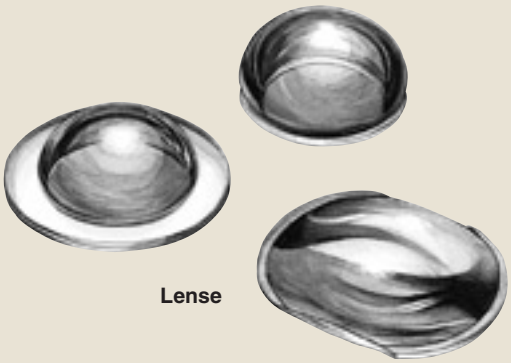
- Superior toughness and mechanical properties under high hardness and best fitted against breakage.
- Super mirror polishability.
- Hardness about 55HRC is obtainable by aging at 480°C with least distortion.

Application

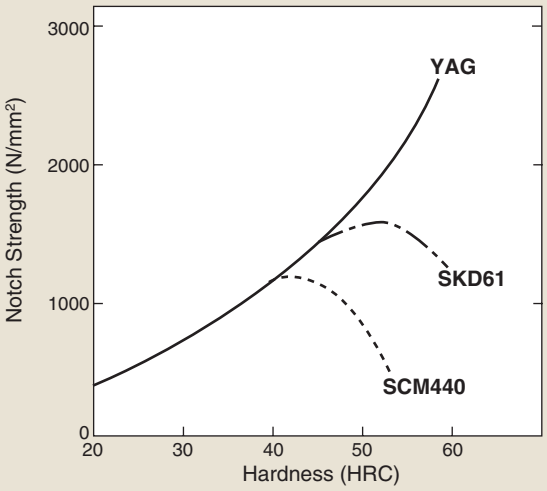
- Optical lense.
- Thin core pin.
- Ejector pin, either of smaller dia-meter or of longer length.



Ejector pin



Lense



Relationship between Hardness and Notched Tensile Strength

HPM75

Hardenable to: 40~45HRC
Non-Magnetic High Hardness Free Machining Plastic Mold Steel

Features

- Permeability (μ) is 1.01, equally non-magnetic as 304.
- 40-45HRC is obtainable by aging of 700°CX5h 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

Higher Grade Polishing Method of Plastic Mold

Polish procedure Example

Polish by oil grinding stone (use kerosene) ---------- #180→#240→#320→#400→#600→#800
Polish by oil sand paper (use kerosene) ---------- #600→#800→#1000→#1200→#1500
Finish Polishing by diamond compound (use felt cloth) #1200→#1800→#3000→#8000

Important points of polishing

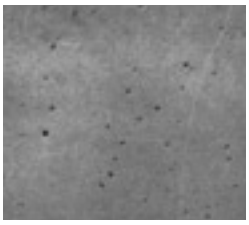
1. Each procedure is to be strictly kept.
2. When changing from one number to another, check if there are remained scrach by changing polishing direction. (move 45-90 degrees)
3. When changing numbers, wash and remove last polishing grains completely.
4. Polishing by diamond compound needs to be done in short times. Excessive polish can produce pinholes or orange peel.
5. Don't use alumina and chromium oxide for finishing as the polish capabilities are lower than diamond.
6. During long interruption, the object must be protected from the rust.

Remarks:

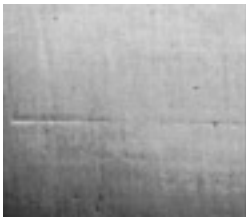
A. For superior polishing use diamondcompound.
Don't use alumina nor chromium-oxide compound.

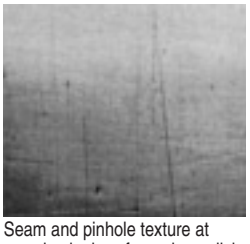

Diamond Compound Finish


Aluminium Oxide Finish Not Good


Chromium Oxide Finish Not Good

B. Lord for polishing should be kept 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 inapropriate rust proof.

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.

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 HPM1, use welding rod made from HPM1-W.
Likewise, in case fo TIG welding there are T-HTM-31 and T-HTM38 in the market for welding for mold made from HPM31 and HPM38.
B. In case of using coated electrode, mold should be dried by heating to 250-300˚C.
C. For cavity welding, TIG welding should be applied.
(TIG: Tungsten Inert Gas)

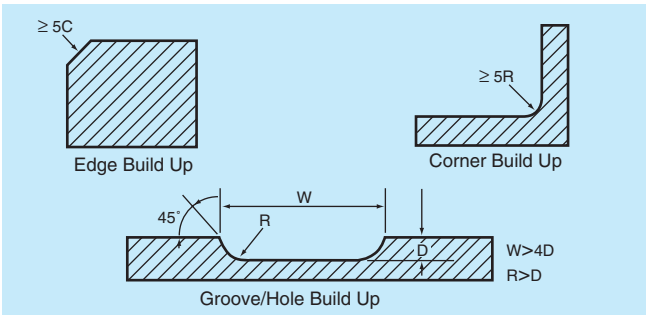


Figure 1. Standing shapes for build up welding

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.

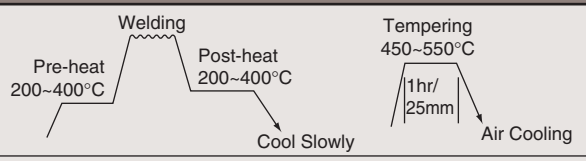
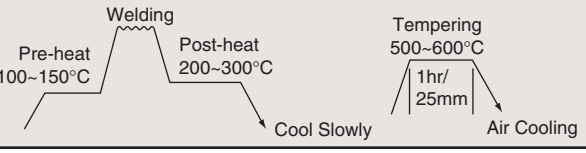
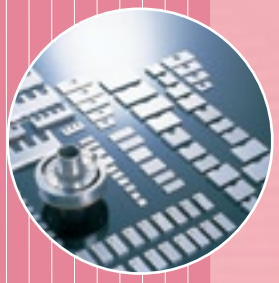
Welding Rod Grade	Welding	Rod	Condition	Heat Cycle
CENA1	TIG	CENA1-W	●TIG Welding Rod Current 2.4φ •••••• 80~160A 3.2φ •••••• 110~200A Flow Rate 10~15ℓ/min	
HPM7	TIG	HPM7-W	●Shielded Metal Ark Welding Rod Current 3.2φ •••••• 90~120A 4.0φ •••••• 130~160A	
	Shielded Metal Ark	TH50		

Figure2. Welding procedure

YSS
PLASTIC MOLD STEELS
CENA1



Innovated for 21century global standard grade.

