Daido's Hot Work Die Steel Series

DHA™-WORLD

DHA is a trademark or registered trademark of Daido Steel Co., Ltd.

Background of development of DHA-WORLD

Die casting parts needs are increasing not only for engine blocks and transmission cases but also chassis and body parts for lightweight demand with aiming higher fuel efficiency. 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 failure such as gross cracking at an early stage.

Repairable damage can be observed gradually, thus it is easier to make maintenance schedule. Furthermore, the gross cracking should also be definitely avoided because it is difficult to predict and repair.

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). In general, molds broken by gross cracking an at early stage trend to have lower impact value. Especially, large size molds have lower impact values metallurgically, so raising hardness is challenging so far.

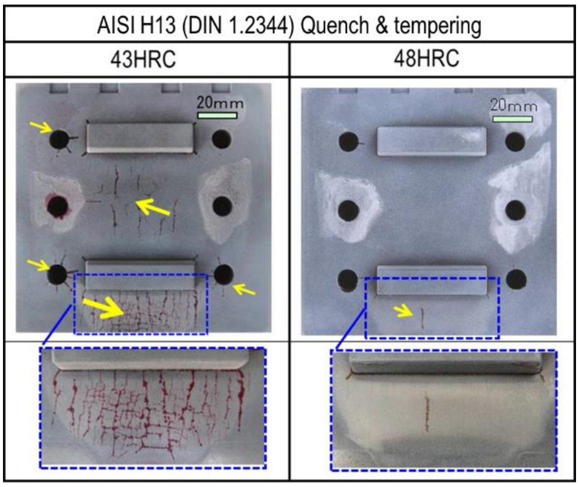


Photo. 1. Effect of hardness on heat checking

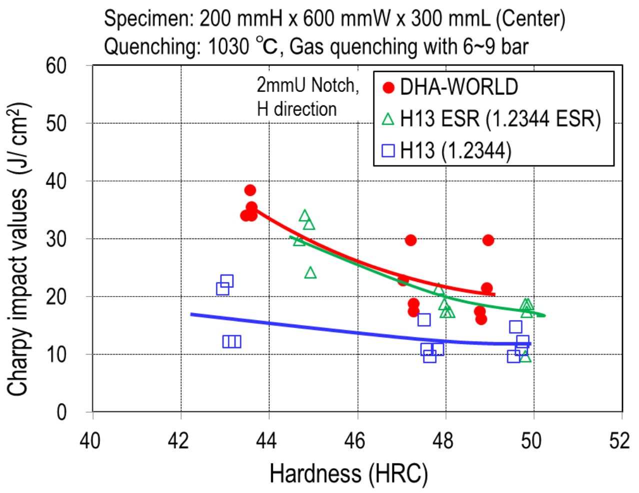


Fig. 1. Relationship between hardness and toughness

Daido Steel have developed and now provides steel "DHA-WORLD" which has stable structure and toughness throughout mold from surface to center so that it can both prevent large size molds from gross cracking and raise large size molds' hardness to have a better heat checking resistance compared with conventional standard grade steel.

Feature of DHA-WORLD

DHA-WORLD, high reliable hot working die steel alternative to AISI H13 (DIN 1.2344), can be used for large size die casting molds with confidence.

- -High hardenability: Improved hardenability by optimization of alloy design makes it possible to obtain higher toughness even in the center of large size die casting mold by simple heat treatment.
- -Air melted grade: Stable quality similar to double melted grade can be achieved by our integrated manufacturing process which Daido Steel have developed based on our accumulated technology. It contributes to reducing cost of mold material.

Chemical composition

Table 1. Typical chemical composition of DHA-WORLD.

Steel grade	C	Si	Mn	Cr	Mo	V	Note
DHA-WORLD	0.35	0.5	0.7	5.5	1.2	0.6	Example
H11	0.33-0.43	0.80-1.25	0.20-0.60	4.75-5.50	1.10-1.60	0.30-0.60	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

DHA-WORLD having uniform microstructure and secured high toughness due to higher hardenability is applicable to large size die casting molds as well as to hot working die steel application widely.

