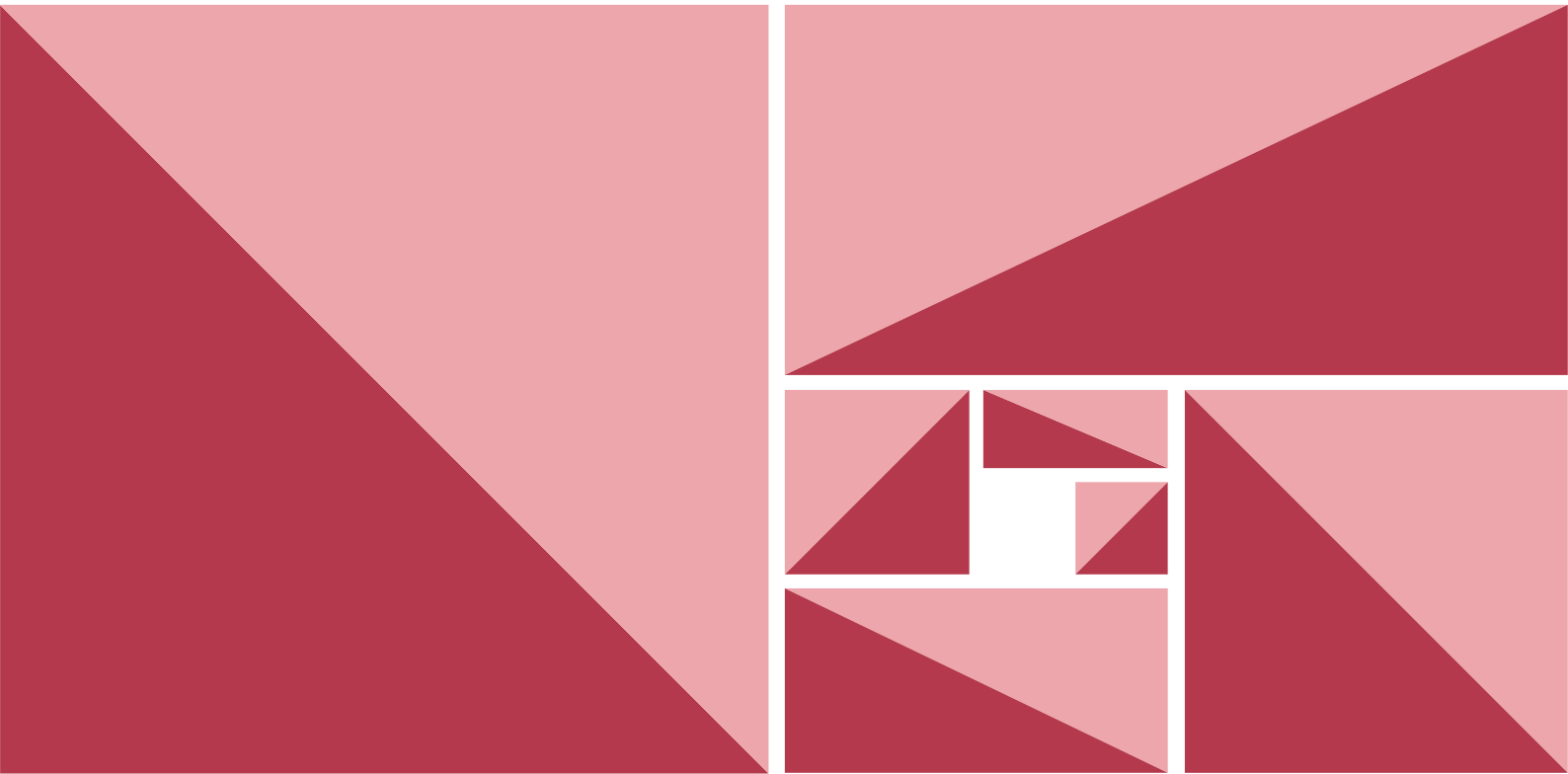


YSS

Hot Work Tool Steels



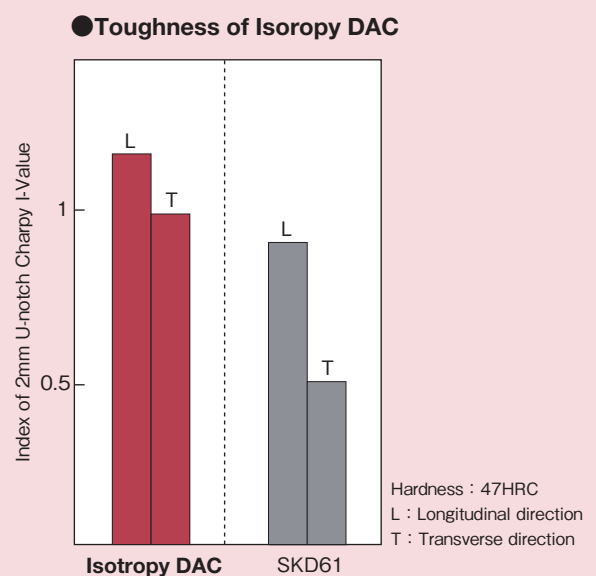
Chemical compositions of YSS hot work tool steels