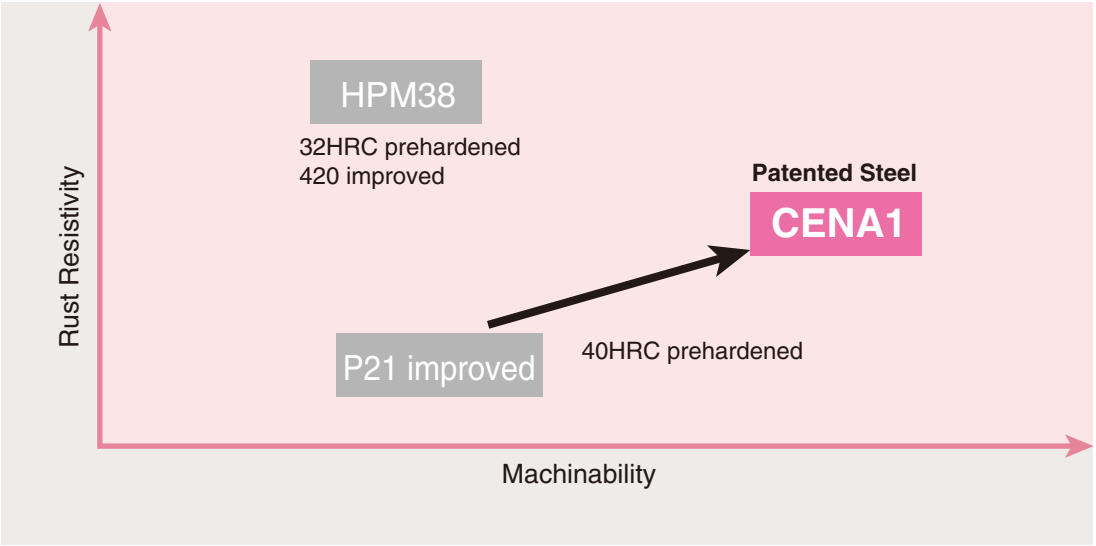
- Solution for Mold Rust Problem
- 40HRC Prehardened Grade with Excellent Machinability
- Excellent Polishability, Crepability and EDMachinability
- Most Suitable for Weldless Molds

Features

CENA1, new concept tool steel for injection mold, breaks through with excellent machinability and rust resistivity. Manufactured by consumable electrode remelting process, CENA1 has low non-metallic inclusion content and excellent mirror polishability. CENA1 is delivered in 40HRC prehardened condition.

- •Solution for Mold Rust Problem
- •40HRC Prehardened Grade with Excellent Machinability
- •Excellent Polishability, Crepability and EDM Machinability
- •Most Suitable for Weldless Molds

Characteristics



●Properties Comparison

excellent ◎>○>△>× poor

Grade	Hardness (HRC)	Machinability	Rust Resistivity	Mirror Polishability	Crepability	EDM Machinability
CENA1	**37-42**	◎	○	◎	◎	◎
P21 improved	37-41	○	×	◎	◎	◎
P21 improved and sulfulized	37-41	◎	×	○	△	△
P20 improved	29-33	◎	×	△	△	△
P420 improved	29-33	△	◎	◎	◎	◎

Application and Actual Performance

●Application

●**Molds for which temperature control is required (Weldless molds, etc.)**
●**Mold reguiring sensitive surface as mirror polishing, creping and EDM**
OA equipment, Communication equipment
(ex.Mobile telephone, Video camera, CD case)
Home Electronics (ex.Cleaner, Air conditioner)
Auto parts (ex.Tail lamp, Inner panel,
Transparent cover)
Cosmetics case, bottle
●**General resin**

●Actual performance Example

Rust Resistivity

Application	Comparison of Actual Performance with Conventional Grade by Customers
Mobile Phone	Less rust and deformation during EDM. Less rust and corrosion by resins during molding. (Mold durability increase more than 4 times compared with conventional grade.)
CD Tray	Resistant to corrosive gas generated by ABS resin, mold maintainance frequency decreased drastically.
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.

Machining

Air Conditioner Filter	**Less tool wear during precise rib machining and better surface obtained. Nitrided hardness 70HRC is effective to prevent mold depression by resin burr.**
Acrylic Lense	Carbide endmill tool life is doubled. Easy to mirror polish EDM surface.
TV Speaker	Many small pins ware EDMachined. Better EDM surface has been obtained compared with conventional grade.
Auto Head-light Lense	Good machinability in ball endmilling. Smooth surface machined with 0.4R ball endmill makes polishing easy.

Rust Resistivity

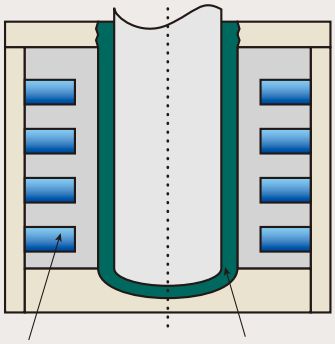
CENA1 has improved rust resistivity compared with conventional 40HRC prehardened grade.

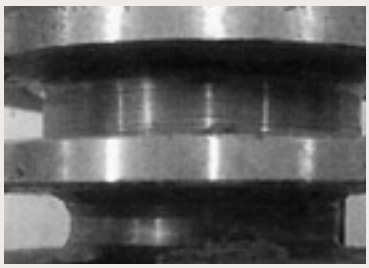
- **Improvement of corrosion problem on mold surface by resins.**
- **Decreased rust formation at cooling water hole makes cooling effect stable.**
- **Fewer rust problem in storage, transportadion, or usage of mold**
- **Much less rust formation on WEDM surface**

Rust Resistivity of Polished Surface

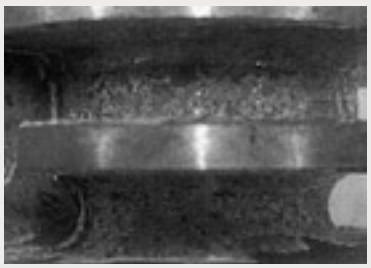
	CENA1	P21 improved
Dip in Water for 24Hrs		

Actual Performance Example of Rust Decreasing at Cooling Water Grooves of PET Parison Mold





CENA1 No plating



P21 improved and sulfurized+Cr plating

CENA1 Molding Result

	CENA1	P21 improved and sulfurized
Surface Treatment	No Plating	Cr Plating
Mold after 2 Months Use	Rust is removed easily by wiping.	Cr Plating came off and material was rusted deeply.