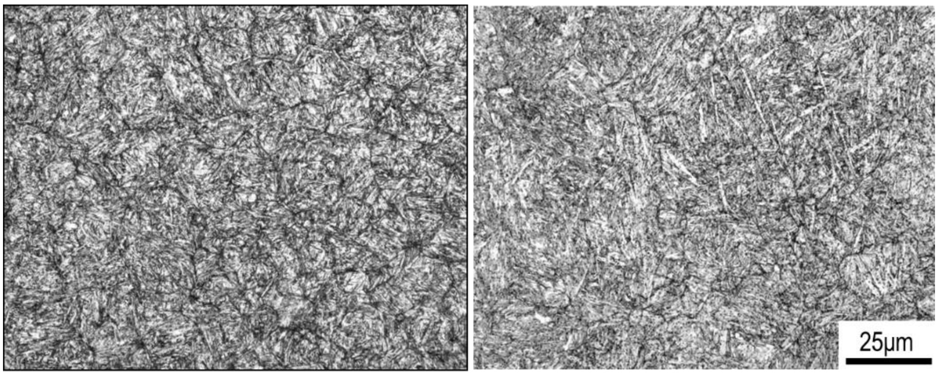
Table 2. Main application of DHA-WORLD

Applications	Hardness (HRC)
Al, Zn, Mg die casting molds	41 ~ 48
Die casting mold parts (Plunger sleeve, Plunger chip etc.)	45~ 50
Hot extrusion dies	43 ~ 50
Hot shear blade	35 ~ 45
Hot forging dies	42 ~ 50

Property of DHA-WORLD

(1) More stable and higher quality than H13 (1.2344)

Photograph 2 shows the microstructure of cutting section from the material center assuming application of large size mold. DHA-WORLD microstructure on Photo. 2(a) did not show white needle-like shape microstructure called bainite that were observed at H13 (1.2344) on Photo. 2(b).



(a) DHA-WORLD (b) H13 (1.2344)

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 2 shows the relationship between the cooling rate in the range from 400 to 200 degrees C where bainitic transformation occurs and Charpy impact values under the same hardness condition (48 HRC). For DHA-WORLD decrease in impact values along with decrease in cooling rates tends to smaller compared with H13 (1.2344).

