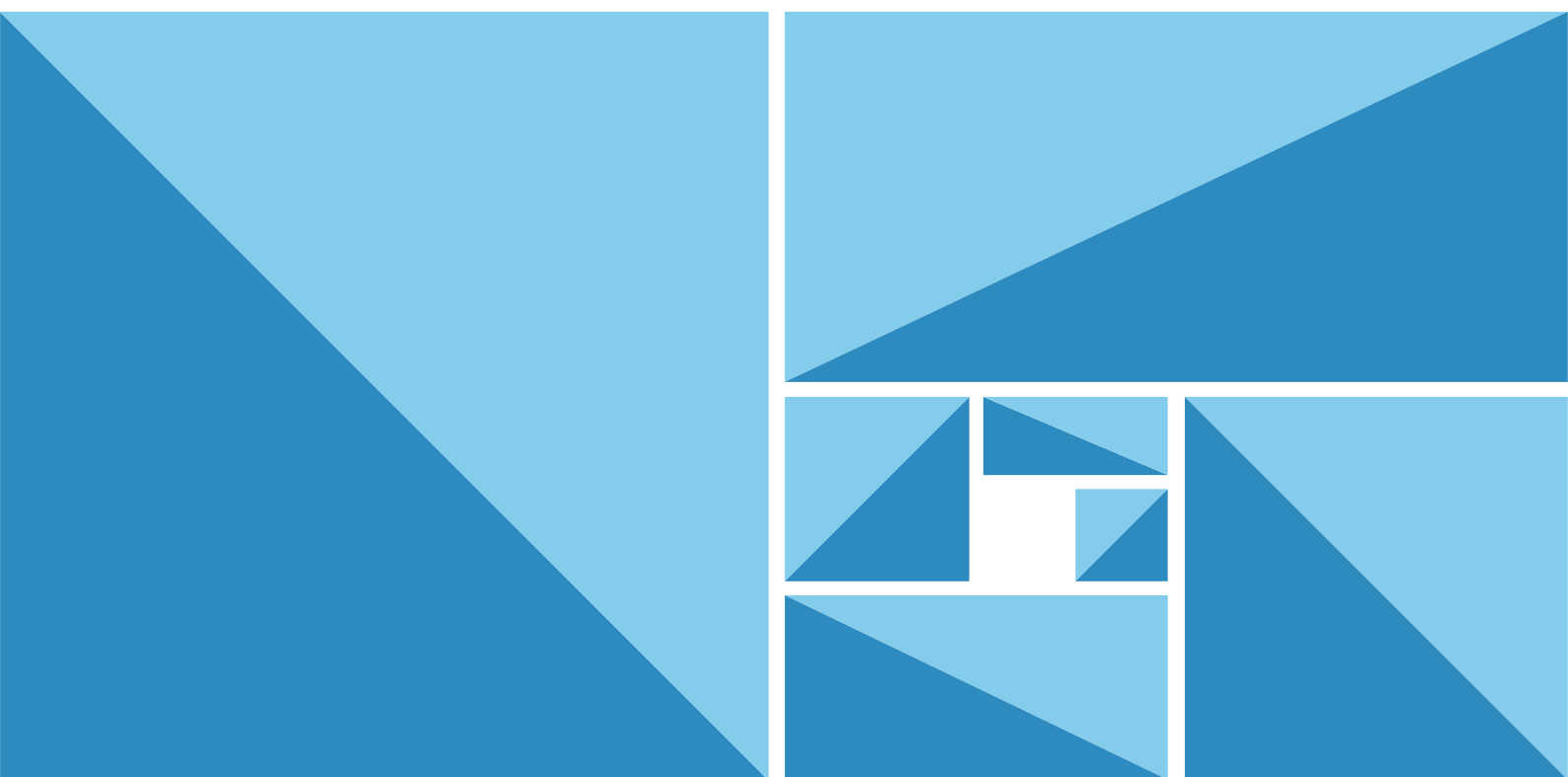


# **YSS**

# **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	—	
	SLD10	8% Cr steel			1.0	1.0	0.4	7.5	—	2.8	0.4	—	
	ARK1	Original steel			0.7	0.3	0.4	7.5	—	1.0	0.3	—	S : 0.05
	<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	—	—	—	—	
	ACD37	Original steel	A4		0.9	0.3	2.0	1.1	—	1.3	—	—	
	HMD5	Original steel			0.7	1.0	1.0	1.2	—	0.2	—	—	
	HI-PM MAGIC	Original steel			40HRC pre-hardened steel								
High speed tool steels	<b>YXM1</b>	SKH51	M2	1.3343	0.9	0.3	0.4	4.2	6.5	5.0	2.0	—	
	YXM4	SKH55		1.3243	0.9	0.3	0.3	4.2	6.5	5.3	1.9	5.0	
	YXR7	Matrix high speed steel			0.8	0.8	0.3	4.7	1.3	5.5	1.3	—	
	<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	HAP5R	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	
	HAP72	P/M high speed steel			2.1	0.4	0.3	4.2	9.5	8.3	5.0	9.5	

## Applications in cold work dies

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



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## Types of YSS cold work tool steels

