Daido's Hot Work Die Steel Series

DH31-EX™

DH31-EX is a trademark or registered trademark of Daido Steel Co., Ltd.

Background of development of DH31-EX

Reducing vehicle weight is progressing proactively for improving fuel efficiency. Die casting parts needs are increasing not only for engine blocks and transmission cases but also chassis and body parts for vehicle lightweighting. Therefore, it requires prolonged die casting mold life.

Typical factors to affect service life of die casting molds can be categorized into 2 groups. One is repairable damage such as heat checking, erosion or corner crack, and the other is unrepairable major failures such as gross cracking at an early stage. Repairable damage can be observed gradually, thus it is easier to make a maintenance schedule. Furthermore, the early destruction (gross cracking) definitely should be avoided because it is difficult to predict and repair.

On the other hand, higher hardness can restrain heat checking which is the main failure mode of die casting molds (Photo. 1). However, since higher hardness gives rise to lower toughness, caution against cracking becomes crucial (Fig.1). Therefore in order to avoid an early destruction and achieve high performance, development has been taken place utilizing high grade steel, which contains high level of Mo, making it have more toughness and higher softening resistance and resulting in longer service life by restraining heat checking. However even in the case of high-Mo steel, when large size molds are prepared, hardness is often aimed lower in fear of early destruction caused by poor impact values.

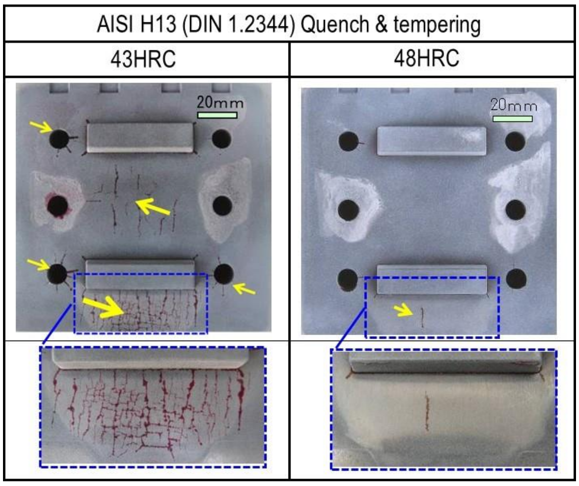

Photo. 1. Effect of hardness on heat checking

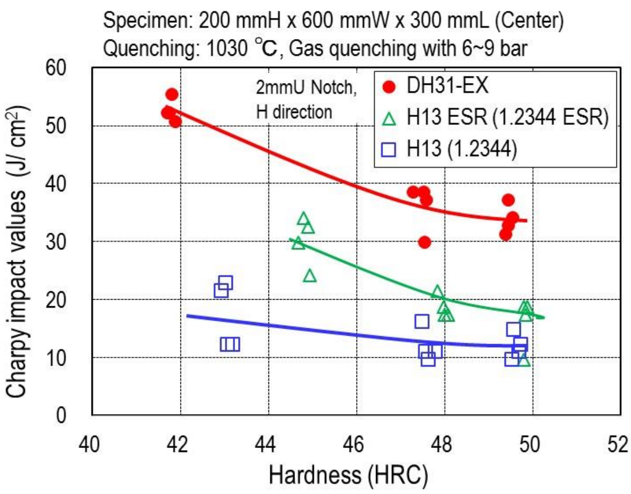

Fig. 1. Relationship between hardness and toughness

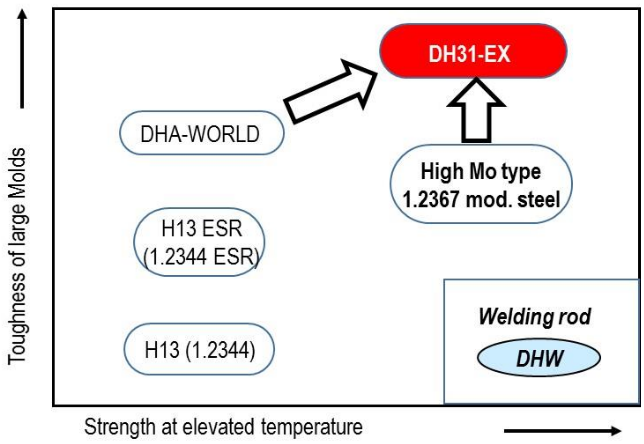

Fig. 2. Positioning of DH31-EX

Daido Steel has developed and now provides new high grade hot work tool steel, “DH31-EX” which has superior stability for preventing gross cracks because of its stable structure and toughness throughout to the center of larger molds.

