DAP™-AM series for 3D printing

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

High Thermal Conductivity Powder Metal DAP™-AM HTC45 and DAP™-AM HTC40

DAP™-AM HTC45 and DAP™-AM HTC40 are・・・

A metal powders created for SLM 3D printing.

Spherical powders with excellent flowability to improve moldability.

Features

・Gas atomized powder with spherical and flowable features as well as low oxygen contents.
・Reduce cracks during 3D printing by improving the powder composition.
・Enhanced cooling efficiency with improved thermal conductivity property, reduced thermal stress, and improved protection of cooling lines from heat checking and cracking.

*1. Recommend 200℃（392F) for base plate temperature to prevent cracks during 3D printing.

Example of applications

- Inserts for die casting mold and injection mold for plastic

Chemical composition and range of hardness

DAP™-AM Series	Equivalent Steel	Range of hardness (HRC)	Chemical Composition (mass%)					Application
			C	Si	Cr	Mo	V	
DAP™-AM HTC45	Type of H13	40~50	0.23	0.1	5	1.2	0.4	Die Casting Mold
DAP™-AM HTC40	Type of	35~45	0.13	0.1	5	1.2	0.4	Die Casting Mold Plastic Mold

Typical Particle size

Particle Size（μm）
-53/+25

Characteristics

Hardness is reduced to a practical level, and cracks during 3D printing are prevented. Hardness can be adjusted by tempering*2 after 3D printing.
(*2 Tempering at 550° C (1022F)
or higher is recommended to release residual stress.)

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.

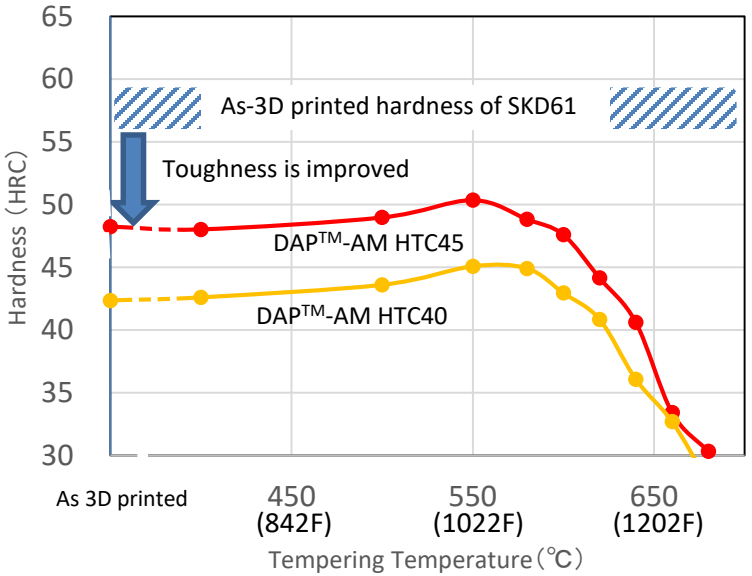


Figure.1
Correlation of the hardness between as 3D printed and tempered after 3D printed.
（Tempering(℃) × 1h] twice)
The temperature of base plate is 200℃ (392F)

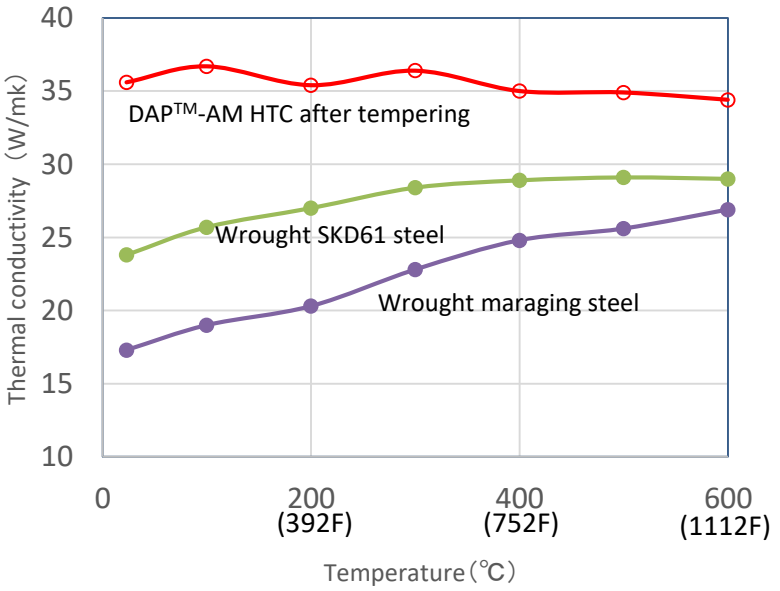


Figure.2
Comparison Table among individual material.
(Tested by laser flash method）

