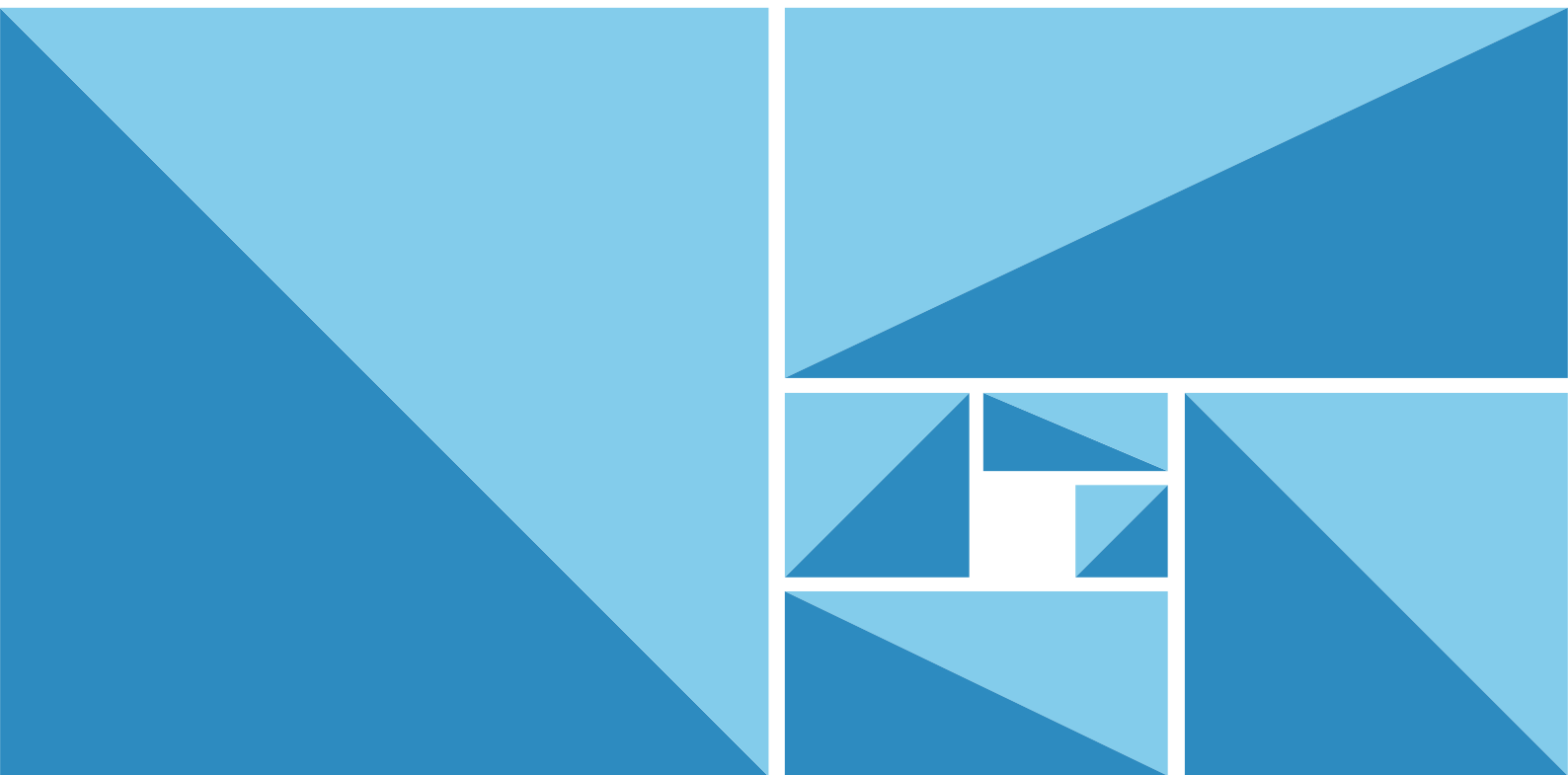


**YSS**

# Cold Work Tool Steels



# Types of YSS cold work tool steels

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

## Applications in cold work dies

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



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## Types of YSS cold work tool steels