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

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

Isotropy

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



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Applications of YSS hot work tool steels

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

*1 Use for bolt hot forming

*2 Use for thick billet shearing



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Types and features of YSS hot work tool steels

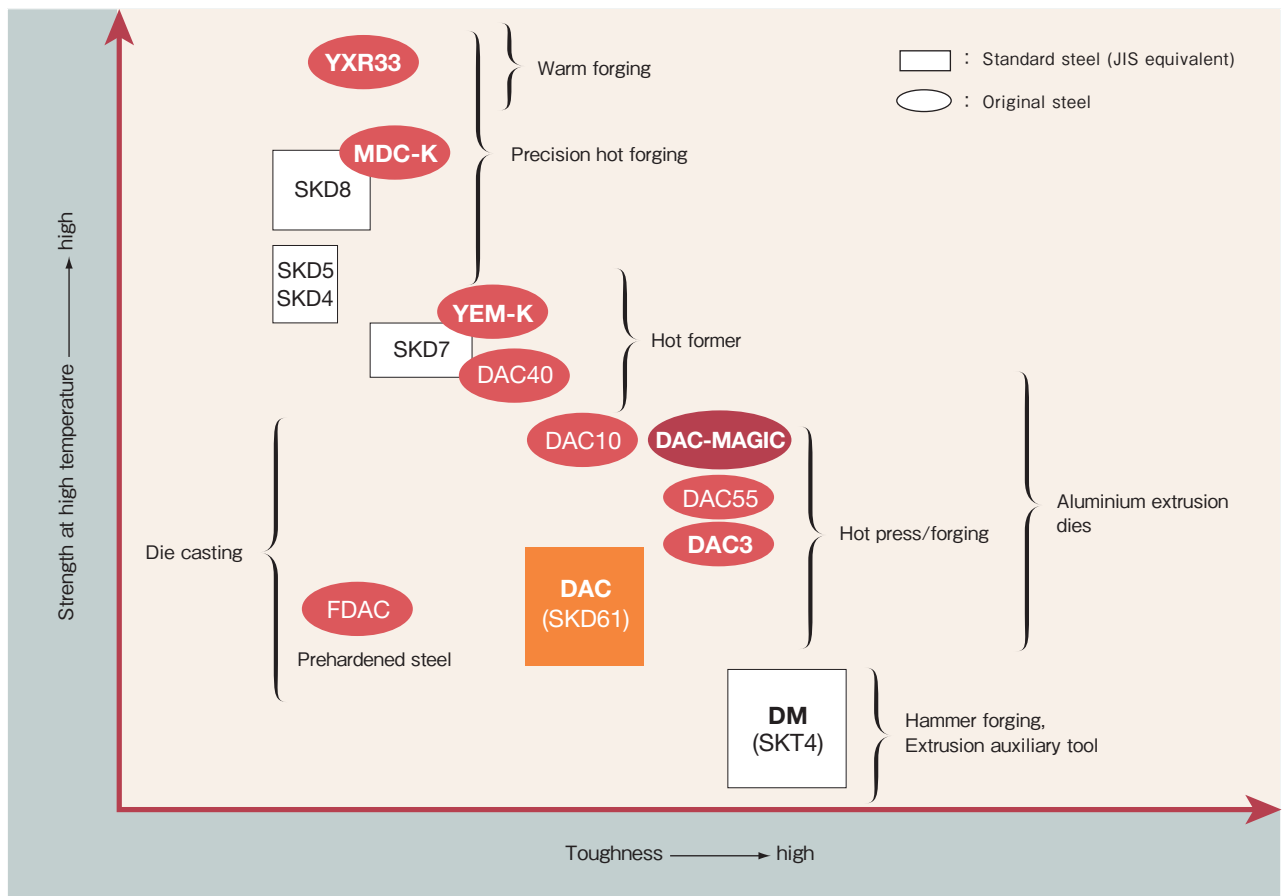
Grade		Features
YSS	JIS equivalent	
DAC	SKD61	Standard grade for general use with good balance of toughness, strength at elevated temperature and with excellent hardenability.
DAC-MAGIC	SKD61 modified	High performance die steel for die casting with well balanced strength and toughness and strength at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



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Characteristics of YSS hot work tool steels