Feature of DH31-EX

Having equivalent performance as 1.2367 modified steel, DH31-EX as a high performance hot work die steel, can be used as large die casting molds with confidence. Figure 2 shows it’s positioning.

-High hardenability: It can obtain higher impact values even in the center of large size mold where the cooling rate becomes slow during the quenching process by raising hardenability while optimizing production condition such as secondary melting and alloy designing. As a result, the risk of molds’ premature destruction can be reduced.

-Higher Mo content than standard steel (AISI H13, DIN1.2344), makes it possible to have high softening resistance and superior heat checking resistance.

Chemical composition

Table 1. Typical chemical composition of DH31-EX.

Steel grade	C	Si	Mn	Cr	Mo	V	Note
DH31-EX	0.33	0.3	0.9	5.8	2.5	0.5	Example
1.2367	0.35-0.42	0.30-0.50	0.30-0.50	4.80-5.20	2.70-3.20	0.40-0.60	From standard
H13 (1.2344)	0.32-0.45	0.80-1.25	0.20-0.60	4.75-5.50	1.10-1.75	0.80-1.20	

Main application

Like other high performance steel, DH31-EX has higher high temperature strength compared with H13 (1.2344) and also has higher hardenability than that of other conventional hot work die steel. Therefore, application to die casting molds which require long service life and high quality, and especially to large size molds is suitable.

Table 2. Main application and hardness range of DH31-EX

Applications	Hardness (HRC)
Al, Zn, Mg die casting molds	41 ~ 48
Hot extrusion dies	43 ~ 50
Hot shear blade	35 ~ 45
Hot forging dies	42 ~ 50

Property of DH31-EX

(1) Stable quality by optimization of chemical composition and production process

DH31-EX which ought to be made by double melt process has a small dispersion of its quality and performance depending on the position or the orientation of products as well as stable toughness in wide hardness range. Figure 1 indicates the result of an impact test to specimens with varied hardnesses that were heat-treated and cut out from the center of large blocks. In the hardness range, DH31-EX showed higher Charpy impact values than both H13 (single-melted) and H13-ESR (double-melted).

Photograph 2 shows microstructures of impact test specimens. DH31-EX has an even and fine microstructure entirely. On the other hand, a white needle-like microstructure was observed on H13 (1.2344). This structure is called bainite structure.

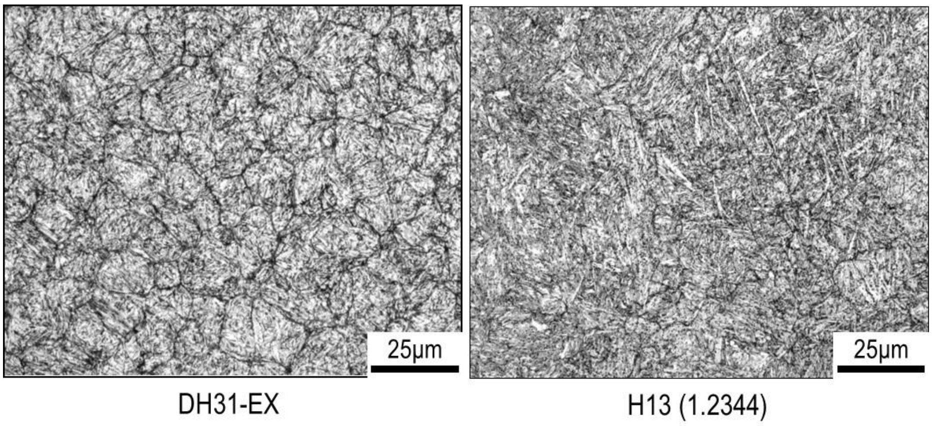

Photo. 2. Microstructure of center of heat-treated specimen simulating large molds

Specimen dimension: 200mm H x 600mm W x 300mm L (Center)

Quenching: 1030℃, 6 bar gas

Figure 3 shows CCT diagram of DH31-EX, conventional H13 (1.2344) and 1.2367 modified steel. In the diagram, DH31-EX has bainitic transformation start time (=time when Ms temperature starts rising) later than H13 (1.2344) and 1.2367 mod. As a result of avoiding the formation of bainitic structure, no bainitic structure was confirmed as shown in Photo. 2.