Photographs show water cooling grooves of the molds after 2 months use.
(3 cavities…CENA1, 3 cavities… P21 improved and sulfurized + Cr Plating, Total 6 cavities with one molding machine)

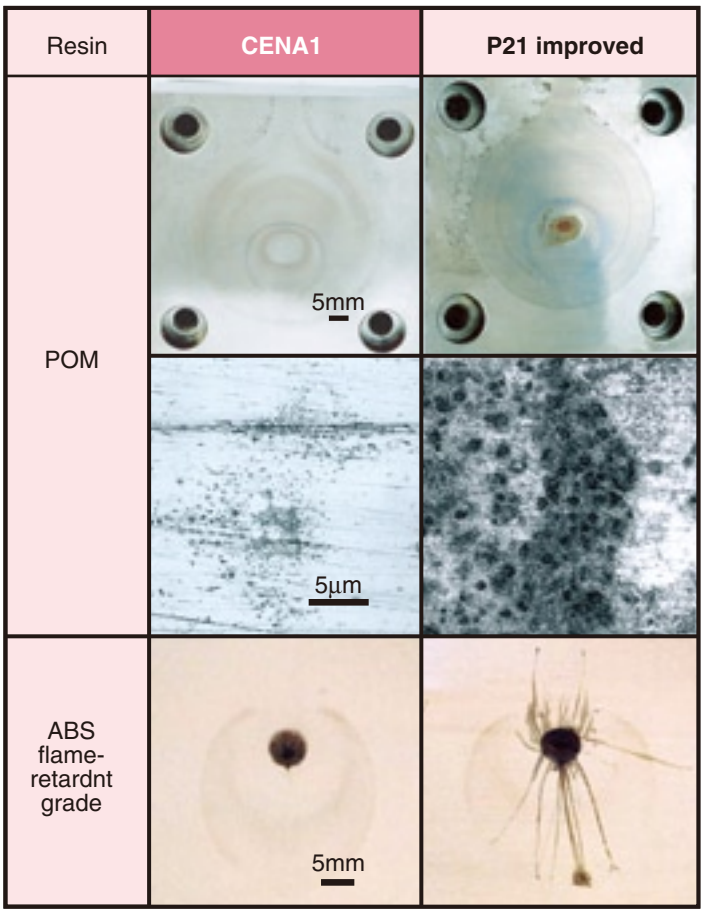
Rust Resistivity

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.

Figure

Acceleration gas-corrosion tests by a mold that is made to shut gas intentionally.
Observation results of the mold surface after 3000 shots of POM and ABS flame retardant grade.



Change on surface of specimens after injection molding tests

●CENA1 and Weldless Molds

CENA1 is most suitable for weldless molds for which temperature control is required, bucause surface condition of heating and cooling holes comes to be less corrosive and more stable.
CENA1 is widely used for the products such as PDP (Plasma display panel) and video cameras for better surface condition is indispensable.

Weldless Molds

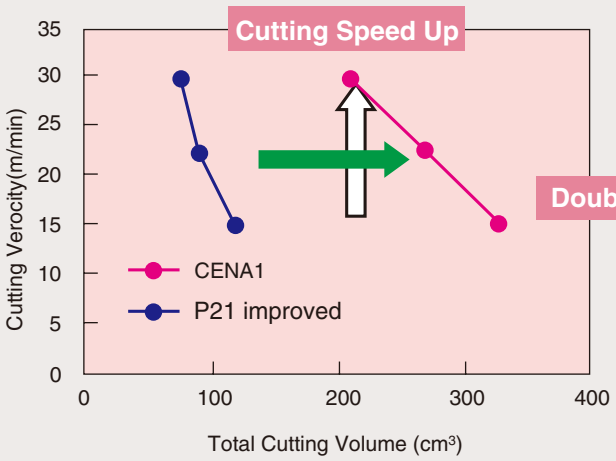
Machinability

Excellent machinability of CENA1 doubles tool life compared with conventional 40HRC grade tool steel in endmilling.

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

1.VT Curve

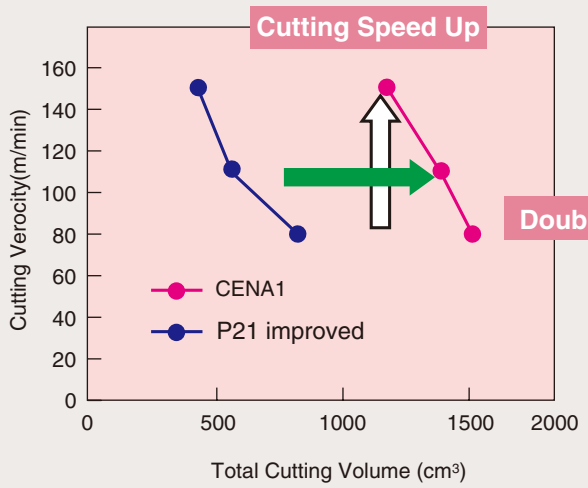
H.S.S.



HSS-Co 2NKR ø10 2teeth
Machine: Matsuura MC-800VF
Side Surface Cutting, Wet (Soluble),
Downcut,
Overhang: 35mm
Tool Life Definition: Tool Wear 0.3mm

Cutting Verocity (m/min)	Feed (mm/teeth)	Cutting Depth (mm)	Cutting Efficiency (cm³/min)
15	0.055	15Hx1W	0.80
22.5	0.055	15Hx1W	1.19
30	0.080	15Hx1W	2.30

Comented Carbide



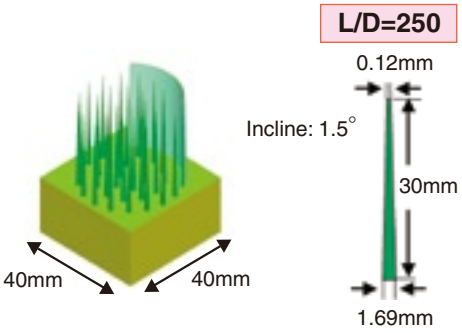
Carbide+Coating EPP4100 ø10 4teeth
Machine: Matsuura MC-800VF
Side Surface Cutting, Dry, Downcut,
Overhang: 35mm
Tool Life Definition: Tool Wear 0.15mm

Cutting Verocity (m/min)	Feed (mm/teeth)	Cutting Depth (mm)	Cutting Efficiency (cm³/min)
80	0.080	15Hx1W	6.11
113	0.080	15Hx1W	8.64
150	0.080	15Hx1W	11.47

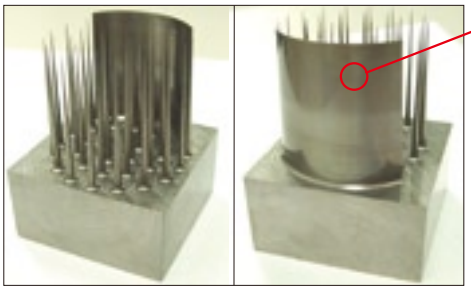
Machinability

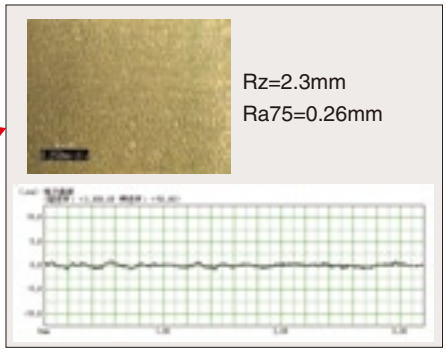
2.Endmilling Example

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



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

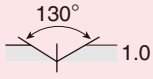




3.Drilling Condition

Deep hole machining condition

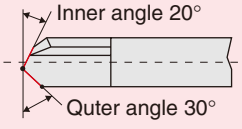
Dia.	Gread	Hole depth (mm)	Cutting Verocity (m/min)	Feed (mm/rev)	Step feed (mm)	Step back	Machined hole number	Remarks
ø0.6	SKH51(M2)	10(16D)	15	0.001	0.1		20	●**Procedure**
ø1	SKH51(M2)	10(10D)	20	0.003	0.2		60	1.Positioning (Starting drill)
ø1	Co-HSS+Coating	10(10D)	20	0.003	0.2		220	
ø1	Cemented Carbide +Coating	10(10D)	25	0.003	0.2		820	
ø2	SKH51(M2)	20(10D)	10	0.05	0.9		55	
ø3	SKH51(M2)	30(10D)	12	0.05	1.2		60	2.Machining drill
ø4	SKH51(M2)	40(10D)	12	0.05	1.3		83	
ø5	SKH51(M2)	50(10D)	12	0.06	1.5		105	
ø7	SKH51(M2)	42(6D)	15	0.1	2		200	
ø10	SKH51(M2)	90(9D)	13	0.13	2		50	