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

## Applications in cold work dies

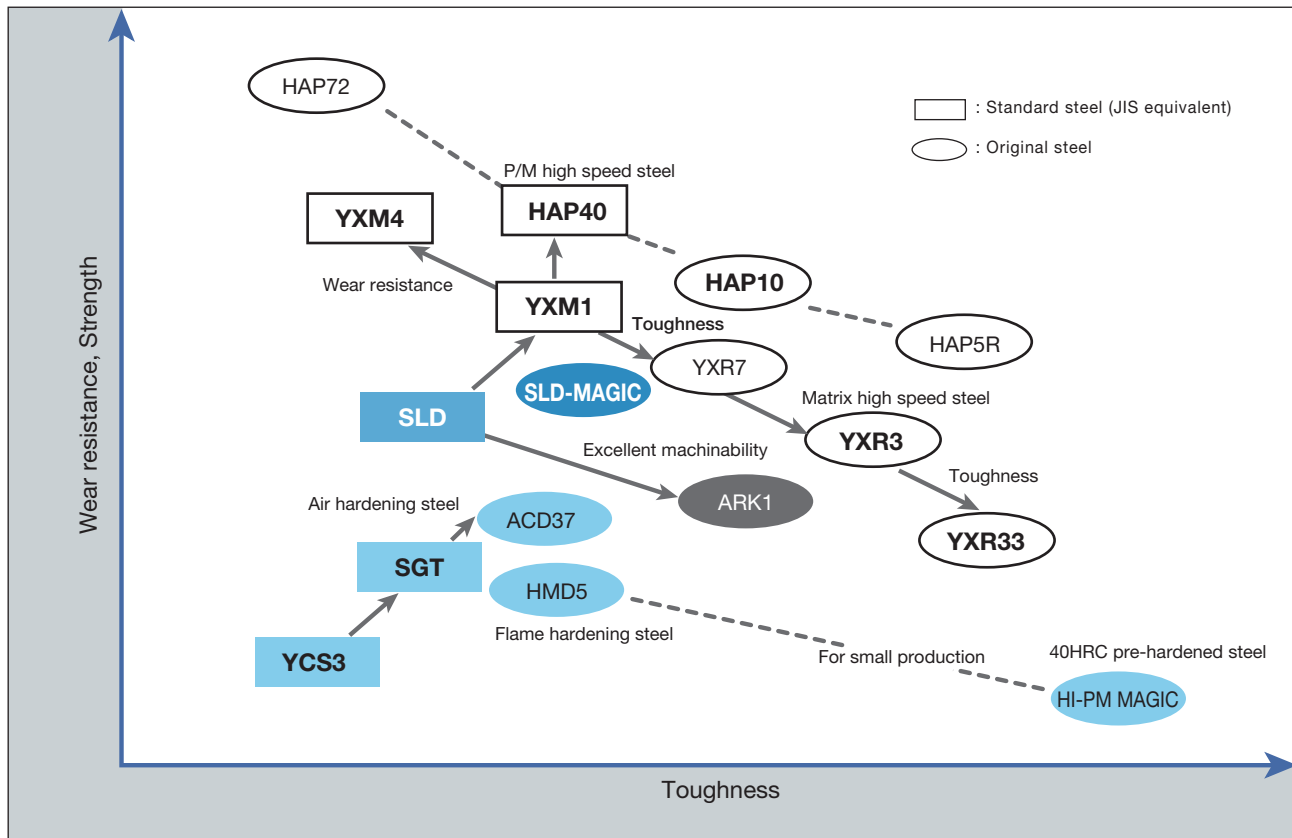
Application		Standard hardness (HRC)	For general use	Recommended YSS steel		
				For mass production use		
				For abrasion resistance	For impact resistance	
For plastic forming	Trimming dies	For sheet use	55-60	SLD, SLD-MAGIC, ARK1	YXM1, HAP40	YXR3, YXR7
		For heavy plate use	50-55	DAC, DM		
	Cold hobbing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



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# Characteristics of YSS cold work tool steels

## Characteristics of steels



## Comparison of characteristics

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

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



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# Characteristics of YSS cold work tool steels