Characteristics of hot work tool steels



Comparison of properties

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

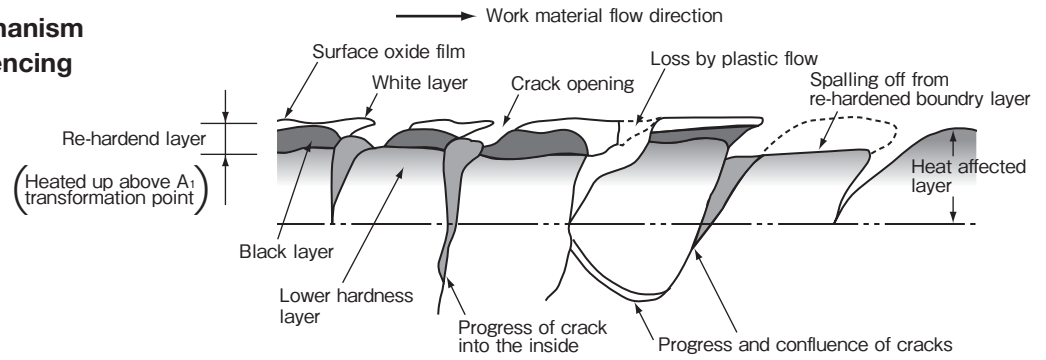
Ratings: A—Best C—Ordinary D—Poor
 (Remarks) Please use above ratings only for general reference.



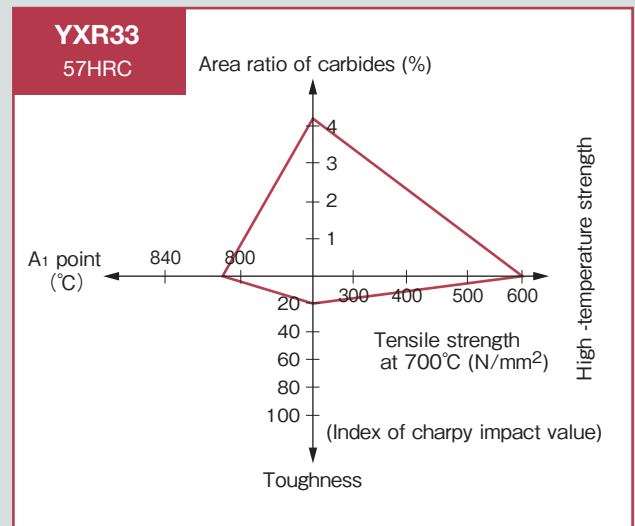
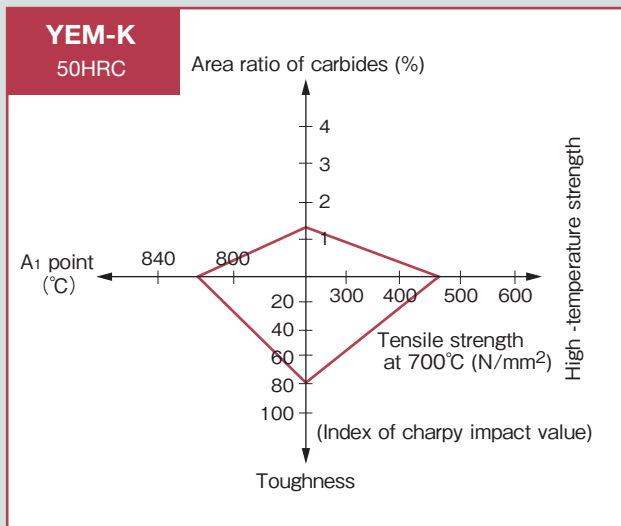
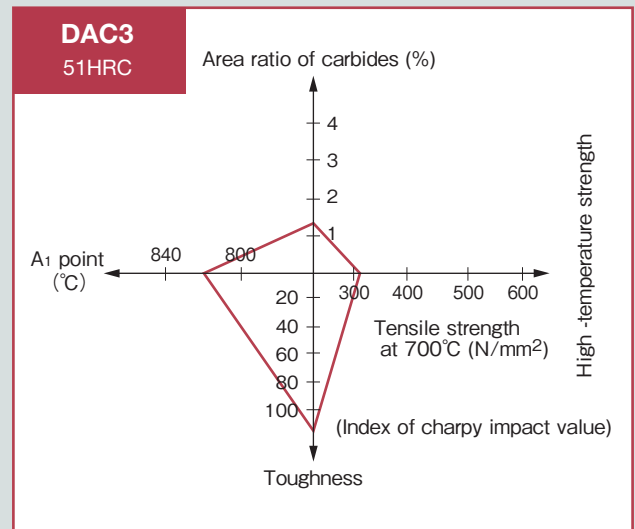
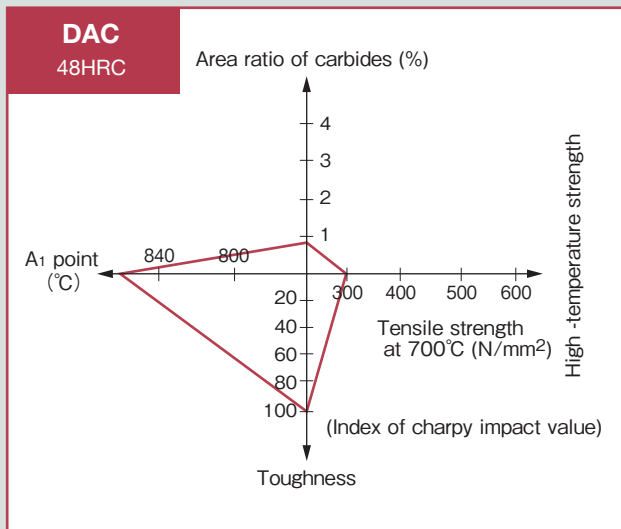
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Properties of YSS hot work steels

