DAP™-AM Series - Metal Powders for 3D Printing -

Daido Alloy Powder – for Additive Manufacturing (High Thermal Conductivity)

High Thermal Conductivity Powders for Molds

DAP™-AM HTC45 and DAP-™AM HTC40 have been developed by adjusting chemical composition of steel to suit additive manufacturing by SLM.

Feature

- DAP™-AM HTC45 and DAP™-AM HTC40 are spherical powders produced by gas atomization and have low oxygen content and high flowability.
- Cracking during 3D printing is suppressed as these powders have been developed by modifying chemical composition of steel conforming to JIS[*1].
- The cooling effect of mold can be enhanced by increasing thermal conductivity. In addition, thermal stress can be reduced, which prevents heat checking, and cracks originating from cooling holes.

[*1] A base plate temperature of 200℃ is recommended to prevent cracking during 3D printing.

Major applications

- Pins and inserts etc. with cooling holes.

Typical Chemical composition and hardness range

DAP™-AM series	Equivalent steel grade	Hardness (HRC)	Typical chemical composition (mass%)					Applications
			C	Si	Cr	Mo	V	
DAP™-AM HTC45	SKD61 type Die steel	40~50	0.23	0.1	5	1.2	0.4	Die-casting molds
DAP™-AM HTC40	SKD61 type Die steel	35~45	0.13	0.1	5	1.2	0.4	Die-casting molds Plastic injection molds

Particle size

Particle size (μm)
-53/+25

Characteristics

Hardness is reduced to a practical level, and cracks during 3D printing are suppressed. Hardness can be adjusted by tempering[*2] after 3D printing.

[*2] Tempering at 550℃ or higher is recommended to release residual stress.

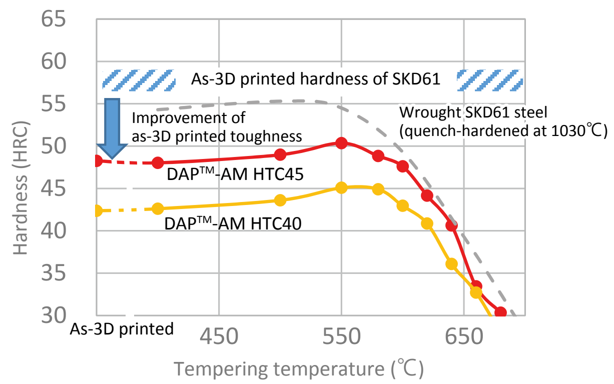


Fig. 1 Correlation of the hardness between as-3D printed and tempered after 3D printing.
(Tempering [T℃ × 1h] 2 times, base plate temperature 200℃)

DAP™-AM HTC series can cool molds efficiently by improving thermal conductivity. They can also reduce thermal stress and prevent heat checking and cracks originating from cooling holes.

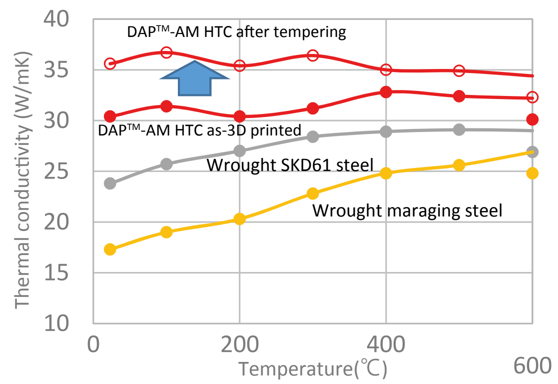


Fig. 2 Comparison of thermal conductivity.
(Laser flash method)

Mold manufacturing process using DAP™-AM HTC

DAP™-AM HTC can be quench-hardened during 3D printing. In order to prevent cracking and deterioration of toughness caused by secondary hardening during tempering, the surface of 3D printed product should be smoothed, and then tempering should be carried out to adjust the hardness or stress-relief annealing should be performed. Distortion after removal from the base plate is reduced if heat treatment is performed without detaching it from the base plate.

3D printing → Shot blasting → Heat treatment (Tempering and stress relief annealing) → Removing from base plate → Machining

Fig. 11 Typical mold manufacturing process using DAP™-AM HTC.

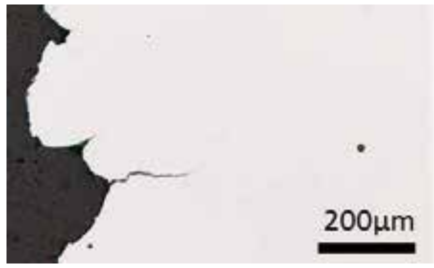


Fig. 12 Initial cracks caused by tempering after 3D printing.