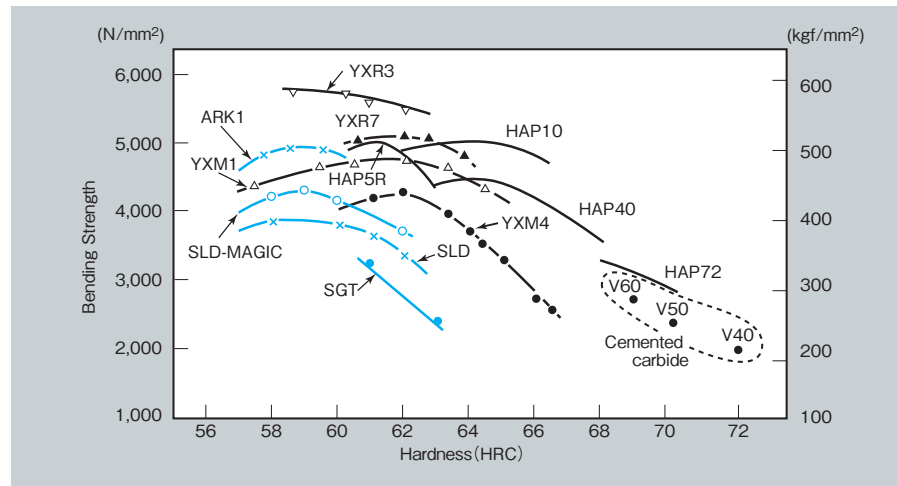
## Wear resistance

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

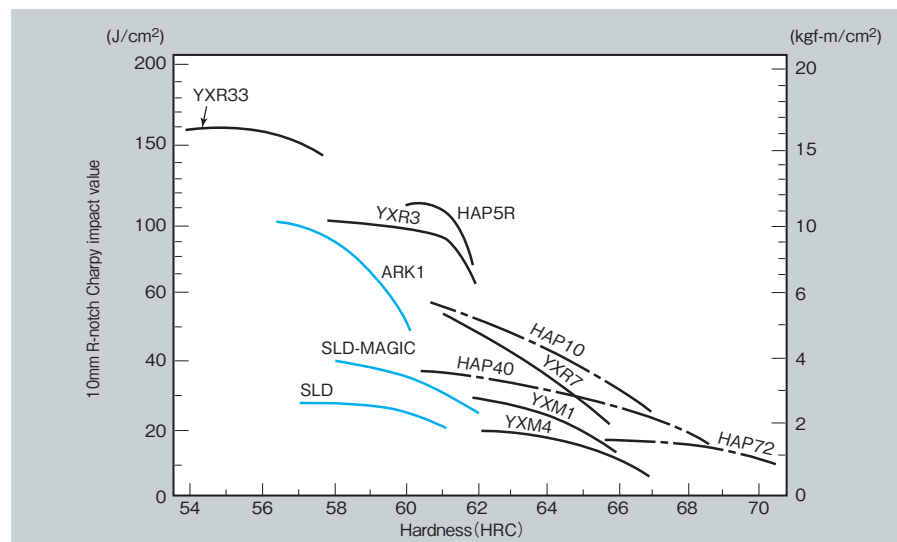
Ongoshi-method wear test  
 Work material : SCM415  
 Friction distance : 400m  
 Friction speed : 0.76m/s  
 Load : 67N

## Toughness

### Bending strength



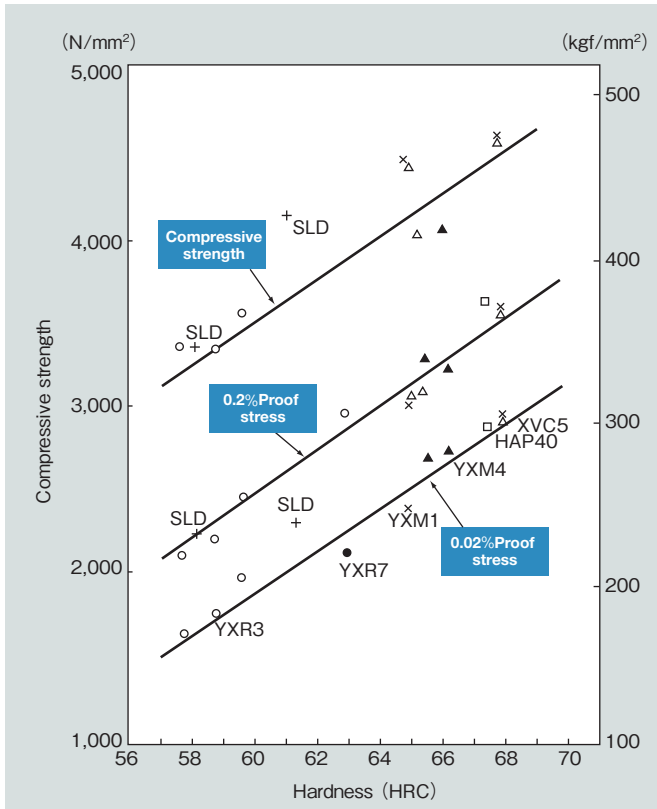
### Charpy impact value



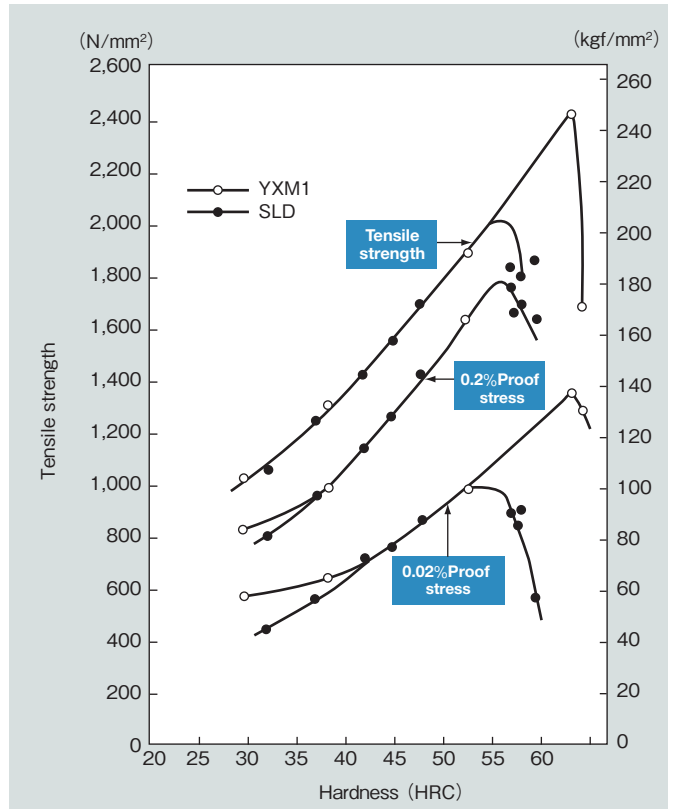
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# Characteristics of YSS cold work tool steels