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



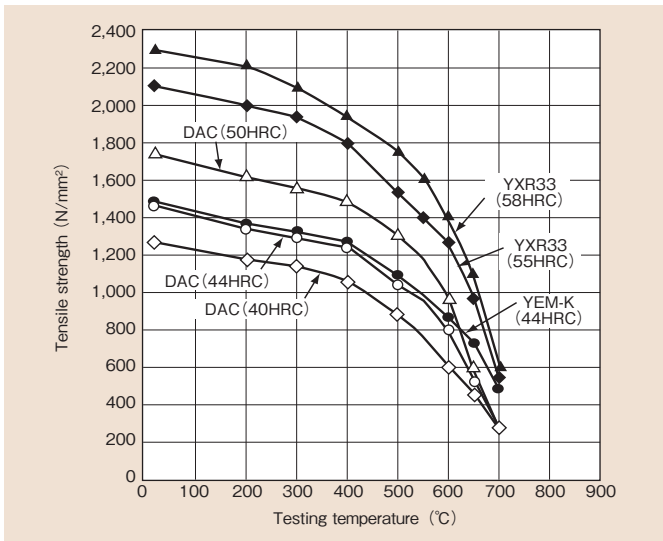
Properties	Influencing factors	Extent of impact on die damage		
		Sliding wear	Softening to abrasion	Minor crack → Catastrophic crack
Area ratio of carbides	Sliding property of die surface (Friction property)	○		
A ₁ point	Anti-rehardenability	○	△	
Strength at elevated temperature	Deformation resistance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



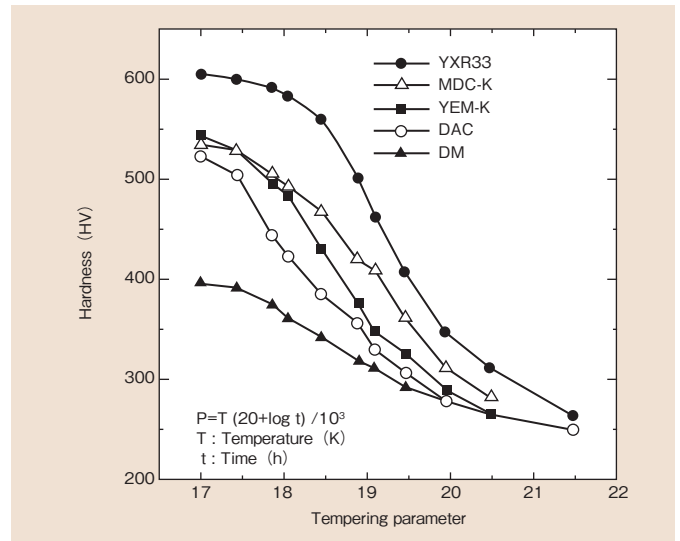
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Properties of YSS hot work steels

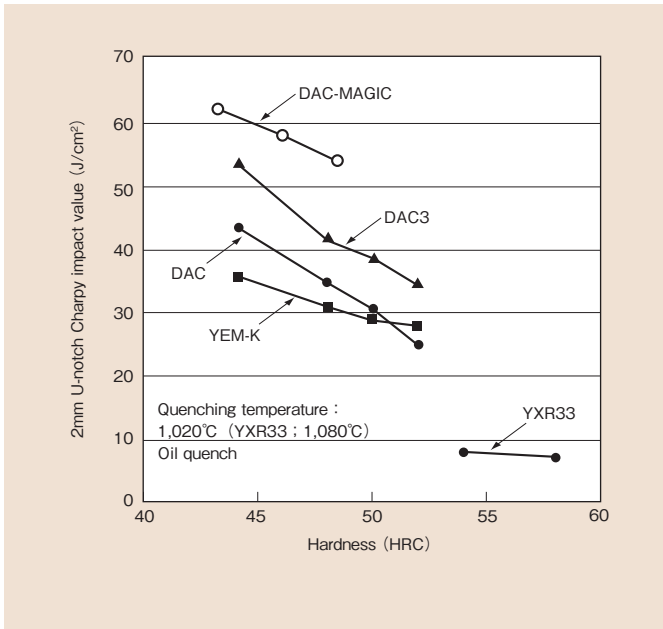
Tensile strength at elevated temperature