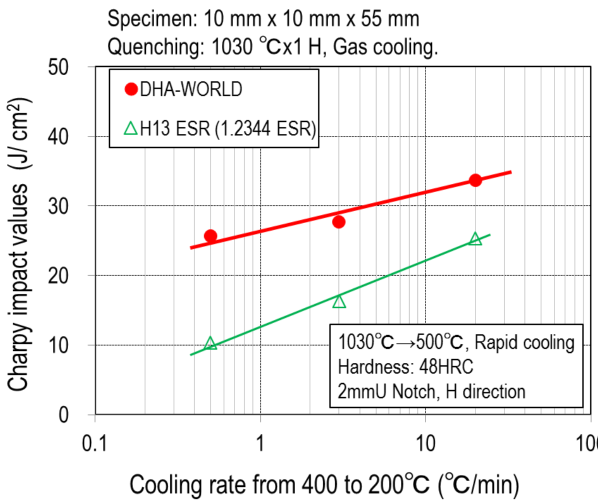


Fig. 2. Cooling rate dependency on impact values

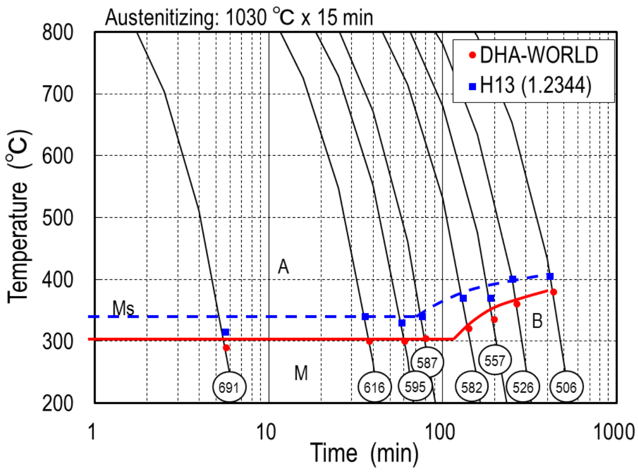


Fig.3. CCT diagrams of DHA-WORLD

Figure 3 shows CCT diagram of DHA-WORLD and H13 (1.2344). DHA-WORLD's bainite transformation start temperature shifts to rightward (longer time) compared with H13 (1.2344). This means it is easier for DHA-WORLD to obtain refined martensitic microstructure even if cooling rates are slow enough for H13 (1.2344) to bring about bainitic transformation and thus, deterioration of impact values can be suppressed. Therefore, DHA-WORLD has an advantage in application of large size molds where the cooling rate ought to be slow.

(2) The result of die casting mold evaluation test

Photograph 3 indicates the difference of the heat checking status in molds made from DHA-WORLD and H13 (1.2344) with the same design and hardness. Even though these molds have the same hardness, DHA-WORLD mold restrains heat checking compared with H13 (1.2344) mold.

It has not been completely explained yet, but the difference in heat checking resistance that Photo. 3 indicate was considered to be caused by a higher thermal conductivity of DHA-WORLD compared with H13 (1.2344), as shown in Fig. 4. Improved thermal conductivity should reduce thermal stress at the surface. Consequently, heat checking have restrained.

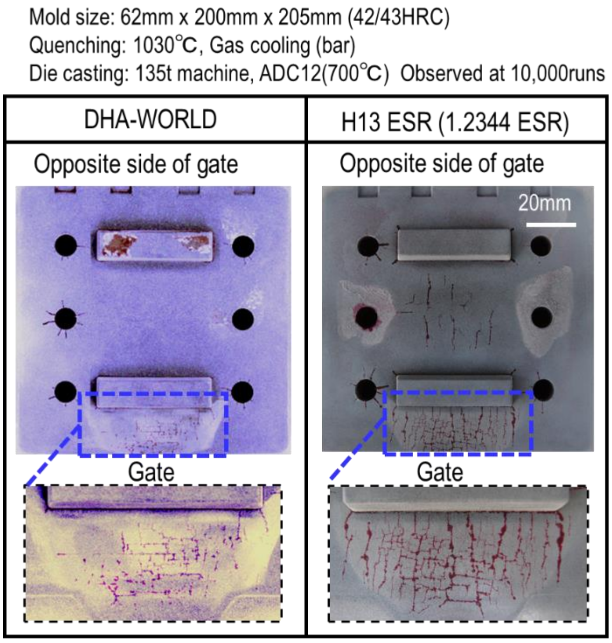


Photo. 3. Heat checking status by die casting trial

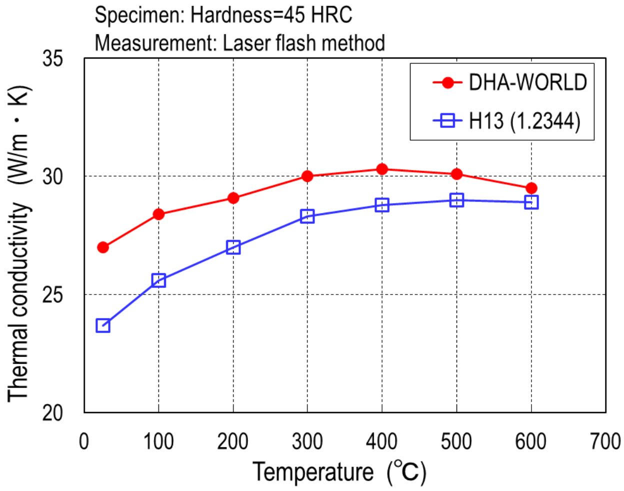


Fig. 4. Thermal conductivity

(3) Heat treatment conditions

Table 3 indicates general heat treatment conditions. The quenching and tempering temperature same as H13 (1.2344) are applicable.