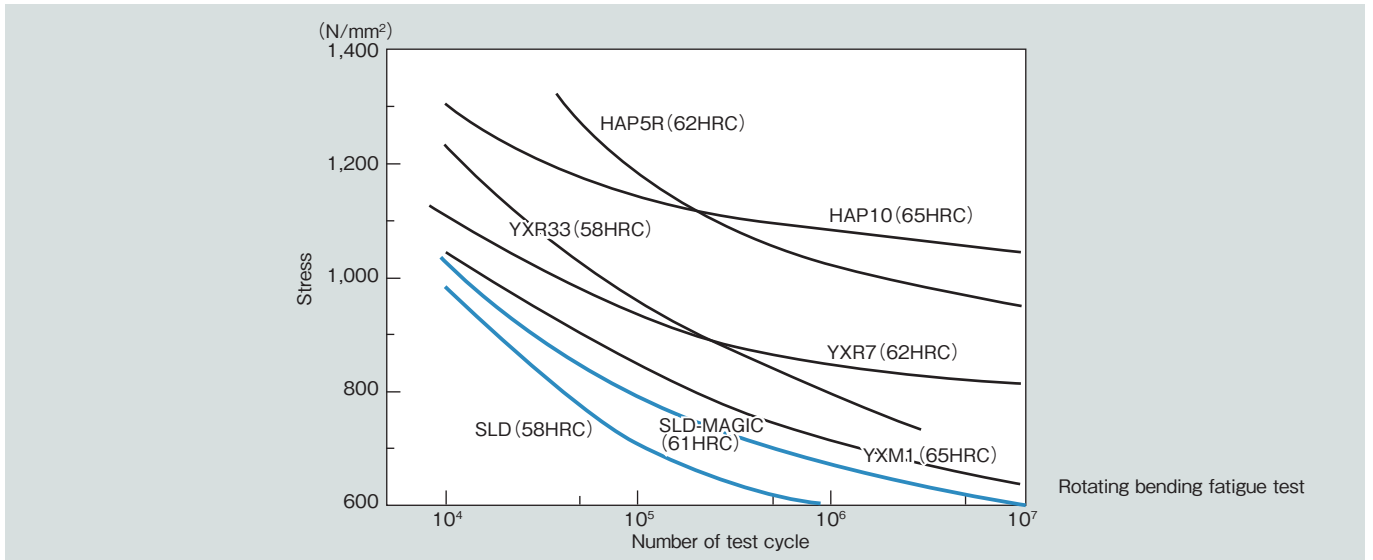
## Compressive strength



## Tensile strength



## Fatigue strength



## Physical properties

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



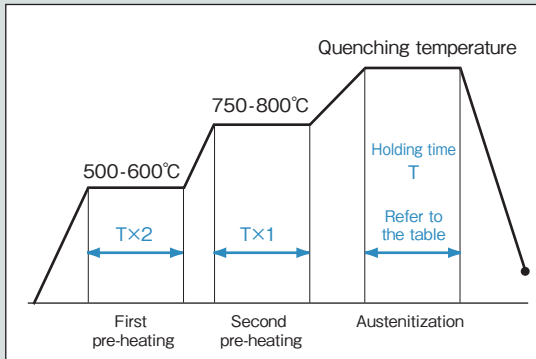
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# Heat treatment of YSS cold work tool steels

## Hardening

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

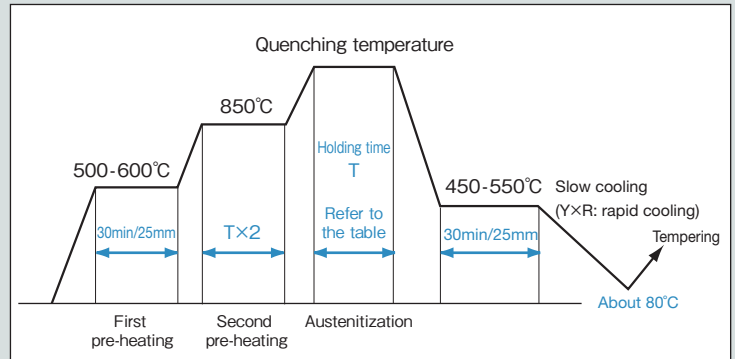
### Alloy tool steels, Carbon tool steels



### Holding time at austenitizing temperature

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

### High speed tool steels

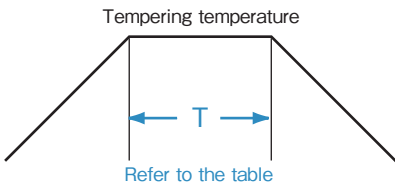


### Holding time at austenitizing temperature

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

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

## Tempering



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

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

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

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

## Annealing

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



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# Heat treatment of YSS cold work tool steels