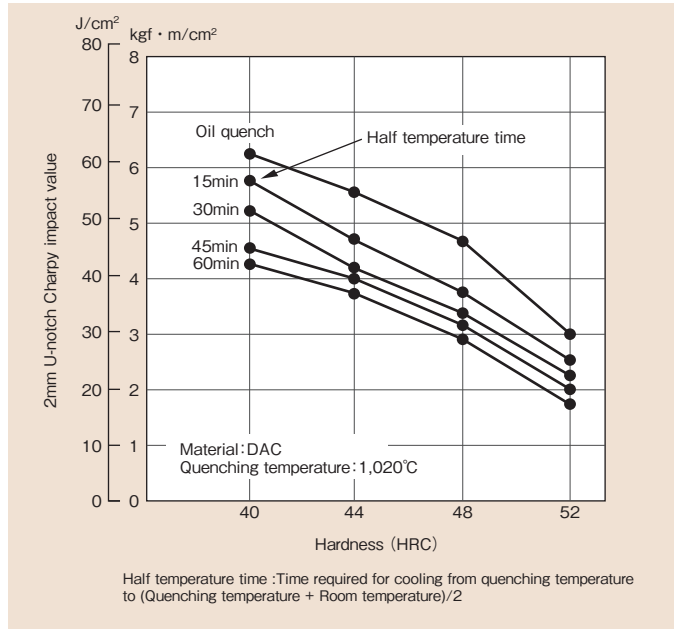
Tempering parameter



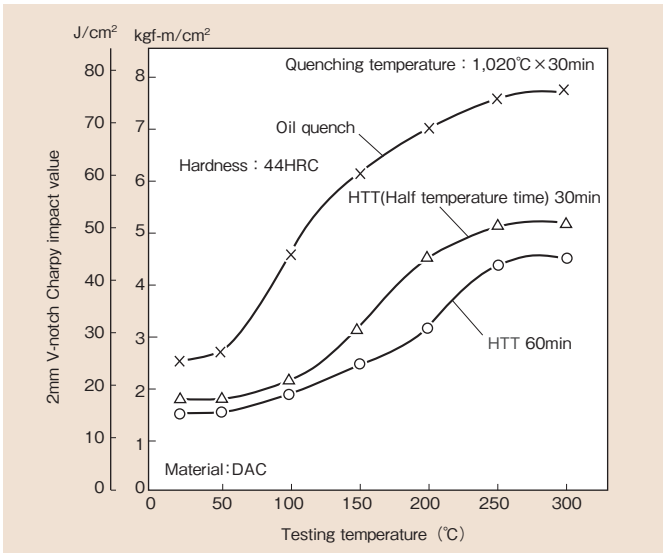
Charpy impact value at room temperature



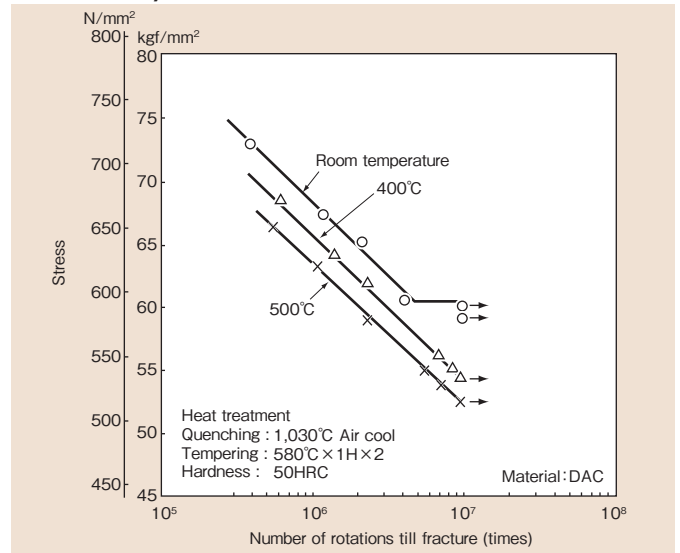
Quenching speed vs charpy I-value



Transition property of charpy impact value



Fatigue strength (Rotating bending fatigue test by Ono method)



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Standard heat treatment conditions for YSS hot work tool steels