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

## Applications in cold work dies

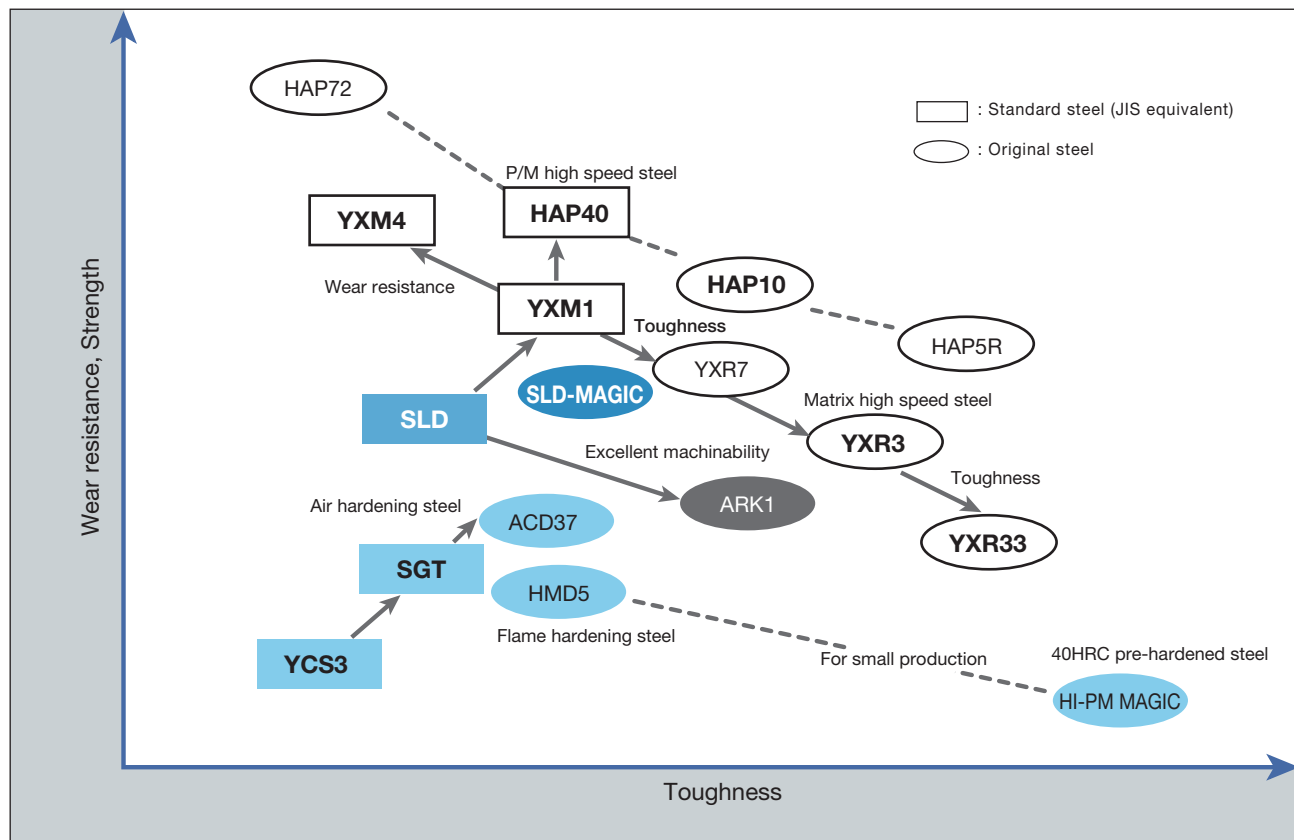
Application			Standard hardness (HRC)	For general use	Recommended YSS steel	
					For mass production use	
					For abrasion resistance	For impact resistance
For plastic forming	Trimming dies	For sheet use	55-60	SLD, SLD-MAGIC, ARK1	YXM1, HAP40	YXR3, YXR7
		For heavy plate use	50-55	DAC, DM		
	Cold hobbing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



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# Characteristics of YSS cold work tool steels

## Characteristics of steels



## Comparison of characteristics

Grade	Wear resistance	Pressure resistance	Toughness	Hardenability	Distortion by heat treatment	Machinability	Weldability	Standard hardness (HRC)
<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

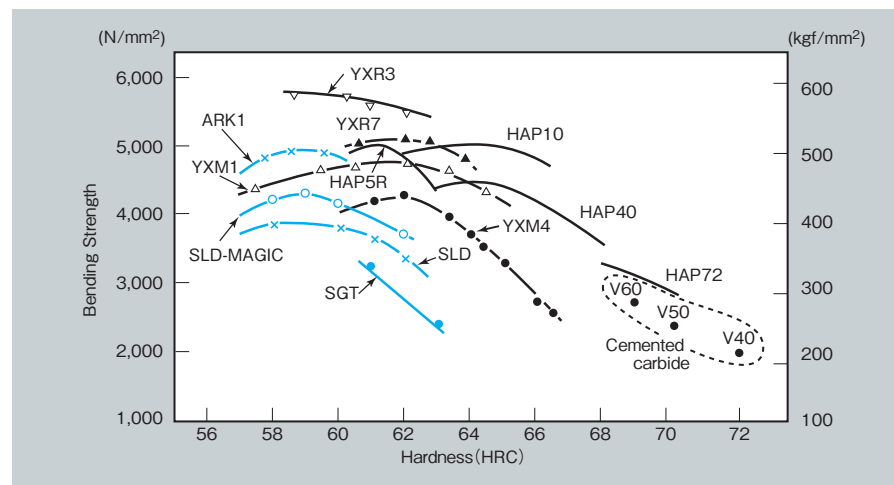
## Wear resistance

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				
SLD	60.0				
ARK1	59.0				
SGT	60.0				
YCS3	60.0				
ACD37	60.0				
YXM1	65.5				
YXM4	66.0				
YXR7	65.0				
YXR3	59.0				
YXR33	58.0				
HAP5R	60.0				
HAP10	64.0				
HAP40	67.0				
HAP72	70.0				