## Standard heat treatment conditions

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

(1) Simple shape tools

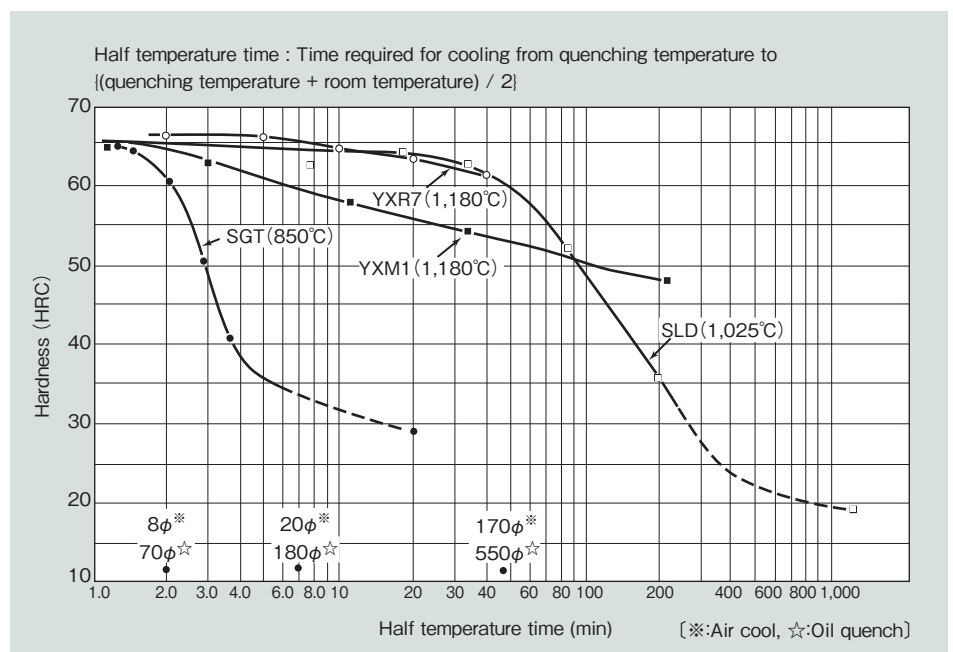
(2) Tools of complicated shape, requiring toughness in particular

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

## Hardenability

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

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

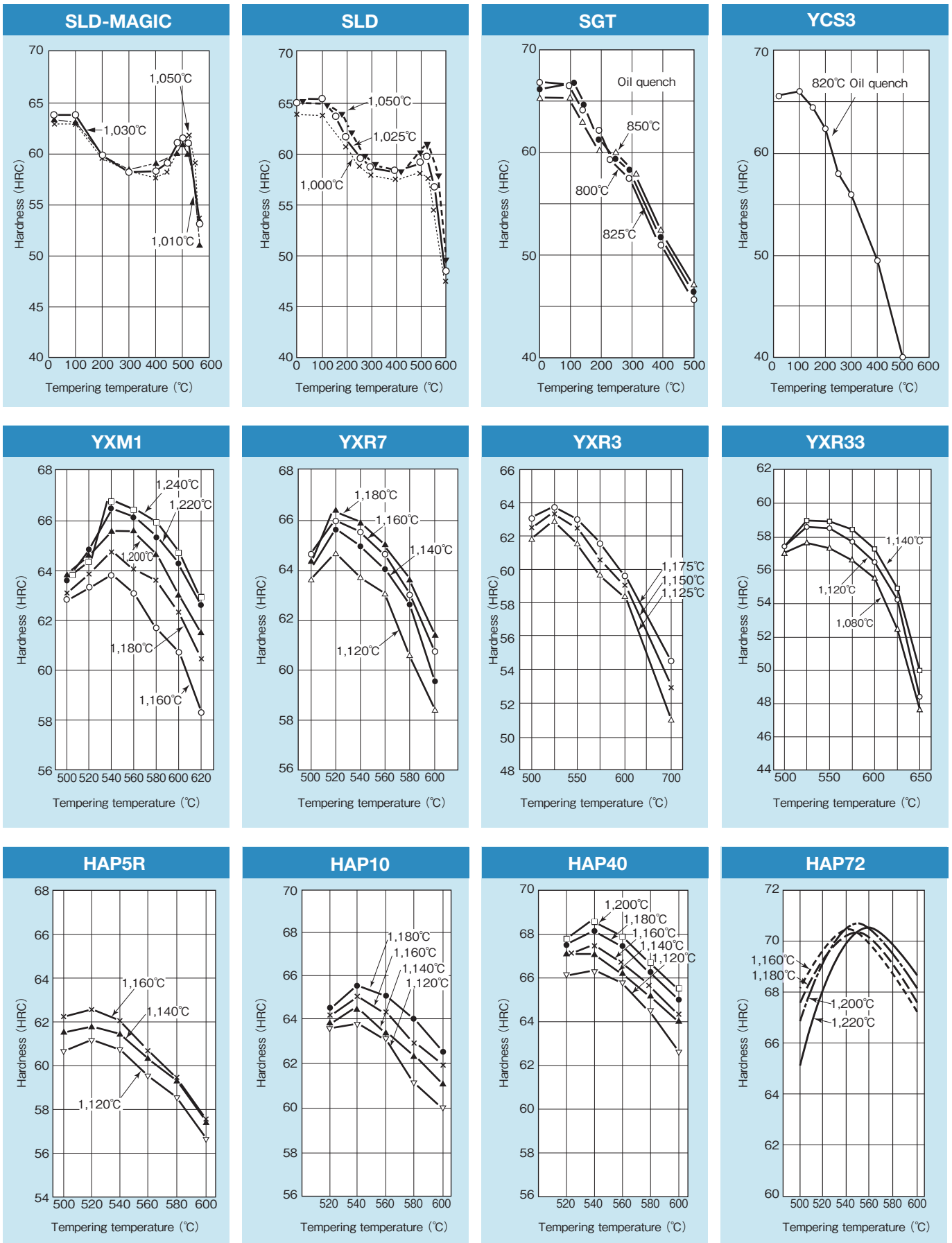


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# Heat treatment of YSS cold work tool steels