The relation between the cooling rate from 400 to 200 degrees C and the Charpy impact value under the same hardness of 48 HRC is shown in Figure 4. Conventional steel grade H13 (1.2344) and 1.2367 modified steel showed the decline of impact values markedly along with the decrease of cooling rate between 400 to 200 degrees C. In contrast, DH31-EX had a higher absolute value, and a restrained value decline even when the cooling rate became slower. This indicates DH31-EX can secure the fine structure even in the case of heat-treatment of large size molds as shown in Photo. 2. Moreover, the reason why this structure can be obtained is that the bainitic transformation start time is delayed largely compared with H13 (1.2344) and 1.2367 mod. as shown in Fig. 3.

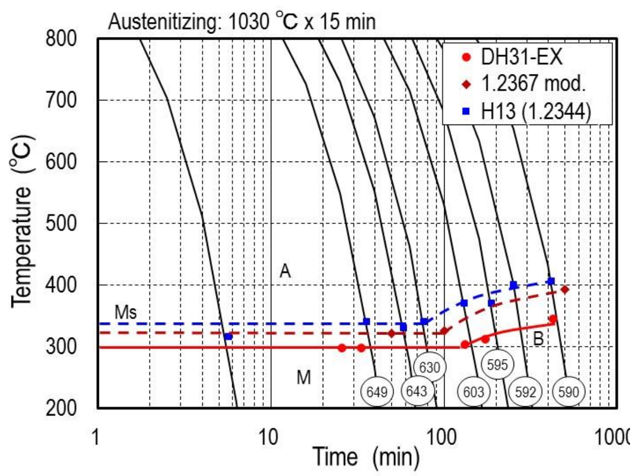

Fig. 3. CCT diagrams of DH31-EX

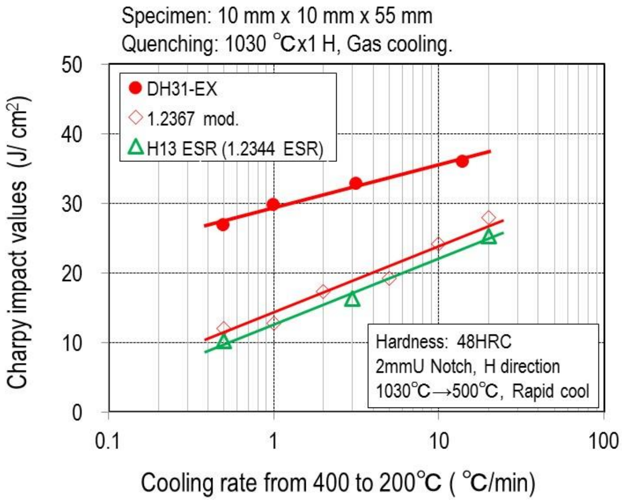

Fig. 4. Cooling rate dependency on impact values

(2) Heat checking resistance

Figure 5 shows the result of heat check simulation test. The heat checking crack length of DH31-EX is less than half of H13 ESR (1.2344 ESR) and similar to conventional high grade steel (1.2367 mod. ESR). Photograph 3 shows the difference of the heat checking status of model molds by small die-casting machine trial. The number of heat checking cracks of mold surface made of DH31-EX is significantly smaller than that of H13ESR (1.2344 ESR).