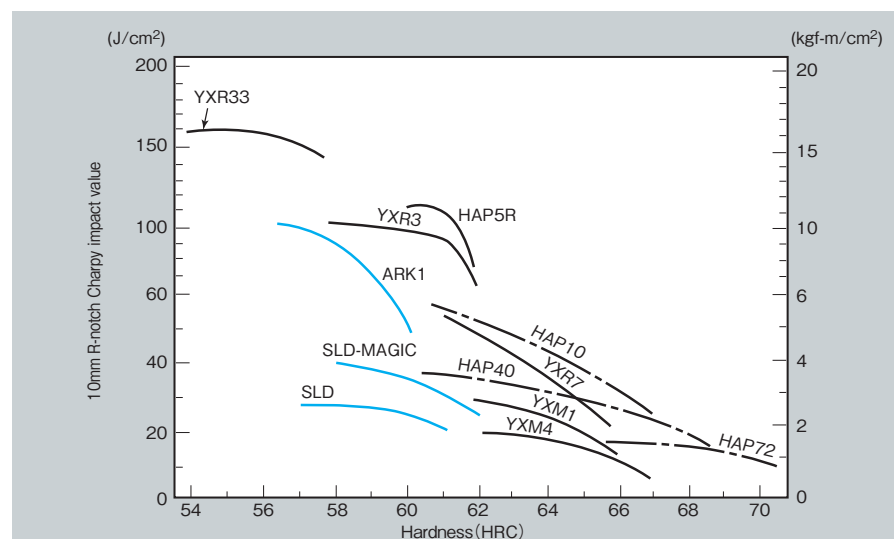
Ohgoshi-method wear test  
 Work material : SCM415  
 Friction distance : 400m  
 Friction speed : 0.76m/s  
 Load : 67N