Figure 5 indicates hardness according to tempering temperatures. DHA-WORLD obtains slightly lower hardness after quenching and tempering than H13 (1.2344). Therefore, adjusting hardness by referring Fig.5 is strongly recommended.

Figure 6 indicates dimensional change according to tempering temperatures. DHA-WORLD shows isotropic behavior regarding the dimensional change by heat treatment and the ratio of dimensional change is smaller than H13 (1.2344). Reference of Fig. 6 is recommended to determine the machining allowance for finishing.

Table 3. Heat treatment condition of DHA-WORLD

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	≦229HB	35~53 HRC	815~875	300 (Austenitized at 1030℃)

(4) Surface treatment conditions

Figure 7 shows the hardness distributions of DHA-WORLD and H13 (1.2344) by applying the same nitriding condition. DHA-WORLD will show nitriding property as same as H13 (1.2344). Accordingly, the same nitriding conditions as H13 (1.2344) can be applied to DHA-WORLD.

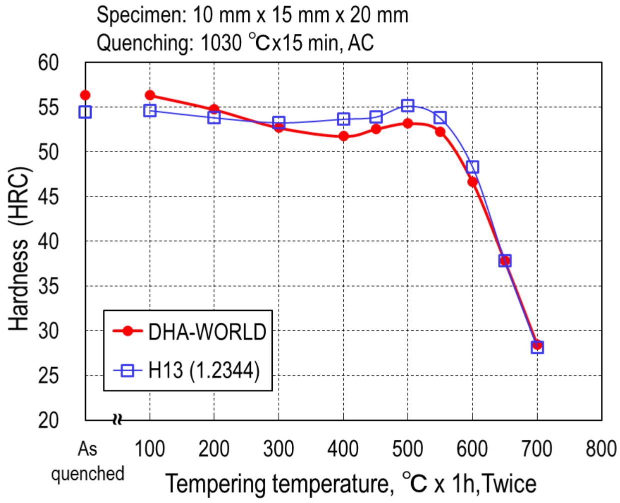


Fig. 5. Tempering temperature and hardness

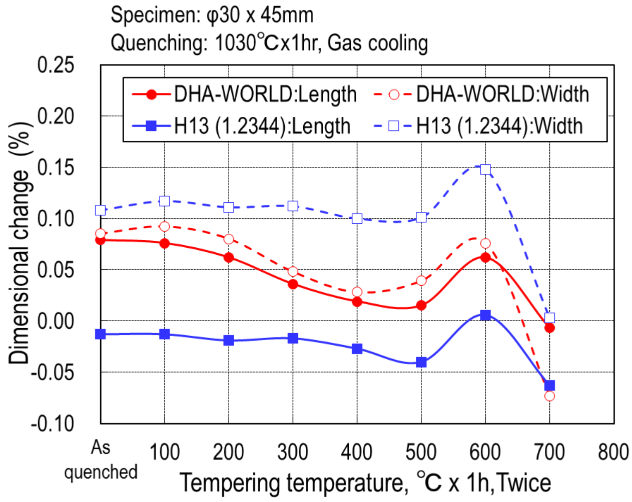


Fig. 6. Tempering temperature and dimensional change

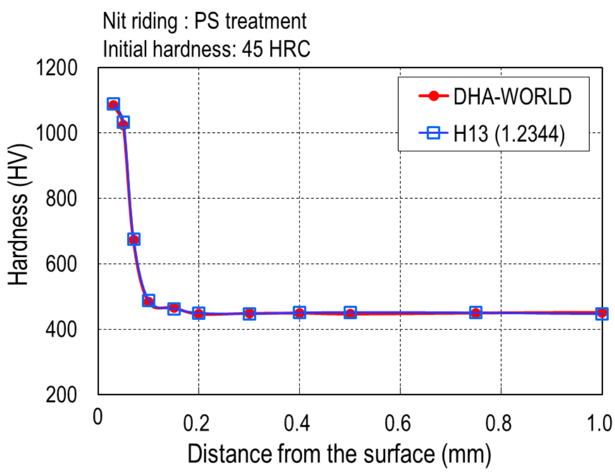
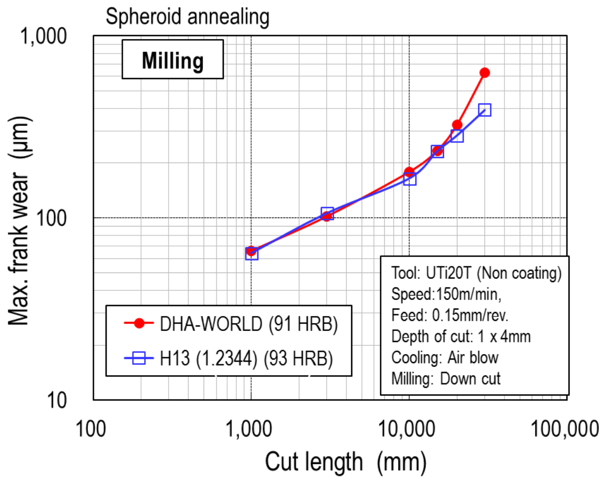


Fig. 7. Hardness distribution after nitriding

(5) Machinability of DHA-WORLD

Figure 8 and Figure 9 indicate the machinability of milling and drilling to DHA-WORLD as annealed status. DHA-WORLD has almost the same machinability as H13 (1.2344).



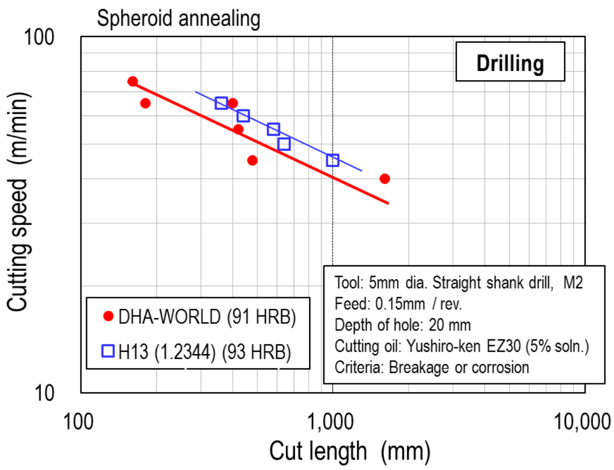


Fig. 8. Machinability of DHA-WORLD (Milling)

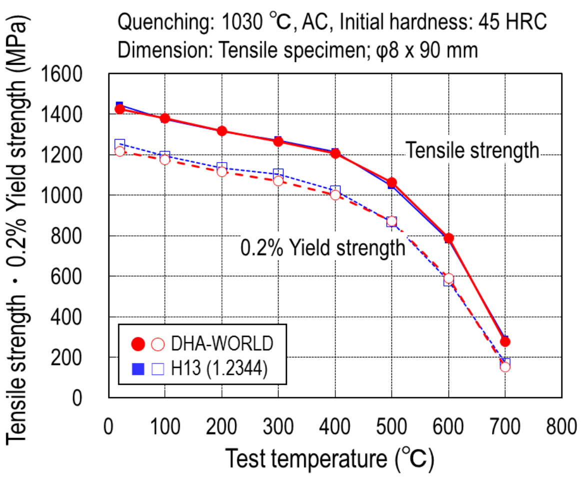
Fig. 9. Drilling Machinability

(6) Basic properties

DHA-WORLD basic properties are shown below.