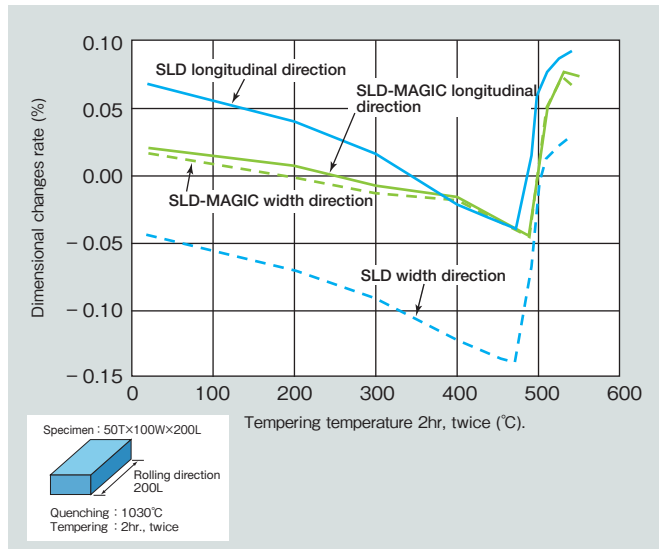
## Quenched and tempered hardness curves



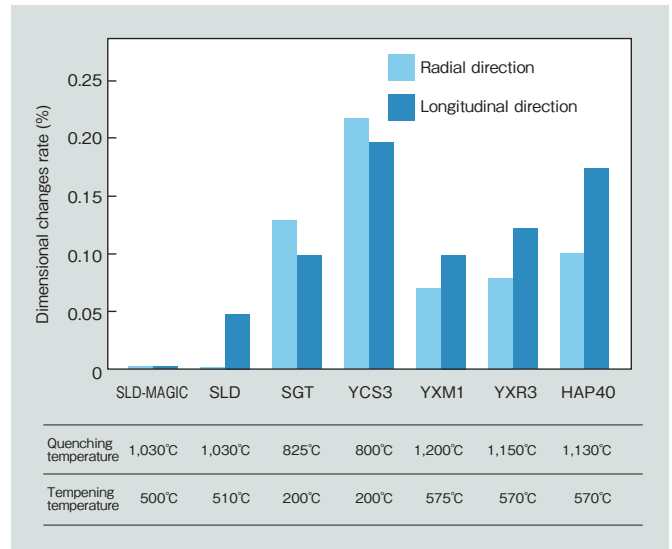
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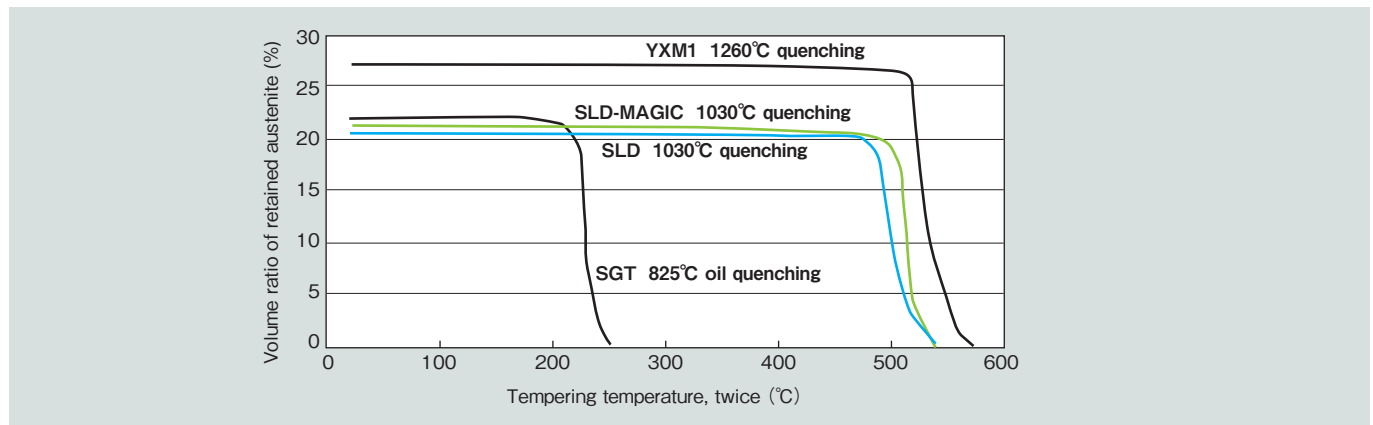
## Dimensional change after heat treatment of cold dies steel