## Toughness

### Bending strength



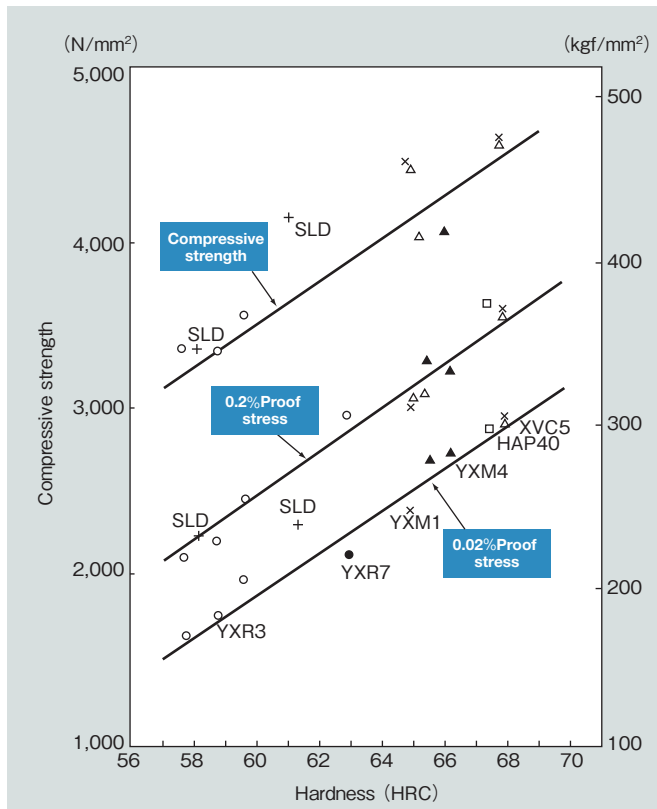
### Charpy impact value



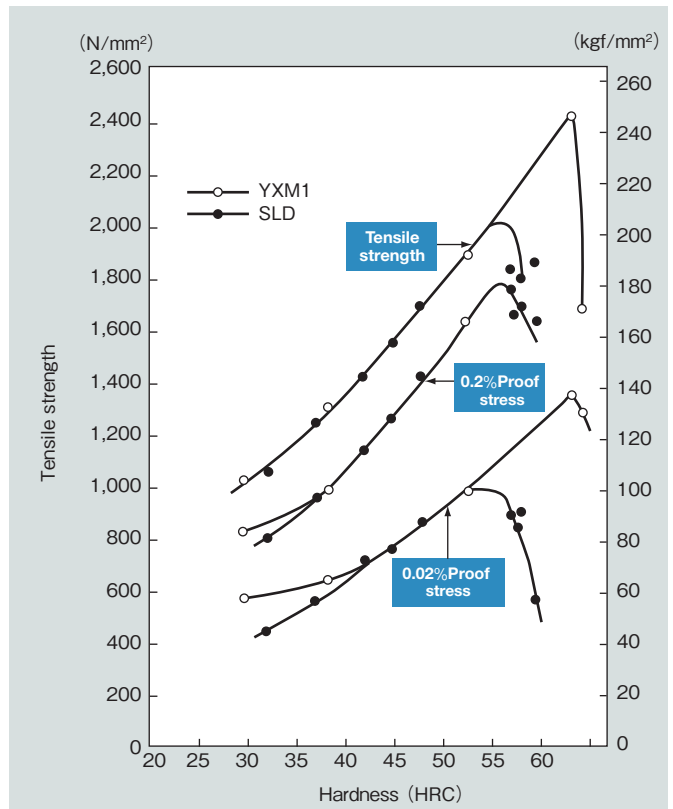
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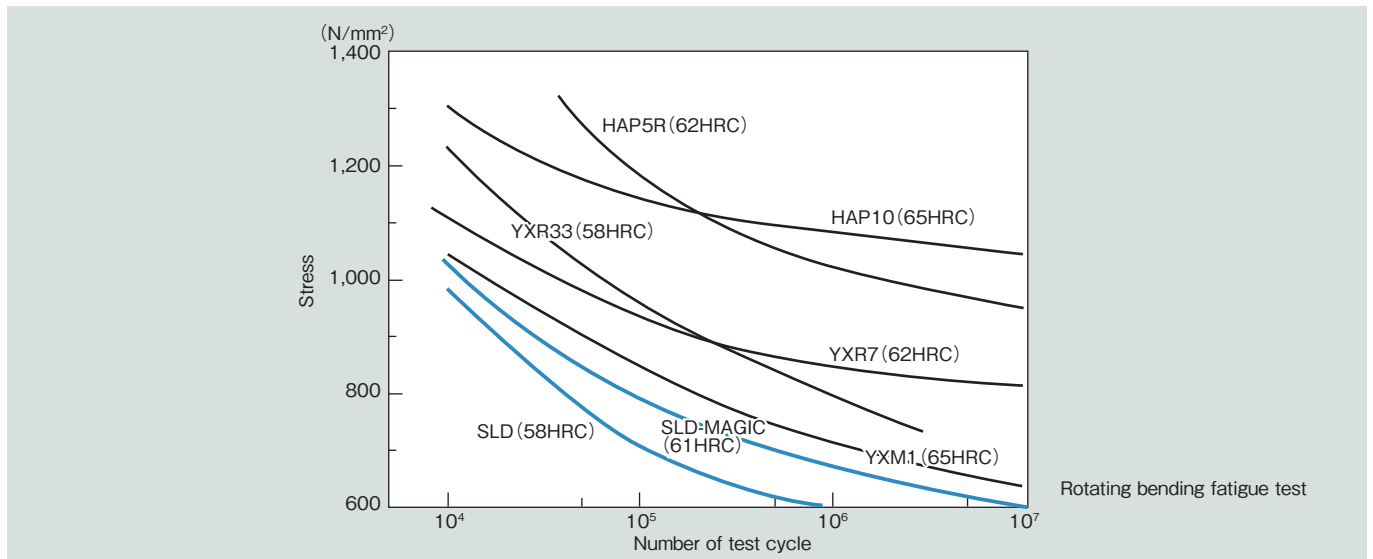
## Compressive strength



## Tensile strength



## Fatigue strength



## Physical properties

Grade	Thermal expansion coefficient $\times 10^{-6}/^{\circ}\text{C}$ 20-200 $^{\circ}\text{C}$	Thermal conductivity $\text{W}/(\text{m}\cdot\text{K})$ 20 $^{\circ}\text{C}$	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



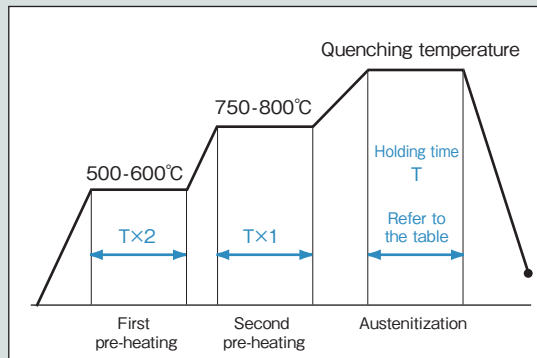
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# Heat treatment of YSS cold work tool steels

## Hardening

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

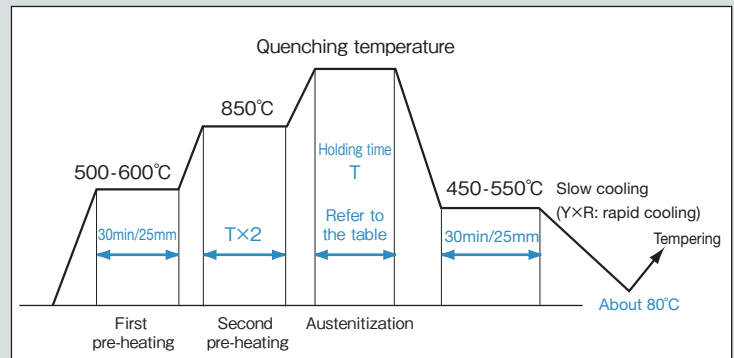
### Alloy tool steels, Carbon tool steels