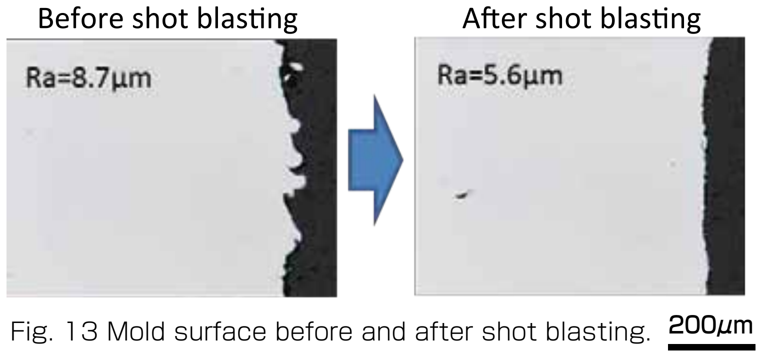
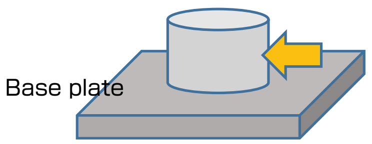


Fig. 13 Mold surface before and after shot blasting.

Cracking of 3D printed object is caused by the surface roughness perpendicular to the base plate. Smoothing the rough surface reduces the risk of cracking.



Smoothing the surface perpendicular to the base plate by shot blasting.

3D printed models

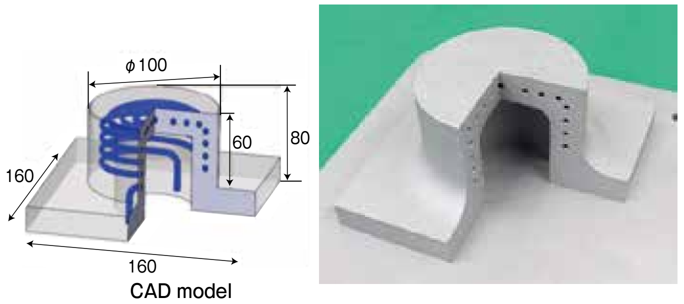


Fig. 14 3D model of a mold manufactured using DAP™-AM HTC40.

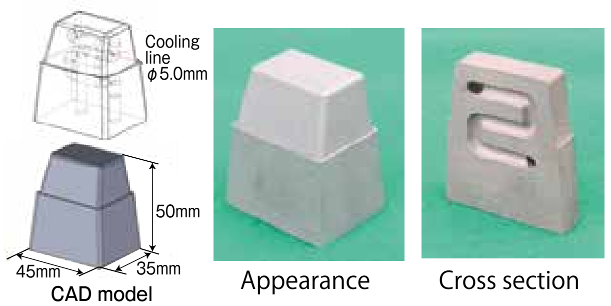


Fig. 15 3D model of a mold manufactured using DAP™-AM HTC45.

DAIDO STEEL CO., LTD.

Tokyo Head Office (Metal Powder Marketing & Sales Sect. Metal Powder Dept.) Daido Shinagawa Building, 6-35, Konan 1-chome, Minato-ku, Tokyo, 108-8478 TEL +81-3-5495-1284

Nagoya Office 10, Ryugu-cho, Minato-ku, Nagoya, Aichi, 455-0022 TEL +81-52-694-0776

Web site: https://www.daido.co.jp/en/products/powder/index.html Email address: funmatsu@ask.daido.co.jp

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The tensile strength and 0.2% proof stress are equivalent to wrought SKD61 type steel with the same hardness as DAP™-AM HTC.

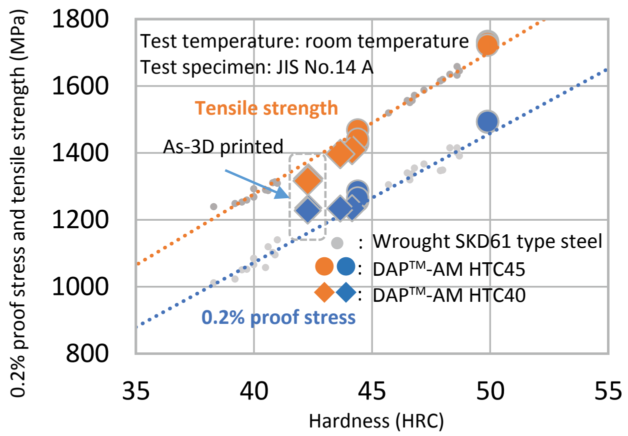


Fig 3. Relationship between hardness, 0.2% proof stress, and tensile strength of DAP™-AM HTC*3.