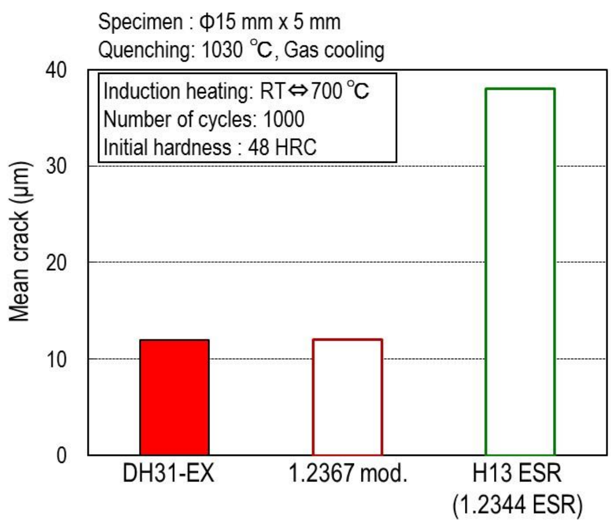

Fig. 5. Results of heat checking test

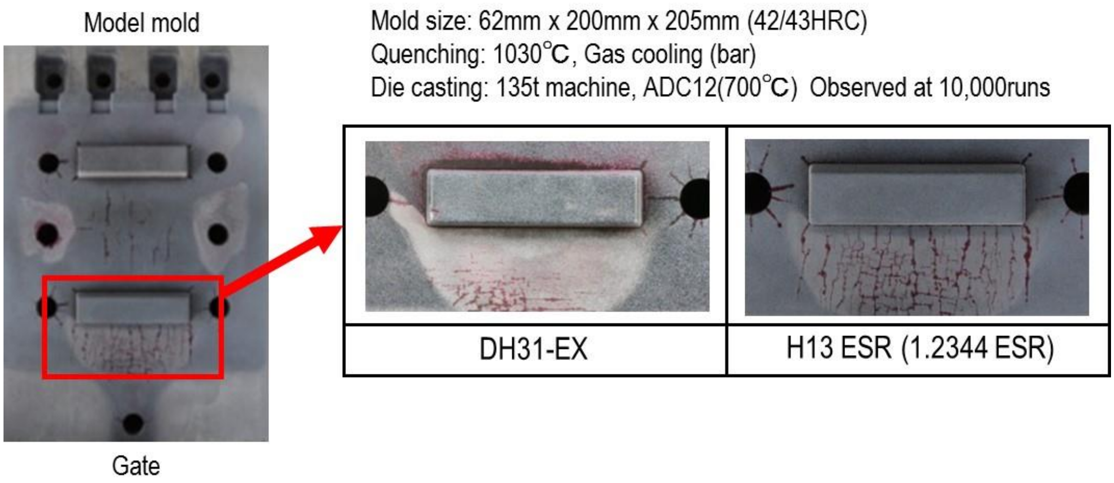

Photo. 3. Heat checking status by die casting trial

It was reported that improving thermal conductivity and softening resistance are effective for improving heat checking resistance under the same hardness condition. Those properties are shown in Fig. 6 and Fig. 7. DH31-EX has higher thermal conductivity than H13 (1.2344) in the temperature range. As for softening resistance, DH31-EX has excellent performance similar to 1.2367 modified steel and better than H13 (1.2344).

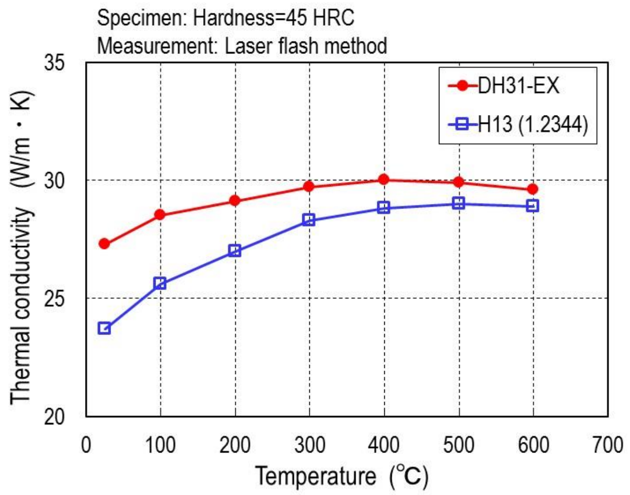

Fig. 6. Thermal conductivity

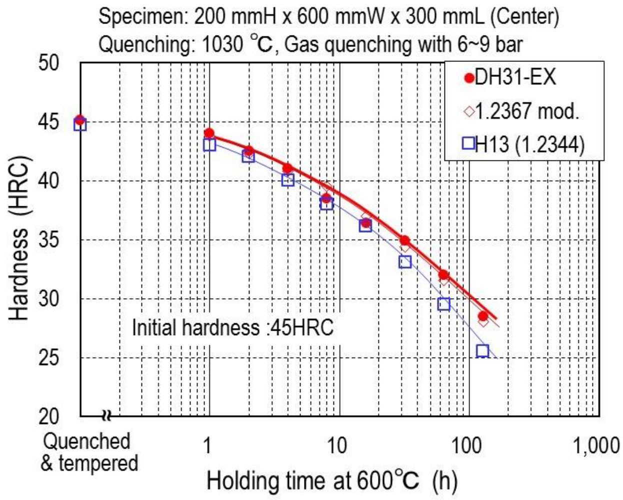

Fig. 7. Softening resistance at 600°C

(3) Heat treatment condition/ Surface treatment condition

Table 3 indicates the general heat treatment conditions. Quenching and tempering temperatures similar to H13 (1.2344) are applicable. Uniform structure can be attained by quenching at the same or smaller cooling rate than that of H13 according to the CCT diagram as shown in Fig. 3. Fig. 8 shows the relationship between hardness and tempering temperature. DH31-EX is featured by higher hardness after quenching and tempering than H13 (1.2344). Please refer to Fig. 8 for choosing tempering temperature.