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

Quenching and tempering time of YSS die steels

1. Holding time at quenching

(1) Preheating time

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

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

(2) Holding time at quenching

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

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

2. Holding time at tempering

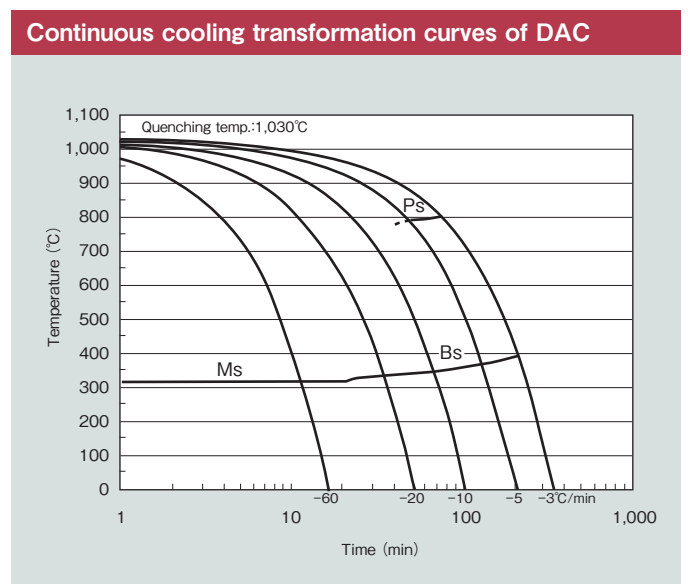
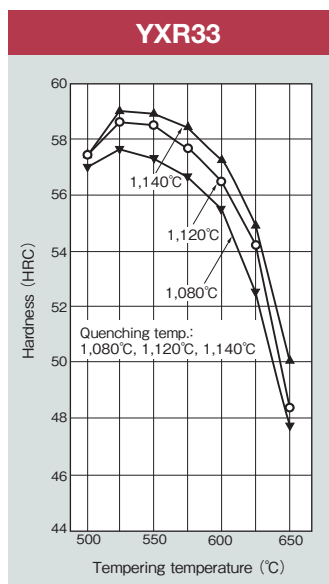
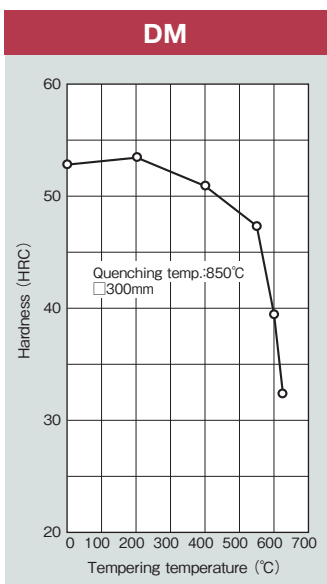
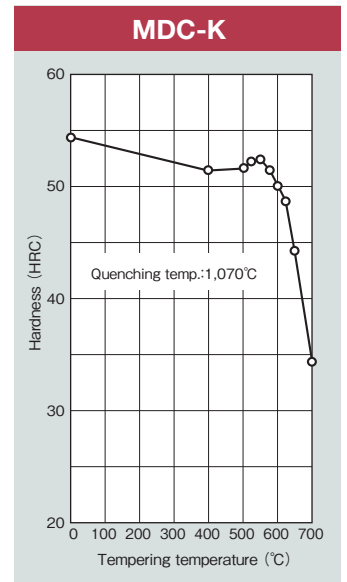
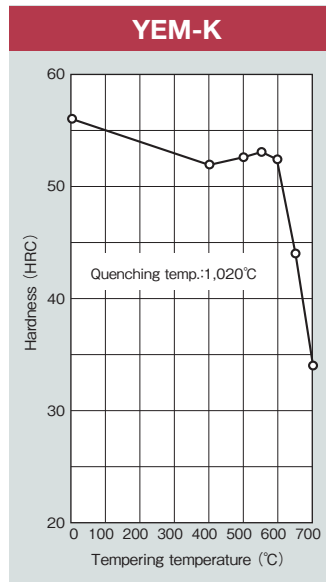
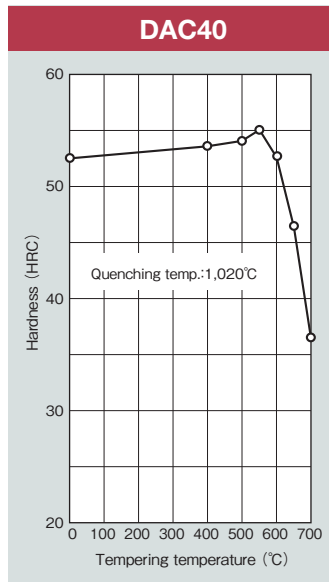
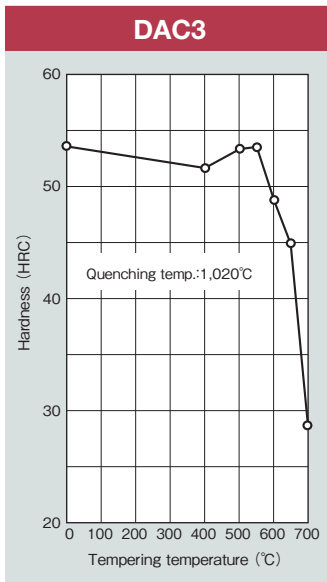
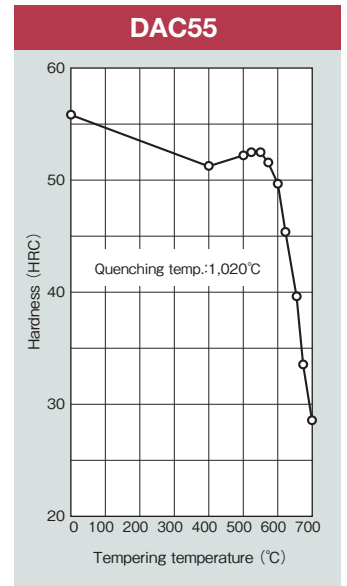
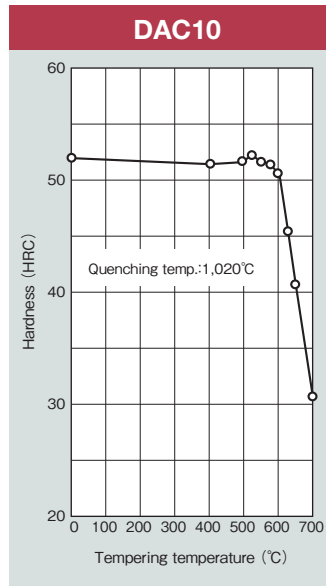
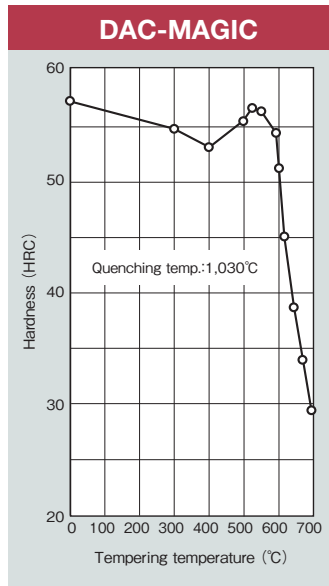
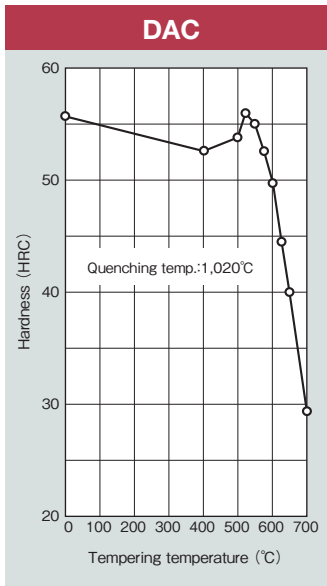
Thickness (mm)	≤25	26 - 35	36 - 64	65 - 84	85 - 124	125 - 174	175 - 249	250 - 349	350 - 499
Holding time (h)	1	1.5	2	3	4	5	6	7	8