Machine : Vertical Machining Center Solution : Emulsion

Deep hole machining condition example by Gun drill

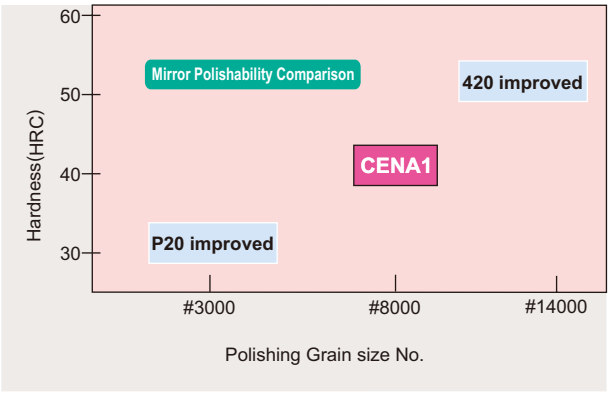
Dia.	Hole depth (mm)	Cutting verocity (m/min)	Feed (mm/rev)	Ejection pressure of cutting fluid (MPa)	Machined hole number	Remarks
ø3	80	25	0.007	4.9	6	
ø5	150	19	0.005	4.9	6	
ø11.5	500	48	0.012	3.6	8	
ø18	600	35	0.014	3.4	7	
ø25	700	47	0.02	2.9	6	
ø30	800	55	0.03	2.9	3	



Machine : Vertical Gundrill Solution : Oil

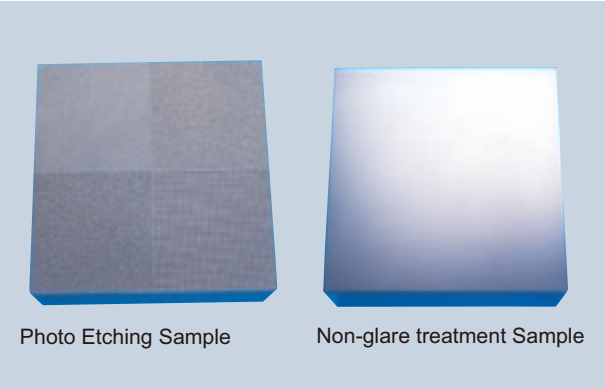
Mirror Polishability

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



Crepability

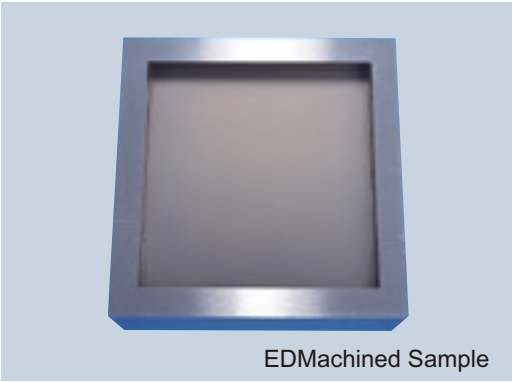
CENA1 has homogenized micro structure and good crepability.
CENA1 is suitable for precise creping.



・EDM surface Etching ・・・ Sand blasting treatment is needed before etching.
・Welded Surface Etching ・・・ Post-heating (≤ 200°C) after welding is needed before etching.

ED Machinability

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



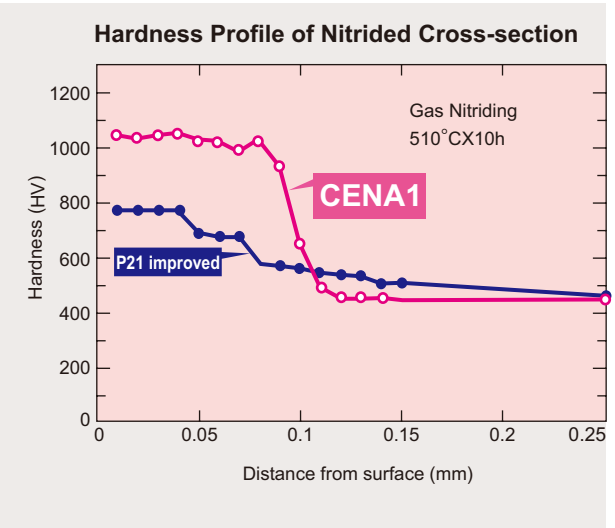
CENA1 100x100x50(mm)

(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

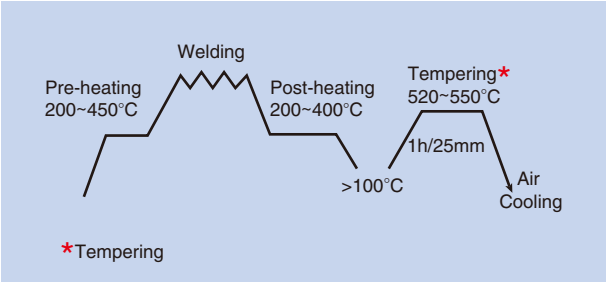
By nitriding, 1000HV surface hardness is obtained easily on CENA1, that is effective against wearing of slide core or mold for reinforced resin.



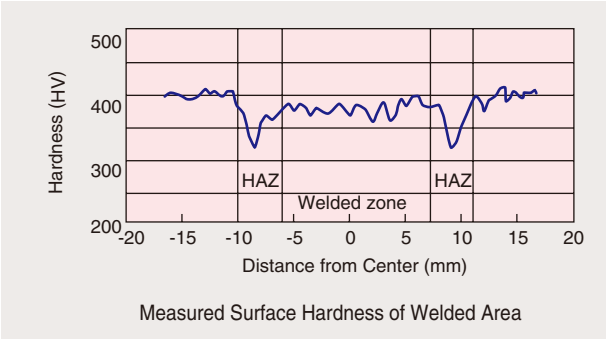
- The care is necessary to avoid breakage by over-hardening especially for small dia. pin or sharp edge part.
  It is recommended to apply lower nitriding temperature or soft nitriding condition.