### 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

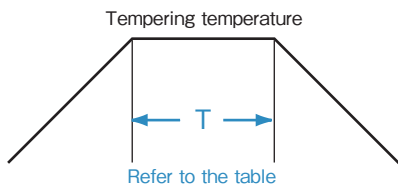


### Holding time at austenitizing temperature

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

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

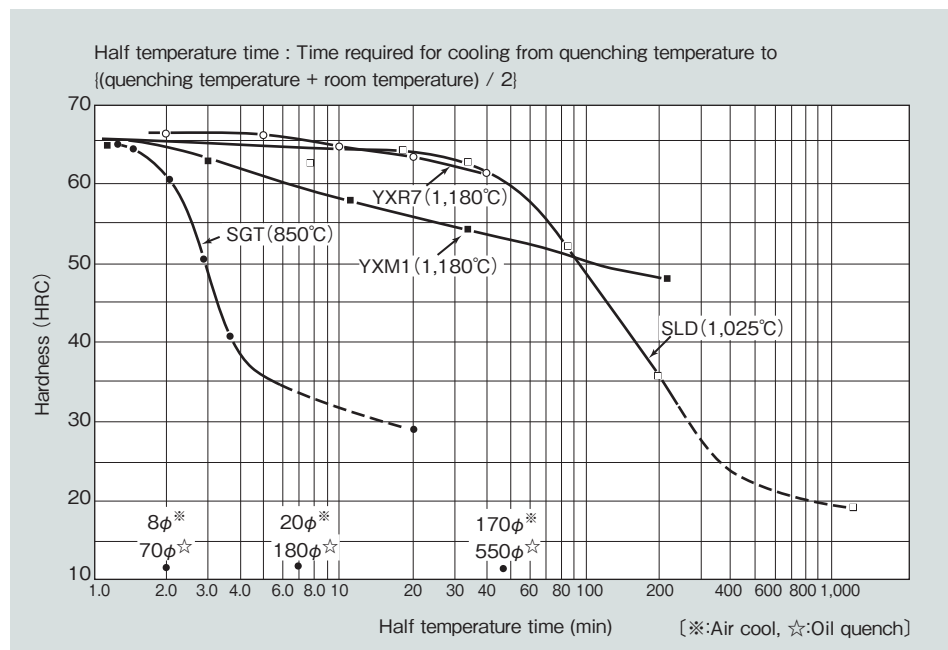
(2) Tools of complicated shape, requiring toughness in particular

\* Specimen size is 15mm square 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