Notice : Tempering is needed more than 2 times.



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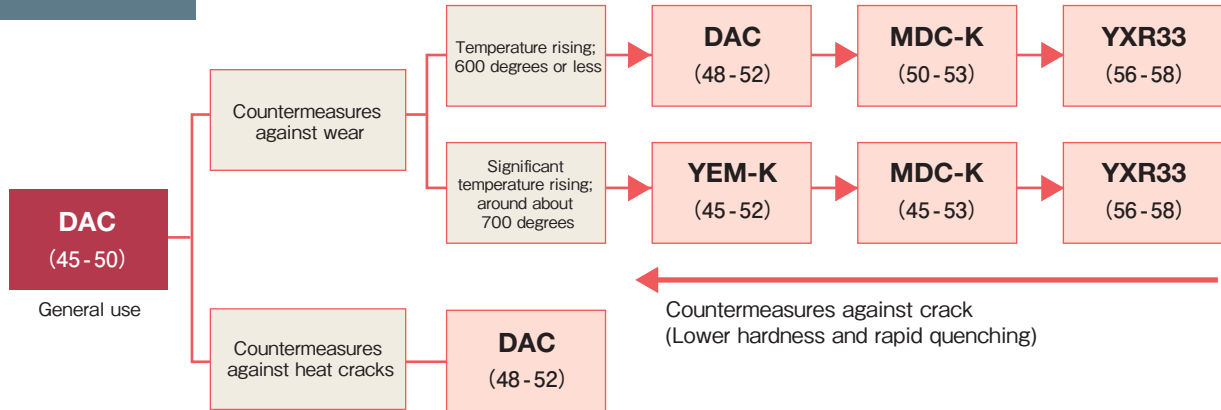
Quenched and tempered hardness curve