Weldability

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

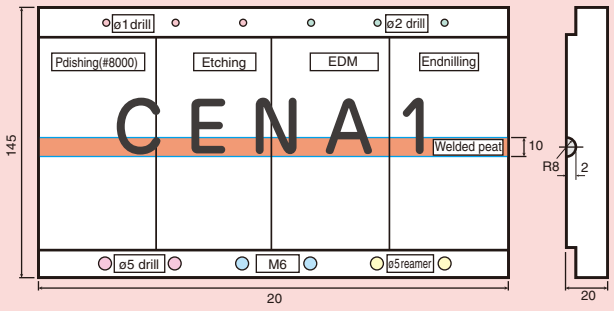


Welding repair is recommended to be done by TIG welding with CENA1-W rod.



Measured Surface Hardness of Welded Area

Welding Procedure Example

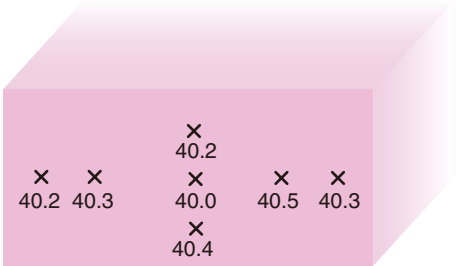


Photograph shows mirror polishing, creping, EDM and endmilling finished sample after welding repair (10mm width).
No weld mark is obserbed on each finished surface.

Hardness Distribution and Machanical Properties

Hardness Distribution

CENA1 shows almost uniform hardness distribution even in large cross-section material.



Measured hardness of flat bar
200^{t} X 510^{w} cross section.

Mechanical Properties

Machanical properties are almost same as P21 improved grade.

Representative value of flat bar 50tX400W.

Grade	Hardness (HRC)	Tensile Strength (N/mm^2)	Elongation (%)	Reduction of Area (%)	2U charpy impact value (J/cm^2)
CENA1	40	1,225	15	50	20
P21 improved	40	1,225	20	50	20

Physical Properties

Specific Grabity 7.78

Thermal Conductivity

W/(m·K)

Grade	20°C	100°C	200°C	300°C
CENA1	28.1	28.3	28.8	30.1
P21 improved	32.2	32.2	33.0	34.3

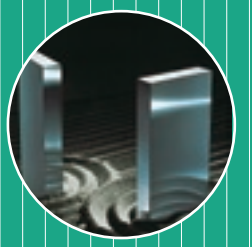
Thermal Expantion Coefficient

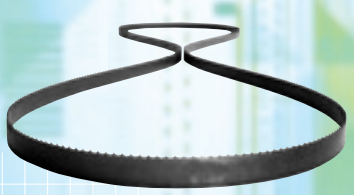
Average value from 20°C, $x10^{-6}$/°C

Grade	100°C	200°C	300°C	400°C
CENA1	11.0	11.4	12.0	12.5
P21 improved	11.3	11.6	12.4	12.8

Young's Modulus 205GPa

YSS
HIGH SPEED TOOL STEELS





Chemical compositions

(mass%)

		Grade	JIS equivalent	AISI equivalent	C	Cr	W	Mo	V	Co
Conventional High Speed Steels	Molybdenum High Speed Steel	**YXM1**	SKH51	M2	0.80~0.90	3.80~4.50	6.00~7.00	4.80~5.80	1.80~2.30	–
		YXM4	SKH55	M35	0.85~0.95	3.80~4.50	6.00~7.00	4.80~5.80	1.80~2.30	4.50~5.50
		YXMT	–	M1	0.75~0.85	3.50~4.50	1.30~1.80	8.00~9.00	0.90~1.30	–
		YXM42	SKH59	M42	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	Original Steel	–	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 High Speed Steel	**XVC5**	SKH57	–	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 High Speed Steel	YHX2	SKH2	T1	0.73~0.83	3.80~4.50	17.00~19.00	–	0.80~1.20	–
	Matrix High Speed Steel	**YXR33**	–	–						
		YXR3	Original Steel	–						
		YXR7	Original Steel	–						
P/M High Speed Steels		**HAP5R**	–	–						
		HAP10	–	–	1.30~1.40	4.50~5.50	2.50~3.50	5.50~6.50	3.60~4.00	–
		HAP40	SKH40	–	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	Patented Steel	–	2.02~2.32	3.70~4.70	9.00~10.00	8.00~8.50	4.80~5.10	9.00~10.00

Applications and YSS grade Features

Grade	Applications	Features
YXM1	Drill, Reamer, Broach, Chaser, Metal saw, Cutters, Cold punch, Dies	Standard Molybdenum high speed steel with superior toughness
YXM4	Hob, Drill, Reamer, Chaser, Cutters, Heading tool for stainless, Endmill	Standard Cobalt alloyed Molybdenum high speed steel with superior heat resistance
YXMT	Tap, Roller dies	Molybdenum high speed steel with superior grindability and toughness
YXM34	Hob, Cutters	Cobalt alloyed Molybdenum high speed steel suitable for intermittent cutting
YXM42	Drill, Cutters, Hob, Tap, Wood working tools	Super-hard high speed steel suitable for cutting for hard materials
YXM60	Endmill, Hob, Broach, Cutters, Drill, Tap, Heading tool for stainless	High-performance high speed steel with superior durability, toughness and grindability
XVC5	Tool bit, Cutters, Hob, Endmill, Cold punch, Dies	High-performance Cobalt alloyed Vanadium high speed steel with wear/heat resistance
YHX2	Cutters, Broach	Standard Tungsten high speed steel
YXR33	Warm forging dies, Hot forging dies, Cold forging dies, Al-die cast insert pin	Matrix high speed steel for forging tools with most superior toughness
YXR3	Warm forging dies, Cold heading punch, Trimming dies, Cold forging punch and die	Matrix high speed steel for forging tools with superior toughness
YXR7	Cold punch and die, Fine blanking die, Thread roller die	Matrix high speed steel for forging tools with superior strength/toughness
HAP5R	Severe forming tools, cold/warm forging dies, fine blanking dies	Toughest P/M high speed steel
HAP10	Heavy duty working tools as fine blanking dies, Lower speed cutting tools as taps	Superior toughness effective to avoid chipping
HAP40	Cutters, Dies	Most standard grade with good balance of hardness, toughness and wear resistance
HAP50	Heavy duty cutting tools for hard material	Higher hardness, good heat and wear resistance
HAP72	Heavy duty cutting tools, Dies	Good heat wear resistance and highest obtainable hardness of 70HRC

Recommended grade by application

●Cutting tools

( ) shows standard employed hardness/HRC.