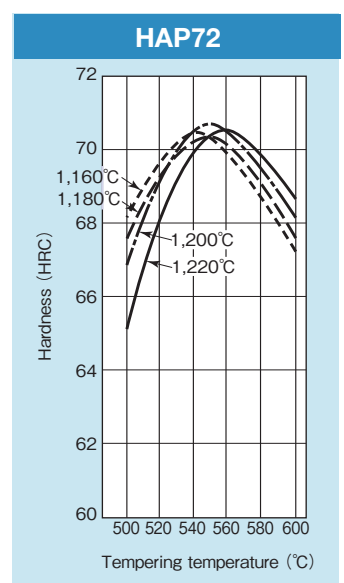
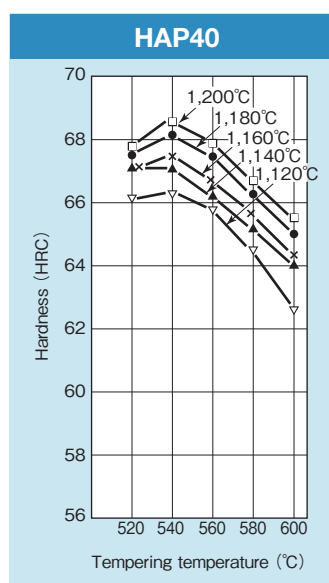
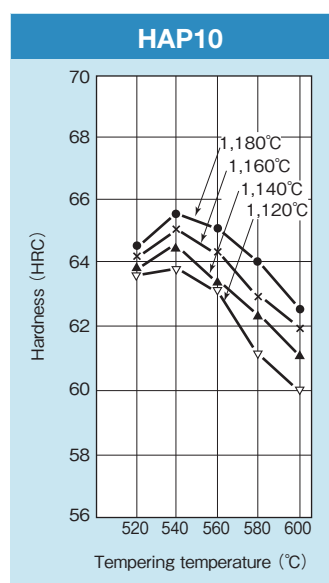
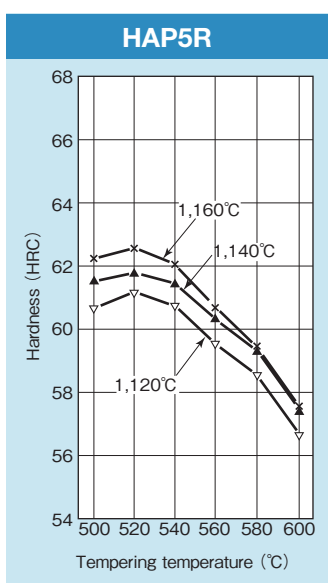
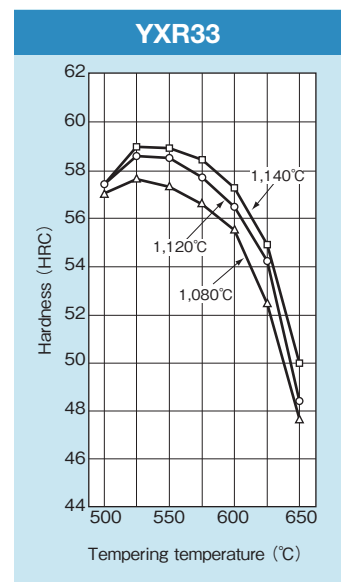
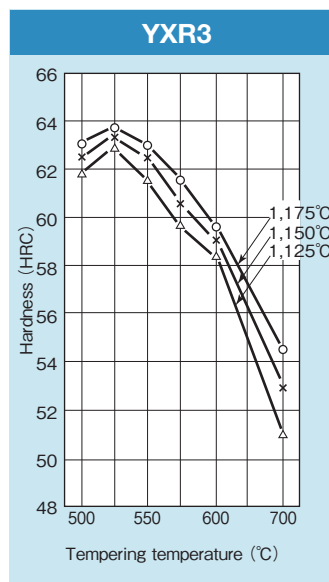
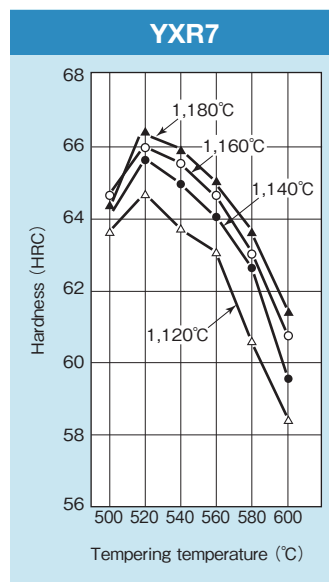
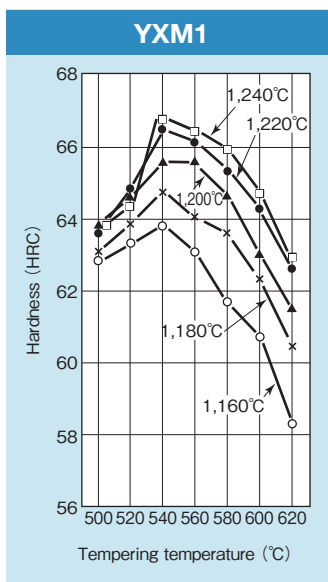
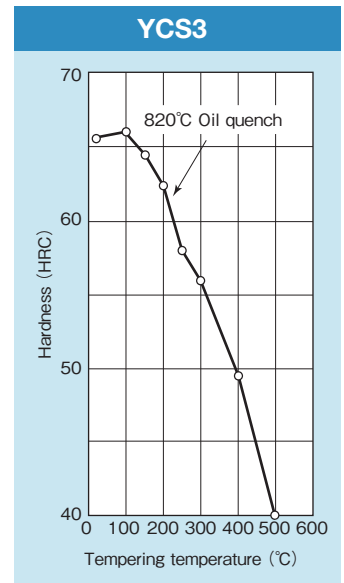
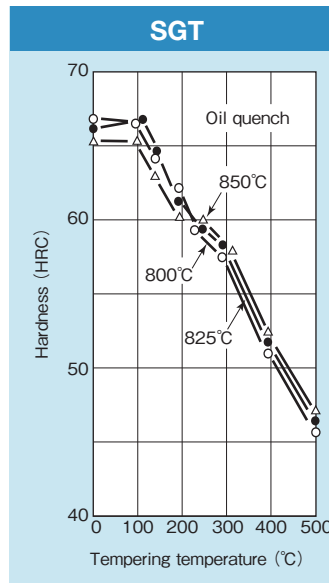
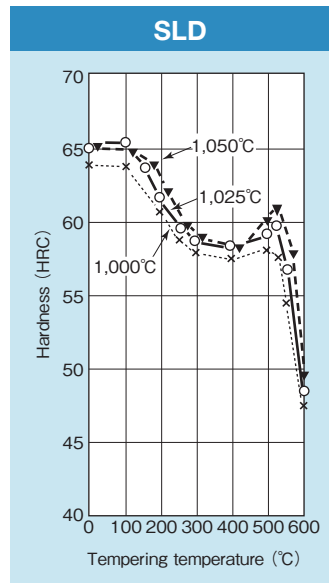
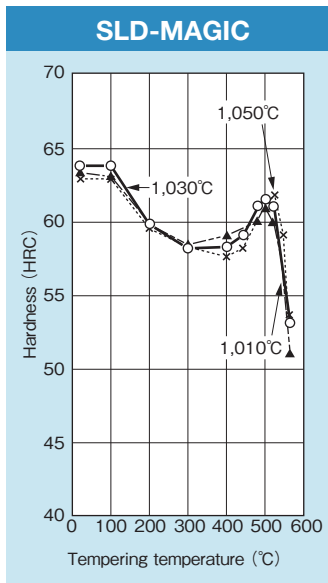


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# Heat treatment of YSS cold work tool steels

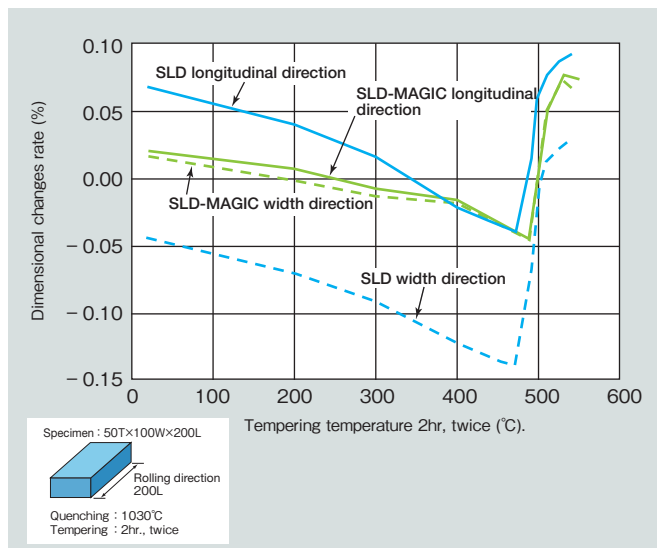
## Quenched and tempered hardness curves