Table 3. Heat treatment condition of DH31-EX

Forging temperature (℃)	Heat treatment (℃)			Hardness		Transformation Temp. (℃)	
	Annealing	Quenching	Tempering	Annealed	Quenched & Tempered	Ac	Ms
900~1200	820~870 Slow cooling	1000~1050 Air cooling	550~650 Air cooling	≦235HB	35~53 HRC	805~885	300 (Austenitized at 1030℃)

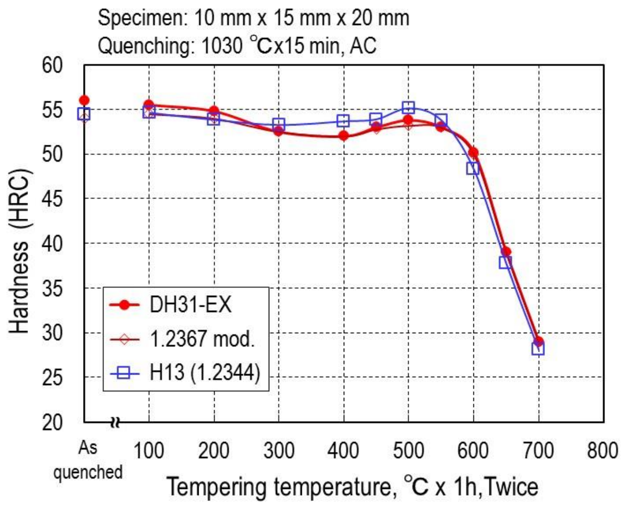

Fig. 8. Tempering temperature and hardness

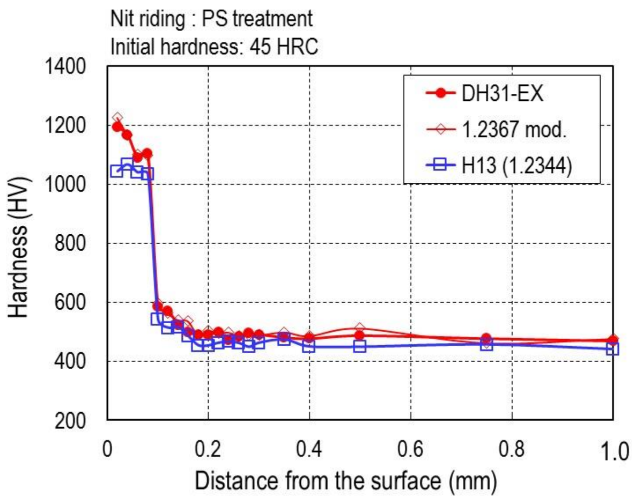

Fig. 9. Hardness distribution after nitriding

Figure 9 shows the result of nitriding after the same treatment condition. The depth of nitriding layers is not substantially different among DH31-EX, 1.2367 mod. and H13 (1.2344), but the DH31-EX surface layer has higher hardness than H13 (1.2344). The difference in hardness can be explained mainly by alloy composition.

(4) Machinability of DH31-EX

Figure 10 and Figure 11 indicate the machinability of drilling and milling to DH31-EX as annealed status. DH31-EX has almost the same machinability to H13 (1.2344) by using AISI M2 homo treatment drill.

As for end-milling machinability, using a cemented carbide tool without surface coating (UTi20) significantly accelerates tool wear. However, by using a cemented carbide tool with suitable surface coating (VP15TF), a sufficient tool life can be secured.