<u>Mechanical properties</u>

Below results has been tested with the same hardness condition between DHA-WORLD and H13 (1.2344).



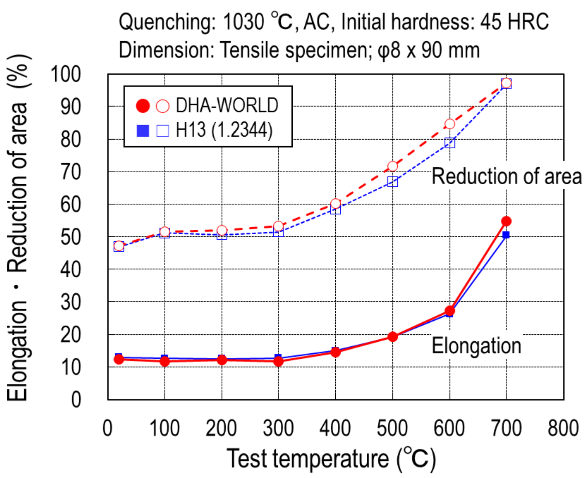


Fig. 10. Tensile property (Tensile strength)

Fig. 11. Tensile property (Elongation and Reduction of area)

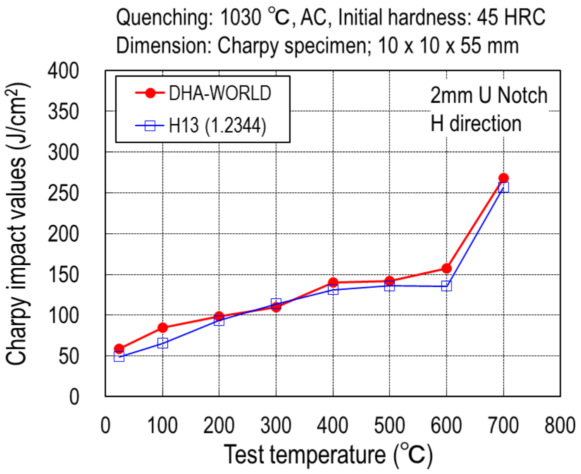


Fig.12. Charpy impact value at high temperature

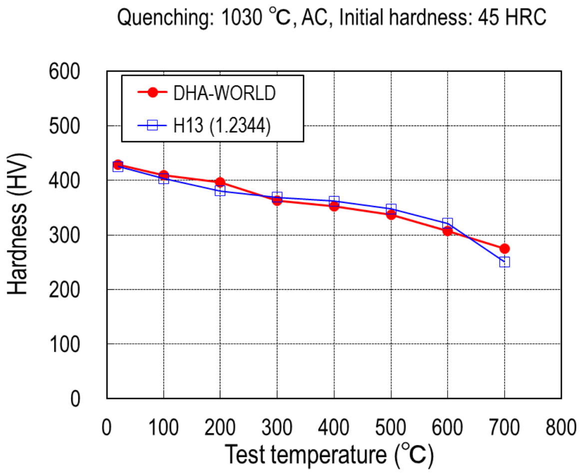


Fig.13. High temperature hardness

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	11.3	11.7	12.1	12.5	12.8	13.1	13.2

Table 5. Thermal conductivity at each temperature

Temp.	100℃	200℃	300℃	400℃	500℃	600℃
W/ m･K	28.4	29.1	30.0	30.3	30.1	29.5

Table 6. Specific heat at each temperature

Temp.	100℃	200℃	300℃	400℃	500℃	600℃	700℃
J/kg･K	473	509	558	604	667	760	934
[cal/ g･℃]	[0.113]	[0.122]	[0.133]	[0.144]	[0.159]	[0.182]	[0.023]

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

■Important Note

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

Please inquire the latest information to our department in charge as the information of this brochure is subject to further updates without any notice.