Application	Recomended 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)	(65~67) HAP40, **HAP50** (66~68)
Tap	**YXM1** (63~66)	**YXM20**, **YXM30** (65~67) **HAP10**, HAP40 (65~67)	**YXM30** (65~67) HAP45 (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**
Broach	**YXM1** (63~66) **YXM4** (64~67)	YXM60 (66~68) HAP10, **HAP40** (66~68)	(69~71) **YXM30** (65~67)
Hob	**YXM4**, YXM1 (64~69)	YXM60 (67~69) HAP50 (67~69)	HAP10, **HAP40** (66~68) **HAP40**, **HAP50** (66~68)
Pinion cutter	**YXM1**, **YXM4** (63~65)	**HAP40** (65~67)	**HAP10**, **HAP40** (64~66)
Shaving cutter	**YXM1** (64~66)	YXM30 (65~67) **YXM42**, **YXM60** (66~68)	
Rack cutter	YXM1 (63~66)	YXM4 (65~67)	YXM4 (65~67)
Chaser	**YXM1** (62~65)	YXM30 (65~67) HAP10 (65~67)	YXM4, YXM30 (65~67)
Metal saw	**YXM1** (63~66)		YXM42, YXM60 (65~67) YXM4 (65~67)
Hack saw	**YXM1** (62~65)	YXM42 (66~68) HAP40 (66~68)	YXM42 (66~68) HAP40 (66~68)
Metal band saw	**YXM1** (64~66)	**YXM42** (66~68) HAP40 (66~68)	HAP40 (66~68)
Wood cutter	**YXR3** (58~61) **YXM1**, YHX2 (62~65)	**YXM42** (66~68)	YXM4 (65~67)

●Cold working tools

Application		Required hardness range HRC	For general use	Recommended YSS steel	
				For mass production use	
				For abrasion resistance	For impact resistance
Blanking die		58~62	SLD, SLD8, ARK1	XVC5, HAP40	YXM1, YXR7, HAP10
Cold heading die	Male die	58~62	SLD, SLD8, ARK1	HAP40	YXM1, YXR7, YXR3
	Female die	55~60	YSM	SLD, SLD8	YXM1, YXR7, YXR3
Shearing blade (Straigh tooth)	For sheet service	55~60	SLD, SLD8, ARK1	YXM1, YXR7	YXR3
	For medium plate	55~58	SLD, SLD8, ARK1		YXR33
	For heavy plate	48~53	DM, DAC		
Rotary shear slitter		54~60	SLD, SLD8, ARK1	YXM1, HAP40	YXR7, YXR3
Trimming dies	For sheet use	55~60	SLD, SLD8, ARK1	YXM1, HAP40	YXR7, YXR3
	For heavy plate use	50~55	DM, DAC		
Bender Swaging dies		58~62	SLD, CRD, ARK1	XVC5	YXM1, YXR7
Cold working dies	Male die	58~62	SLD, SLD8, ARK1	YXM1, HAP40	YXR7, YXR3, HAP10, HAP5R
	Female die	55~63	SLD, SLD8, ARK1	YXM1, YXR7	YXR3, HAP5R
Drawing dies		57~62	YXM1, CRD	XVC5	
Cold working rolls		≧80HS	SLD	YXM1, HAP40	
Thread rolling dies		58~64	SLD, SLD8	SLD10, YXM1, YXR7	
Coining dies		57~62	SLD	YXM1, YXR7	
Cold hobbing dies		55~60	SLD	YXM1, YXR7	
Thead cutting dies		60~64	SGT, SAT	YXM1, YXR7	

Heat Treatment Conditions

Standard heat treatment conditions

●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 occured by cold working such as cold drawing, cold rolling or cutting and machining.

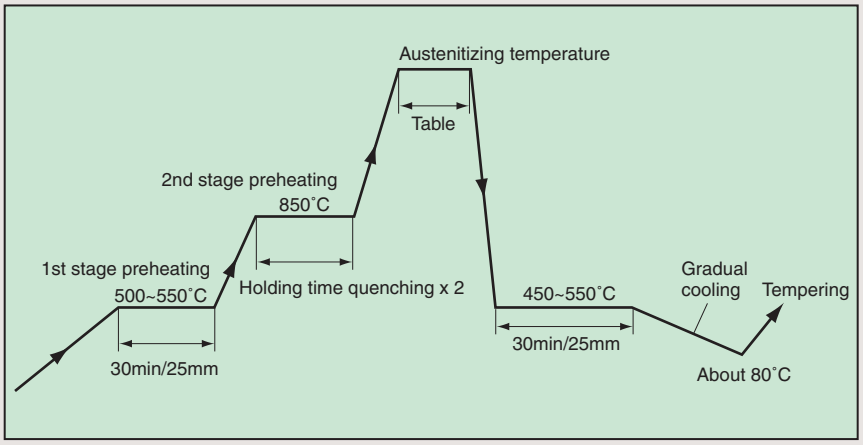
- Heating temperature : 650~750˚C
  (to aim higher temperature when softening required)
- Holding time:1h/25mm thickness

●Holding time of austenitizing

Preheat 1st 500-550˚C 30minutes/25mm thickness
2nd 850˚C 2 X figure of following table
3rd 1,050˚C 2 X figure of following table

When the object is of simple shape with thickness less than 50mm or when facilities are restricted, 2nd and 3rd steps are combined to one step with 850~900˚C X 2 X table-1. When the object is small, 1st step may be skipped.

●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

Heating furface	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

(Remarks) Holding time in salt bath = dipping time

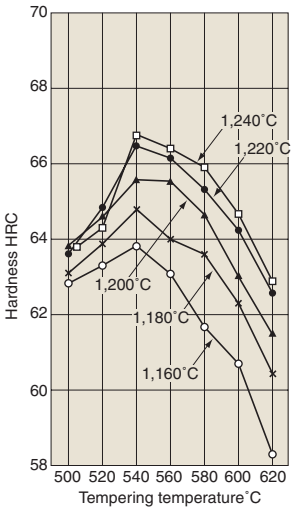
●Holding time at tempering temperature

Thickness	≤ 2.5	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 contain no cobalt and needed more than 3 times for grades cobalt alloyed in order to make it tough enough.