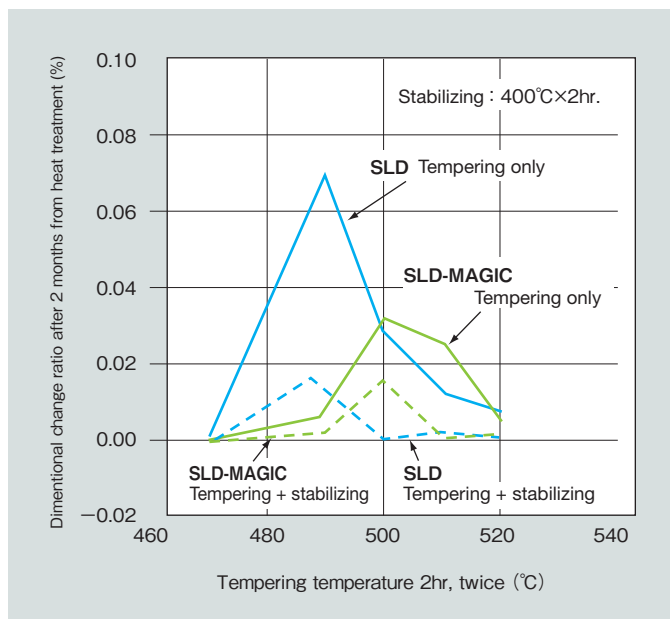
## Dimensional changes after heat treatment



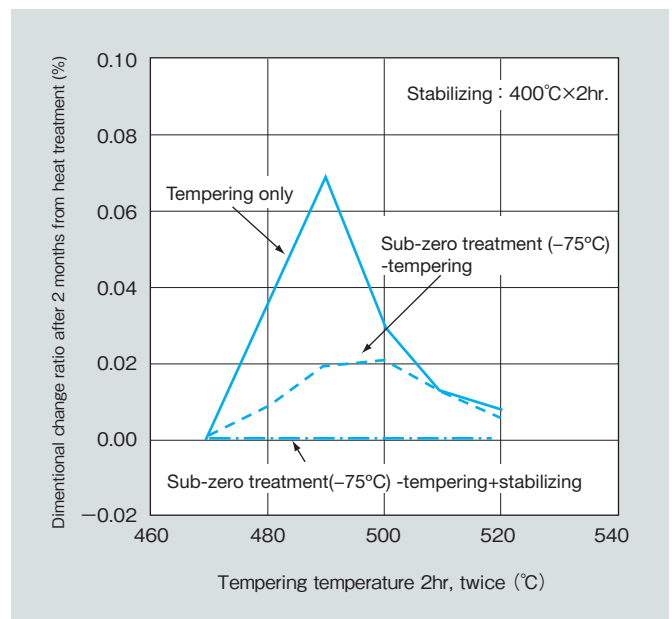
## The retained austenite



## Secular change and stabilizing treatment on cold work tool steel



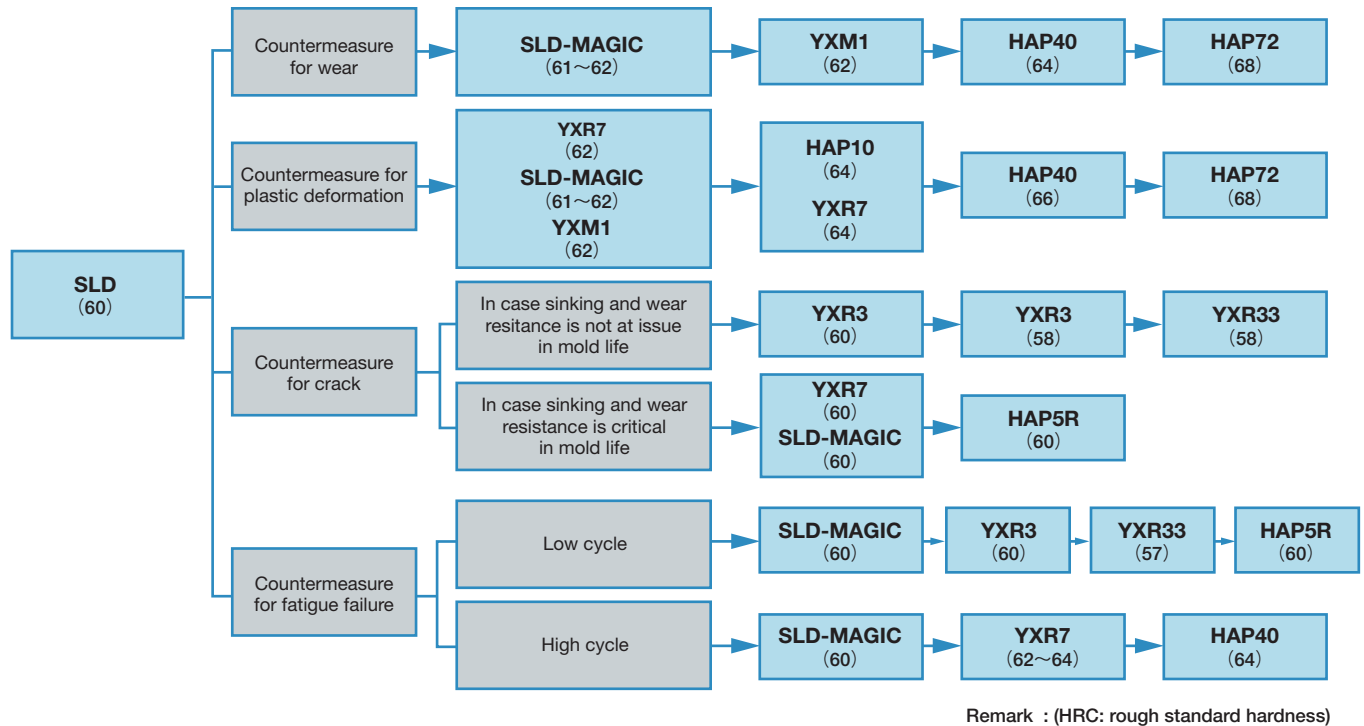
## Secular change and sub-zero treatment