The impact value is higher than that of wrought SKD61 type steel with the same hardness as DAP™-AM HTC due to lower carbon content.

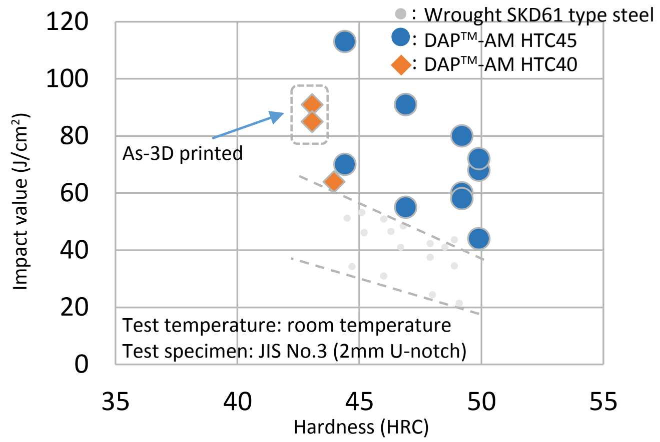


Fig. 4 Relationship between hardness and impact value of DAP™-AM HTC*3.

Fatigue strength of 3D printed specimens are lower than that of wrought steel with the same hardness due to defects formed during 3D printing. It is possible to improve the fatigue strength by optimizing the 3D printing parameters.

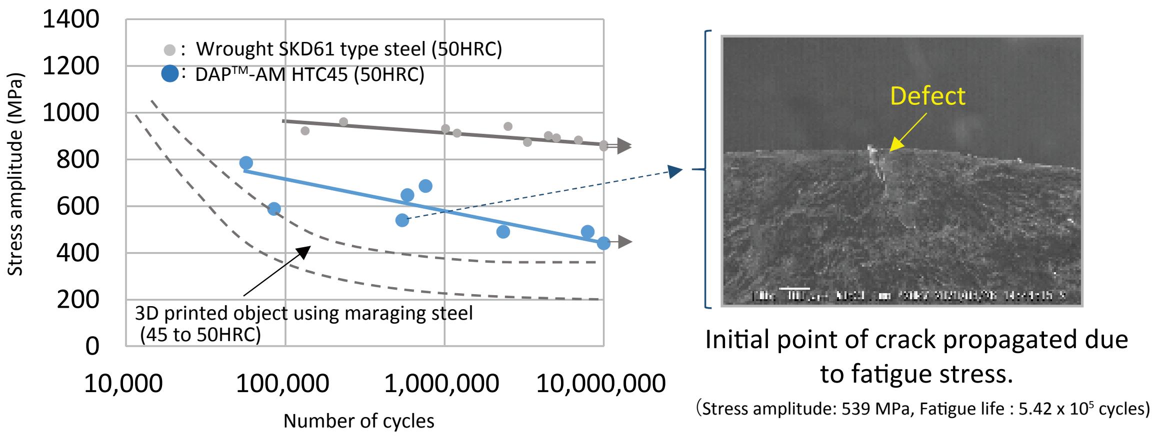
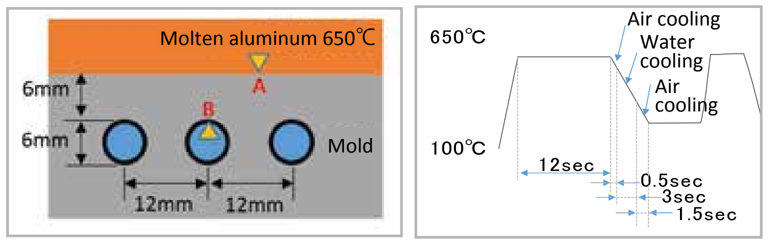


Fig. 5 Fatigue strength and typical fatigue fracture surface of DAP™-AM HTC*3.

Table 1. Expected improvement by increasing thermal conductivity compared by maraging steel by FEM analysis.

Calculation item	Calculation results	Expected improvements
Decrease in maximum temperature of the mold surface (point A)	-17℃	Restrain mold from seizing and improving cycle time
Decrease in stress amplitude on the surface of cooling hole (point B)	-10%	Prolonging die life of crack initiation from cooling hole



The improvement of thermal conductivity lowers the temperature of the mold surface and further reduces the seizure of die-casting molds. The stress on the surface of the cooling hole also decreases, which can prolong mold life by preventing cracking from the cooling hole.

Fig. 6 FEM analysis model and thermal history.

DAP™-AM HTC has higher thermal conductivity, which results in lower thermal stress and reduced heat checking in comparison to SKD61 under the same thermal history.