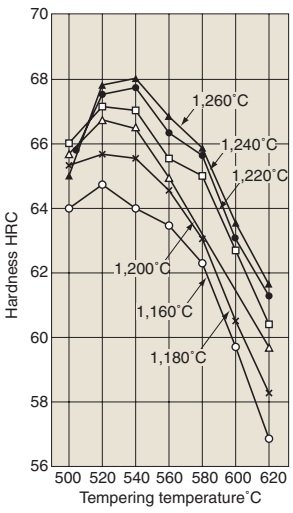
Quenched and tempered hardness curve

YXM1



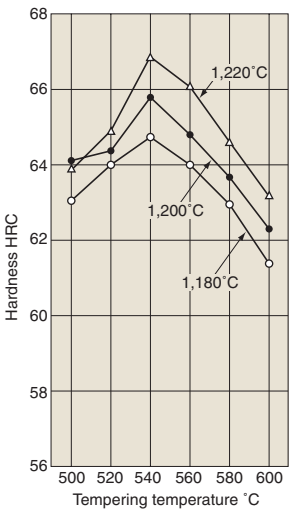
YXM1 Tempered hardness

YXM4



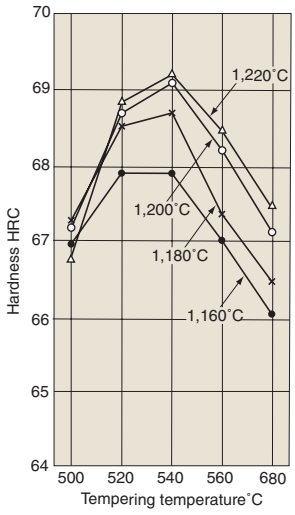
YXM4 Tempered hardness

YXMT



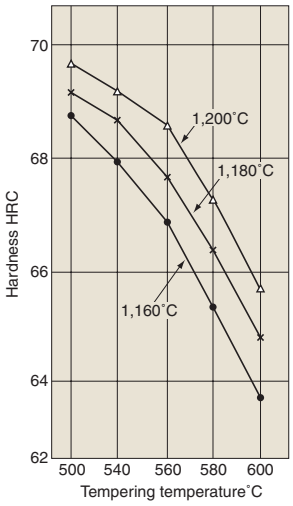
YXMT Tempered hardness

YXM42



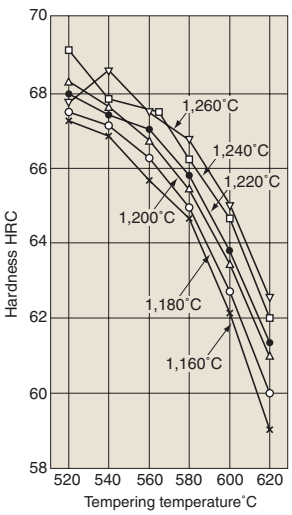
YXM42 Tempered hardness

YXM60



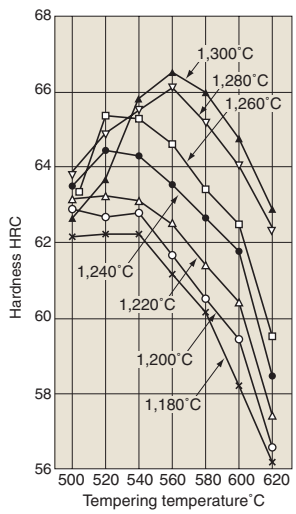
YXM60 Tempered hardness

XVC5



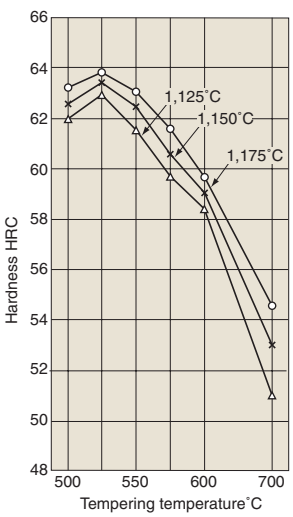
XVC5 Tempered hardness

YHX2



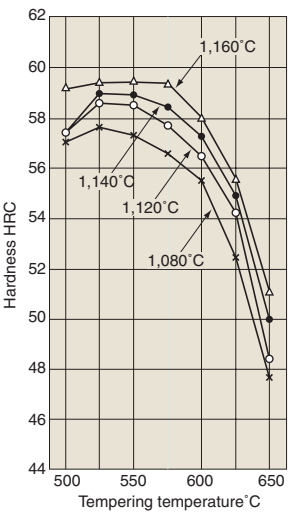
YHX2 Tempered hardness

YXR3



YXR3 Tempered Hardness

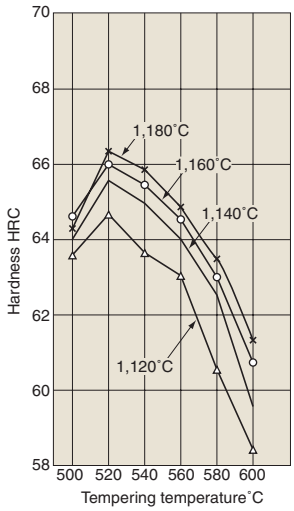
YXR33



YXR33 Tempered hardness

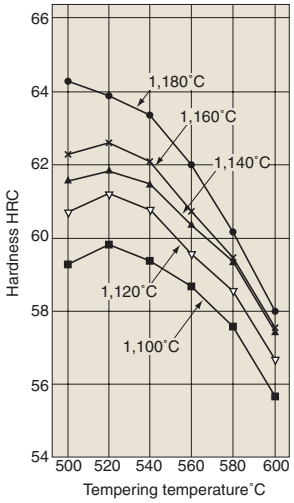
Quenched and tempered hardness curve

YXR7



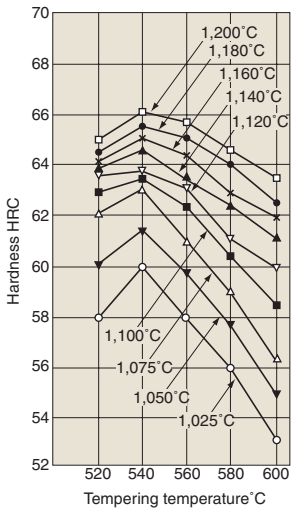
YXR7 Tempered hardness

HAP5R



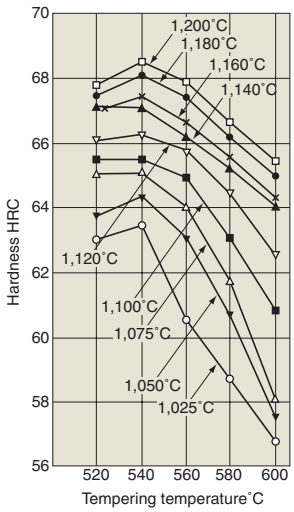
HAP5R Tempered hardness

HAP10



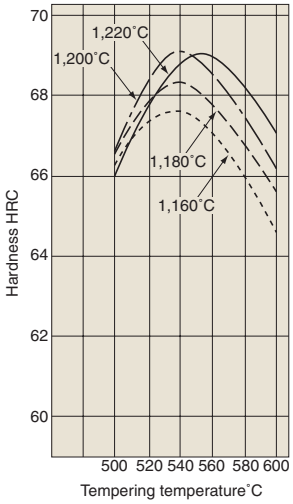