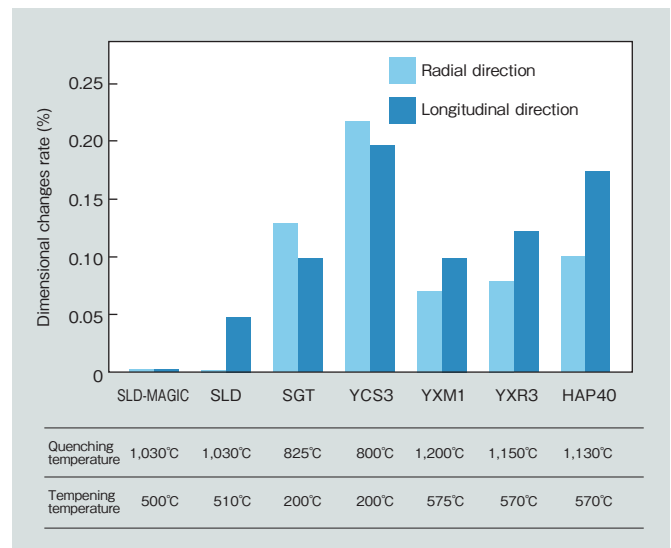
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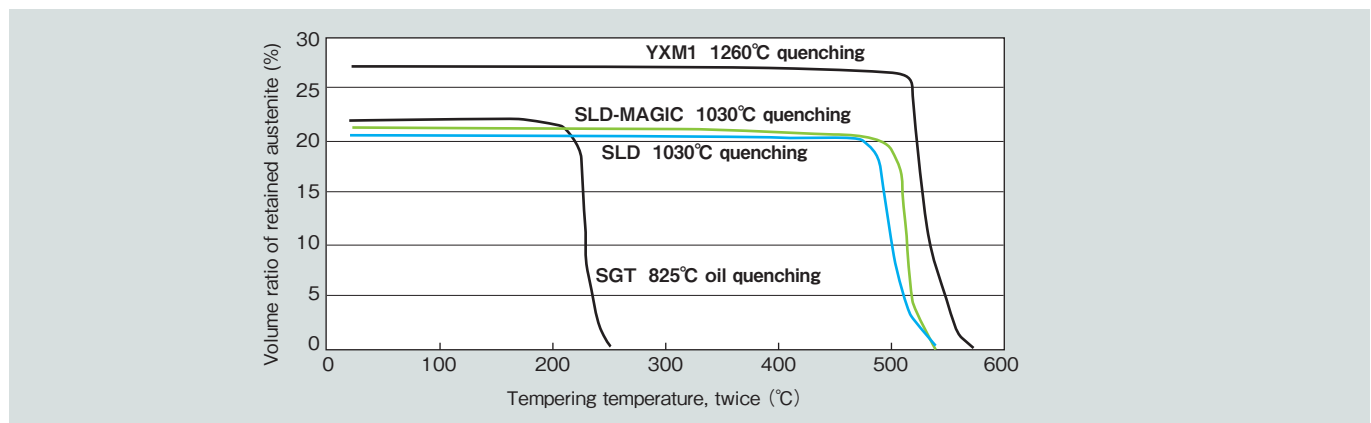
## Dimensional change after heat treatment of cold dies steel



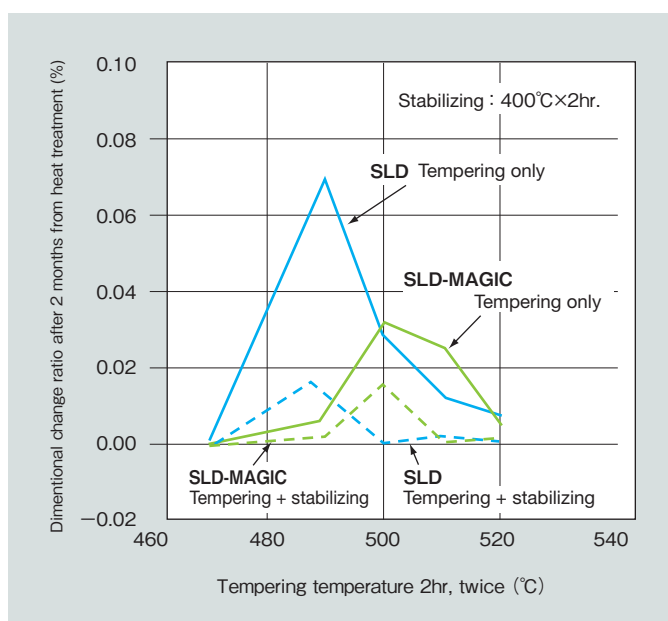
## Dimensional changes after heat treatment