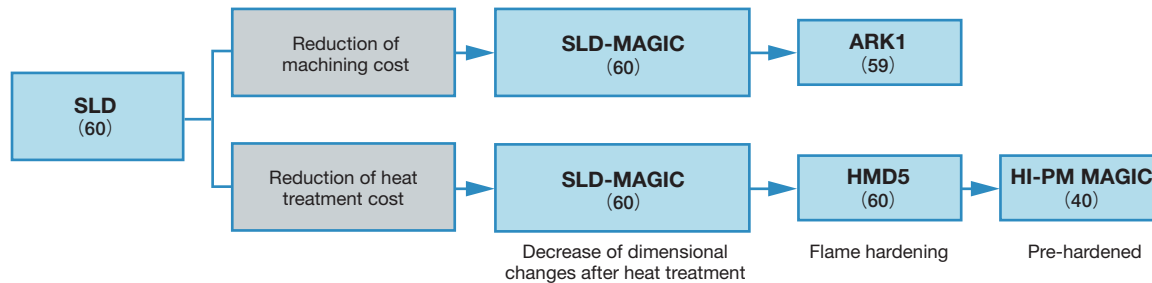
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# Improvement processes of YSS cold work tool steels in terms of hardness and dies for various applications

## Flowchart to improve die life of cold work tool steels



## Flowchart to reduce die cost of cold work tool steels



## Isotropy



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



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## **Hitachi Metals, Ltd.**

**Head Office** SEAVANS North Building, 1-2-1, Shibaura, Minato-ku, Tokyo 105-8614, Japan  
High-Grade Metals Company  
Tel. +81-3-5765-4410  
Fax. +81-3-5765-8317

## **Hitachi Metals America, Ltd.**

**Head Office** 2 Manhattanville Road, Suite 301, Purchase, NY 10577, U.S.A.  
Tel. +1-914-694-9200  
Fax. +1-914-694-9279

**Other Office** Chicago, Detroit, Pittsburgh, San Jone, Novi Michigan

## **Hitachi Metals Europe GmbH**

**Head Office** Immermannstrasse 14-16, 40210 Duesseldorf, Germany  
Tel. +49-211-16009-0  
Fax. +49-211-16009-29

**Other Office** London, Milano, Paris

## **Hitachi Metals Singapore Pte. Ltd.**

12 Gul Avenue, Singapore 629656  
Tel. +65-6861-7711  
Fax. +65-6861-1519

## **Hitachi Metals (Dong Guan) Specialty Steel Co., Ltd.**

**Head Office** Cha Shan Town, Dong Guan City, 522380, China  
Tel. +86-769-8640-6726  
Fax. +86-769-8640-6716

**Shanghai Branch** No.155 jiu yuan road, Qingpu industrial zone, Qingpu District, Shanghai, 201712, China  
Tel. +86-21-3929-2202  
Fax. +86-21-3929-2201

**Tianjin Jinnan Branch** No.11, Jianshe 4th Branch Road, Balitai Town, Jinnan District, Tianjin, 300350, China  
Tel. +86-22-8699-3101/3102  
Fax. +86-22-8699-3103

**Dalian Branch** 3<sup>#</sup>-2, Koushin Mould Industrial Park III B-1-1-1F. T. Z. Dalian, 116600, China  
Tel. +86-411-8718-1011/1022  
Fax. +86-411-8718-1033

## **Hitachi Metals (Suzhou) Technology, Ltd.**

88 Xing jin Street, Suzhou Industrial Park, Jiangsu Province, 215027, China  
Tel. +86-512-6790-2106  
Fax. +86-512-6790-2128

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Our address and contact indicated in this catalog are those as of January 2015.  
If you cannot put a call through, please contact our Corporate Communications Office in Tokyo below.

Hitachi Metals, Ltd.  
Corporate Communications Office  
Tel: +81-3-5765-4076 Fax: +81-3-5765-8312