HAP10 Tempered hardness

HAP40



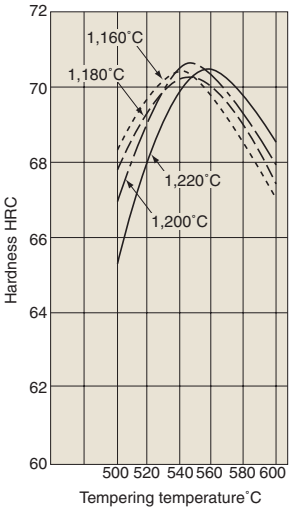
HAP40 Tempered hardness

HAP50



HAP50 Tempered hardness

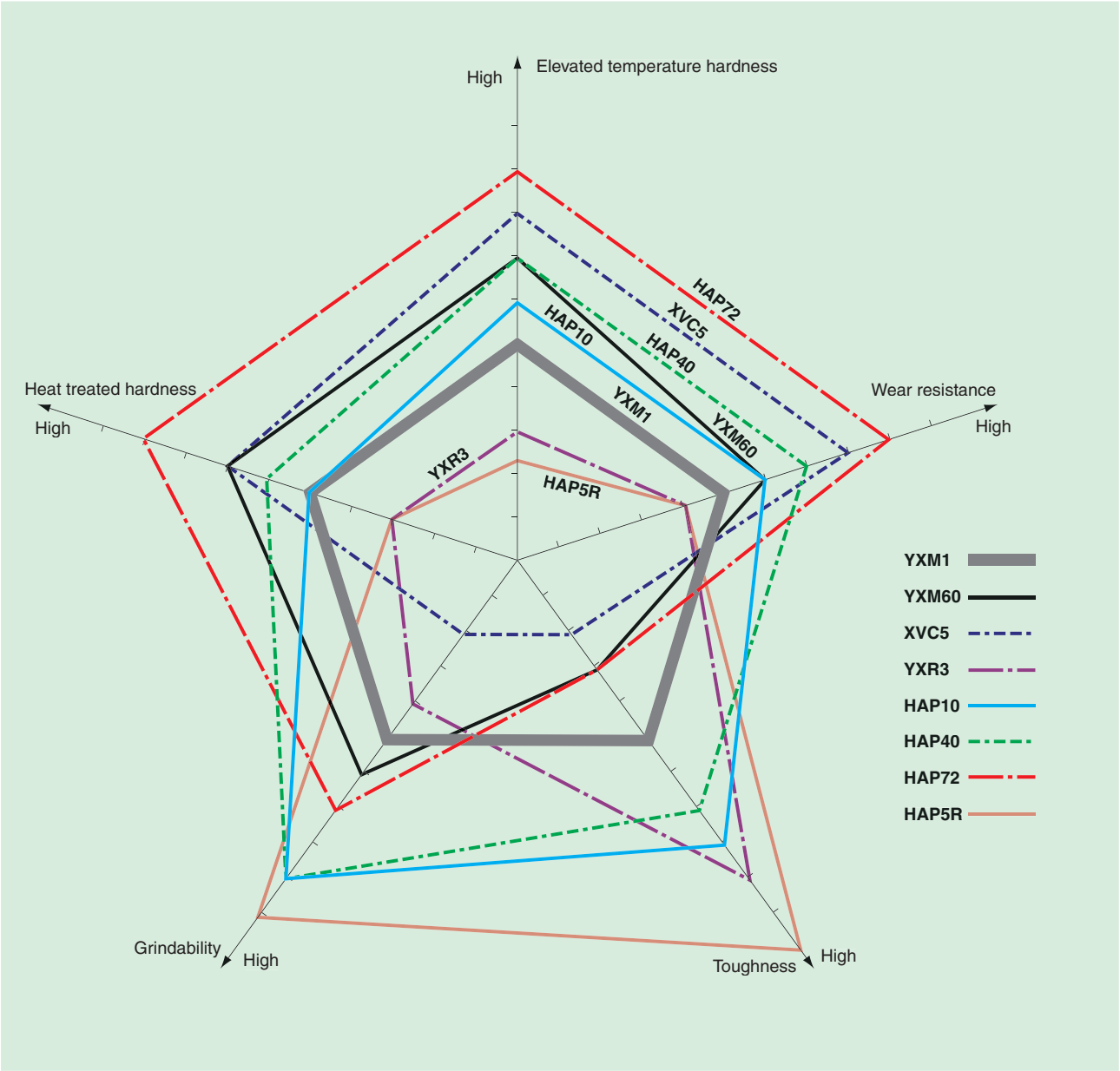
HAP72



HAP72 Tempered hardness

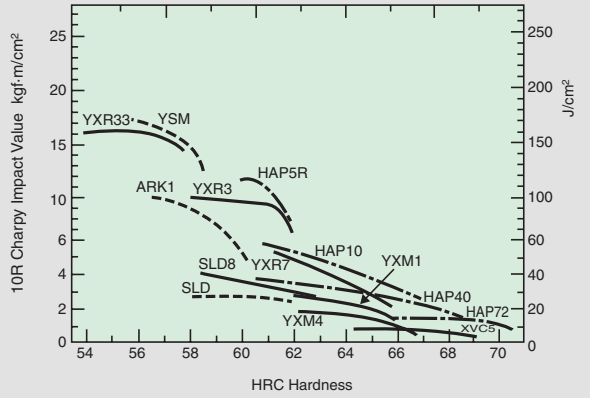
Properties

Comparison of Properties (Based on YXM1 properties)

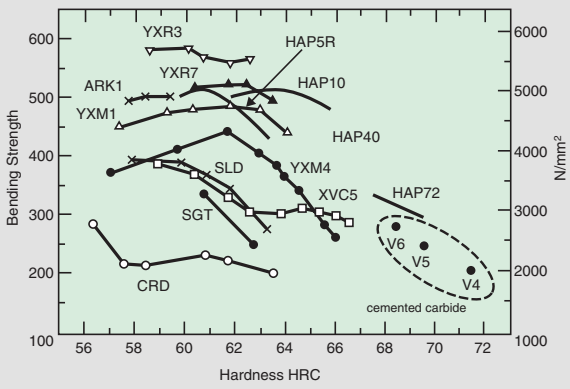


Properties

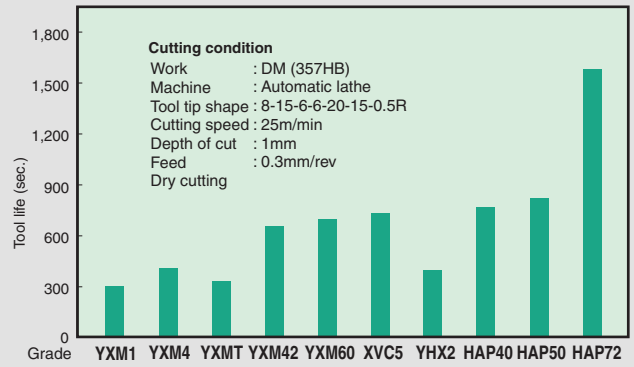
Charpy impact value



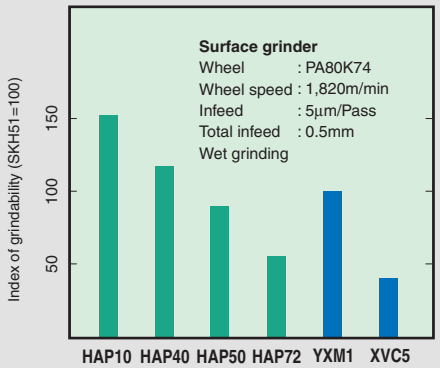
Bending strength



Continuous Cutting test by turning tool



Grindability



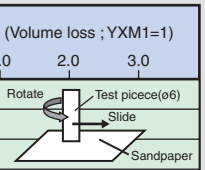
Wear resistance (Ogoshi method)

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

Co-friction material Friction length Load Friction speed

Wear resistance (Abrasive Wear)

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



Test condition
Sandpaper: Al_2O_3 #500
Revolution: 980rpm
Friction length: 1000mm
Lubricant dry
Load: 49N (5kgf)

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