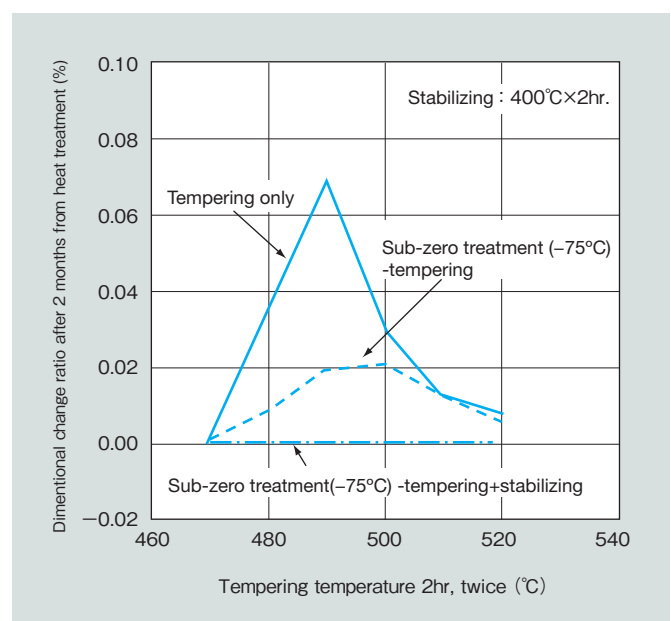
## The retained austenite



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



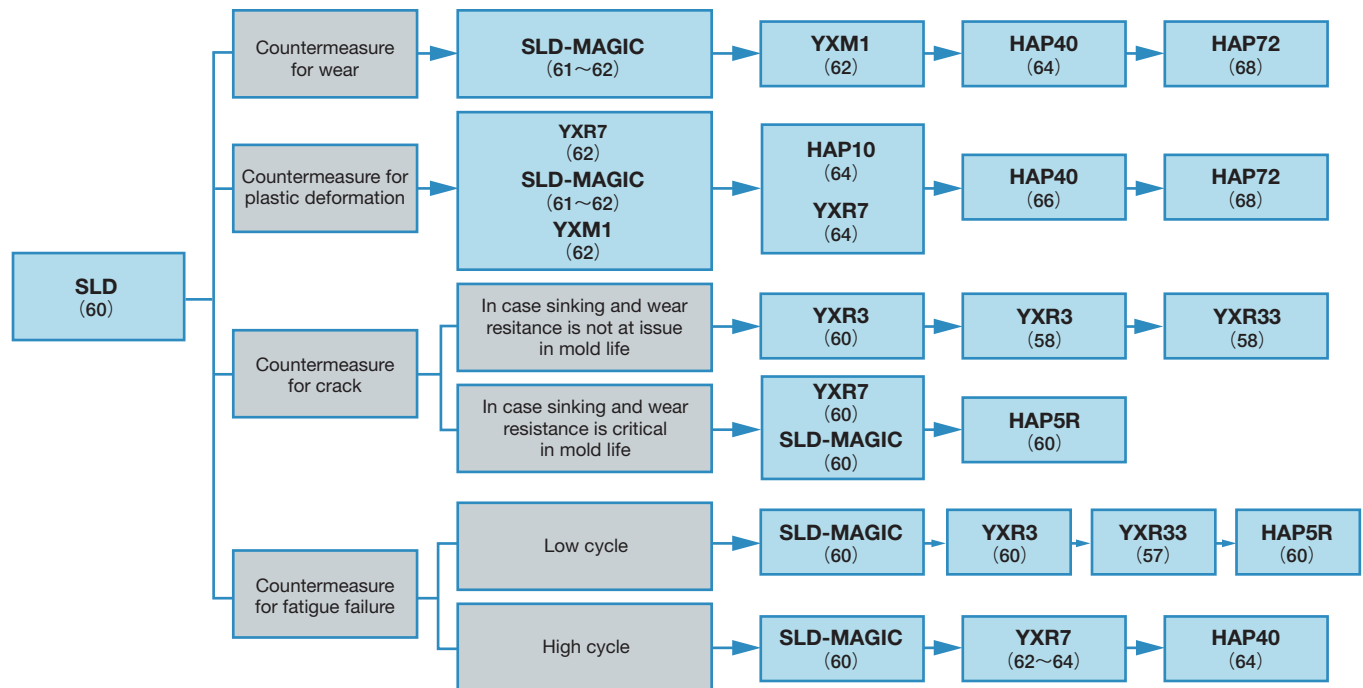
## Secular change and sub-zero treatment



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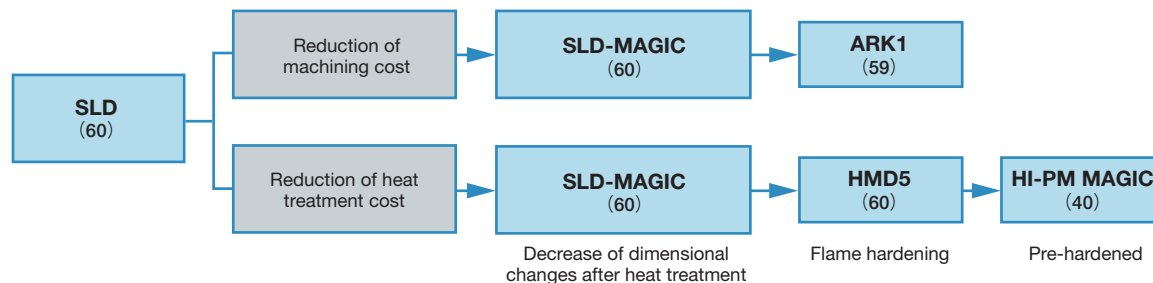
# Improvement processes of YSS cold work tool steels in terms of hardness and dies for various applications

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



Remark : (HRC: rough standard hardness)

## 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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