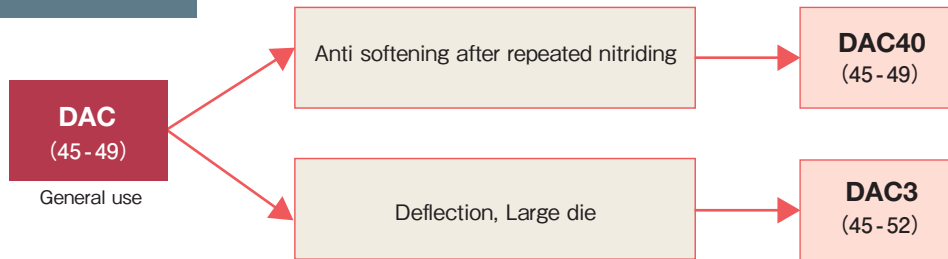
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Guide for selecting YSS die materials (Example)

Hot forging dies



Extrusion dies



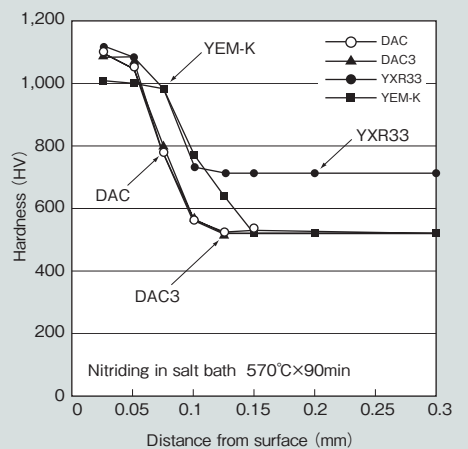
Remark 1 : HRC hardness
 Remark 2 : By surface treatment such as nitriding, the wear resistance is improvable.

Comparison of various nitrided layers

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

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

Nitriding property

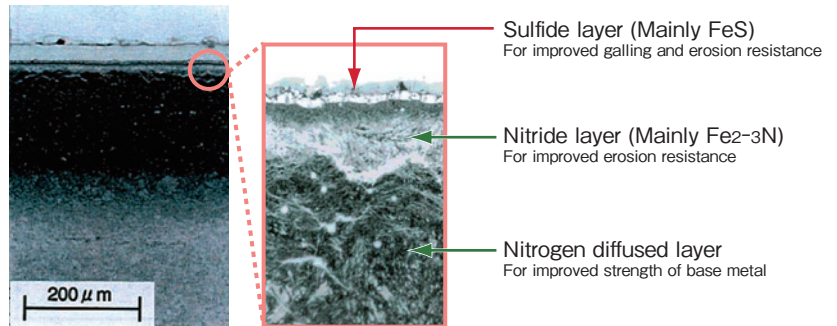


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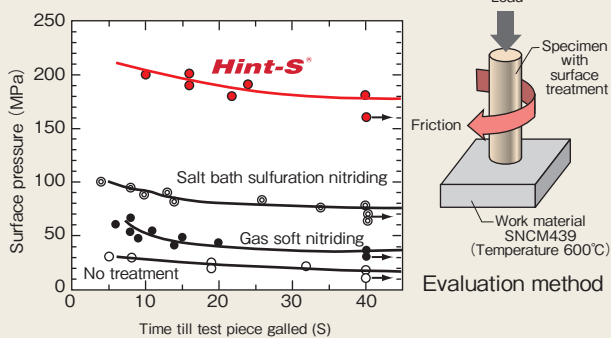
Sulfuration nitriding for hot work die *Hint-S*[®]

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

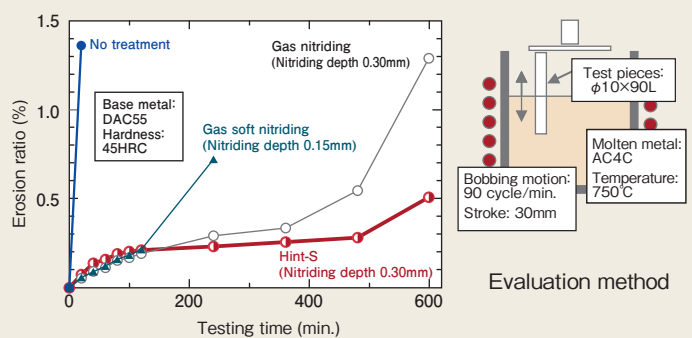
The Hint-S is a surface treatment technique developed by Hitachi Metals which improves significantly wear and erosion resistance of a die by forming both sulfides and nitrides on its surface.



Simulation test of hot galling resistance (On forging die)



Simulation test of erosion resistance (On casting die)



Data sheet

1. Coefficient of thermal expansion

Average value from 20°C to each temperature. ($\times 10^{-6}/^{\circ}\text{C}$)

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

2. Thermal conductivity

(W/(m·K))

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

3. Modulus of elasticity

(GPa)

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



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

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