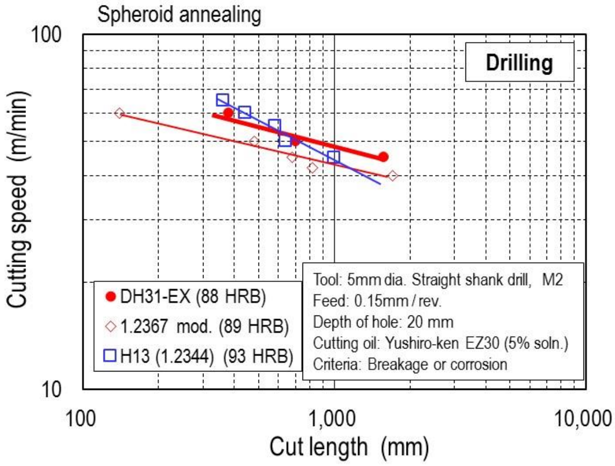

Fig.10. Drilling Machinability

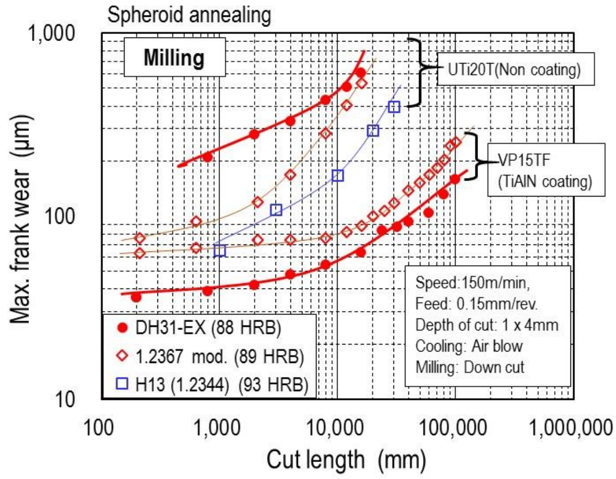

Fig.11. End-milling Machinability

(5) Basic properties

<u>Mechanical properties</u>

Figure 12 and Figure 13 indicate the test result of fatigue strength and fracture toughness. The fatigue strength of DH31-EX is higher than H13 (1.2344ESR) under the same hardness. Moreover, DH31-EX has superior fracture toughness in the hardness range according to the test result of the fracture toughness value of specimens cut out from a large mold simulating block. Thus, DH31-EX has superior properties on both fatigue strength and fracture toughness than H13 (1.2344), where both factors have a significant relation to actual mold failure.

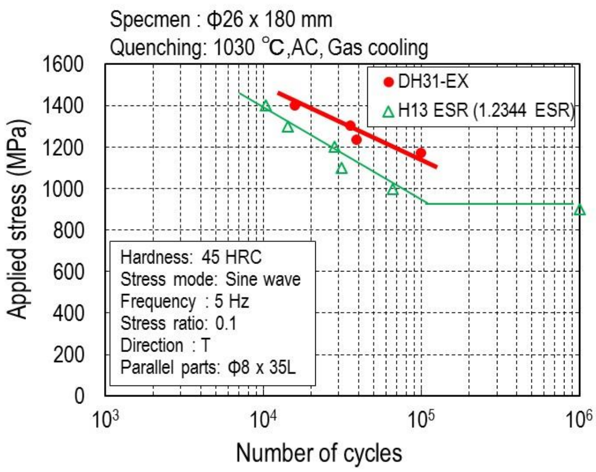

Fig.12. Low cycle fatigue property

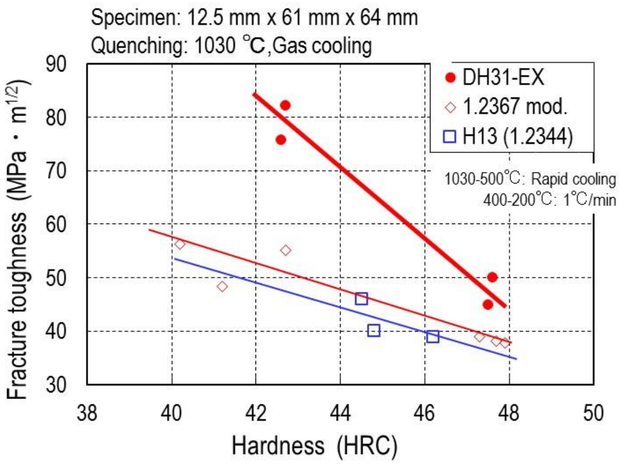

Fig. 13 Fracture toughness

Physical properties

Table 4. Average coefficient of thermal expansion from room temperature.

Temp.	20～100℃	20～200℃	20～300℃	20～400℃	20～500℃	20～600℃	20～700℃
$\times 10^{-6}$/K	11.6	11.8	12.0	12.2	12.5	12.8	12.9

Table 5. Specific heat at each temperature

Temp.	100℃	200℃	300℃	400℃	500℃	600℃	700℃
J/kg・K	487	527	572	626	703	802	985
[cal/ g・℃]	[0.116]	[0.126]	[0.137]	[0.150]	[0.168]	[0.192]	[0.235]

Measuring method: Laser flash method, Heat treatment of specimen: 1030 ℃ quenching, 610 ℃ tempering

■Important Note

The product characteristics included in this brochure are representative values based on the result of our measurements, and do not guarantee the performance in use of the products.

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