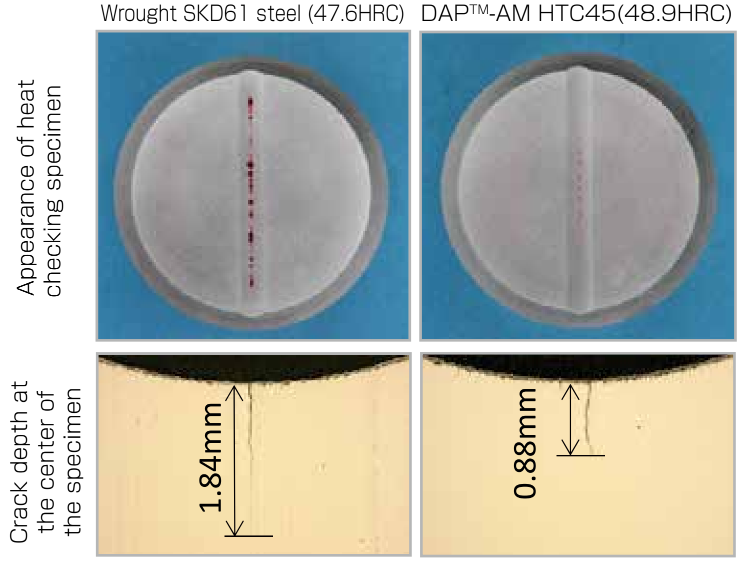


Fig. 7 Heat checking test results*3.
(Notch shape: R=6mm, depth 1mm)

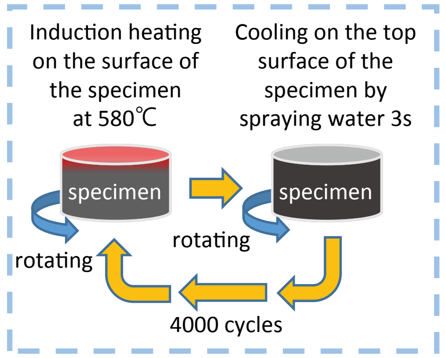


Fig. 8 Overview of heat checking test.

*3 All the test results of tensile strength, Charpy impact value, fatigue strength, and heat check were carried out with the material 3D printed in accordance with the original recipe of Mitsubishi Corporation Technos.

3D printing process parameters

The data shown in Table 2 are 3D printing process parameters established with Concept Laser M2 machine. When using other equipments, please refer to the table for optimizing conditions. Please feel free to ask our Metal Powder Department about the process parameters.

Table 2. Recommended process parameters*4.

Part		Laser power (W)	Laser spot diameter (μm)	Scanning speed (mm/s)	Hatching distance (mm)	Layer thickness (μm)
Product	Inside	300	180	600	0.13	50
	Contour*5	150	100	300	—	50
Supporting part		150	100	700	—	50

The recommended laser scanning pattern is checker-board type and the recommended base plate temperature is 200℃.

*4 Recommendations are for reference only and do not guarantee the aforementioned quality of mechanical properties and fatigue strength, etc.

*5 Process parameters for forming contour part

2 times irradiating laser on the contour part (2nd time is shifted 70 μm inward from 1st time) can reduce defects in the border between contour part and inside part.

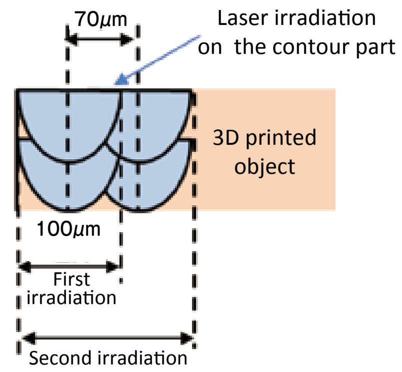


Fig. 9 Image of laser irradiation (2 times) to form the contour part.

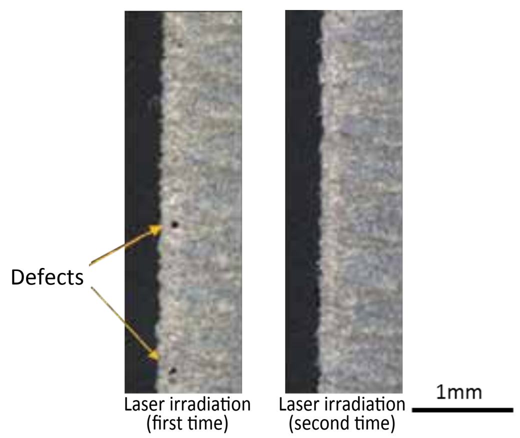


Fig. 10 Defects in the border between contour part and inside part.