Tensile Strength and 0.2% proof stress are equivalent to SKD61 type steel in case of the same hardness

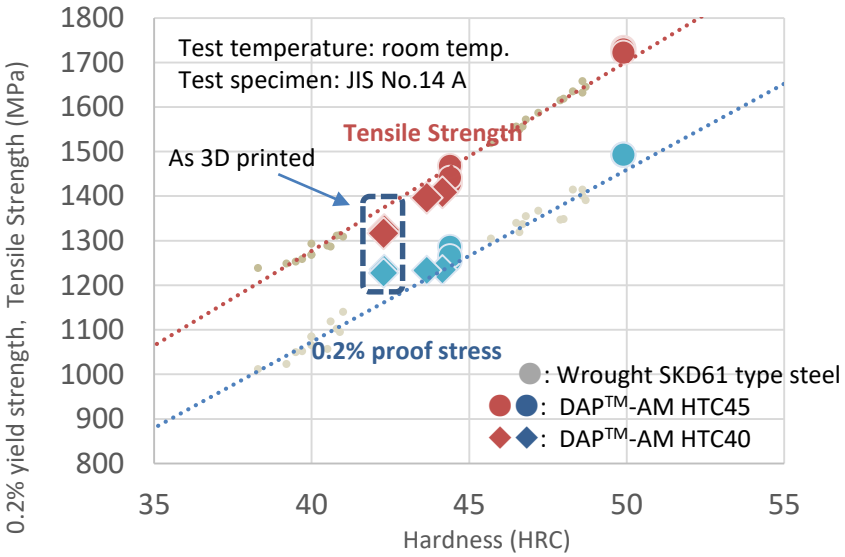


Figure.3

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

Charpy impact value is much better than that of wrought SKD61 type steel in case of the same hardness by reducing carbon content

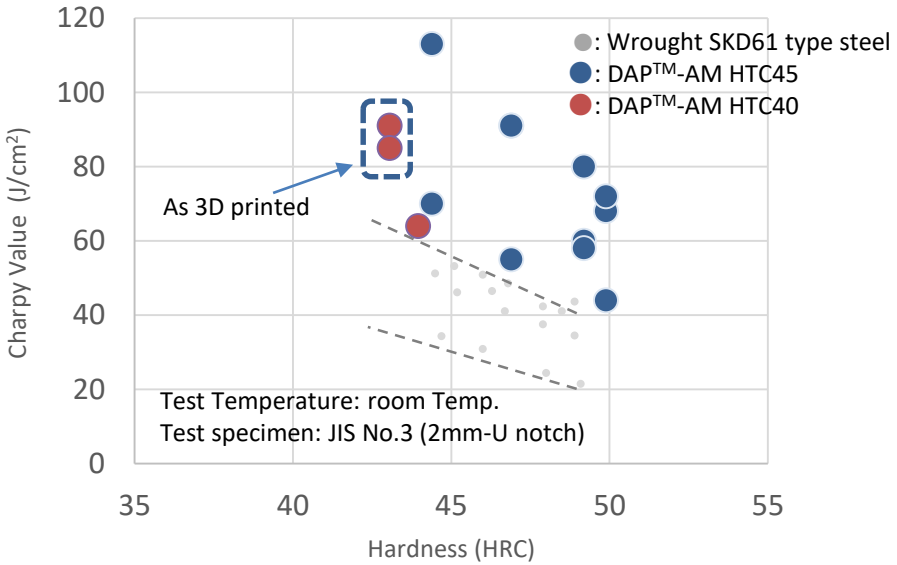
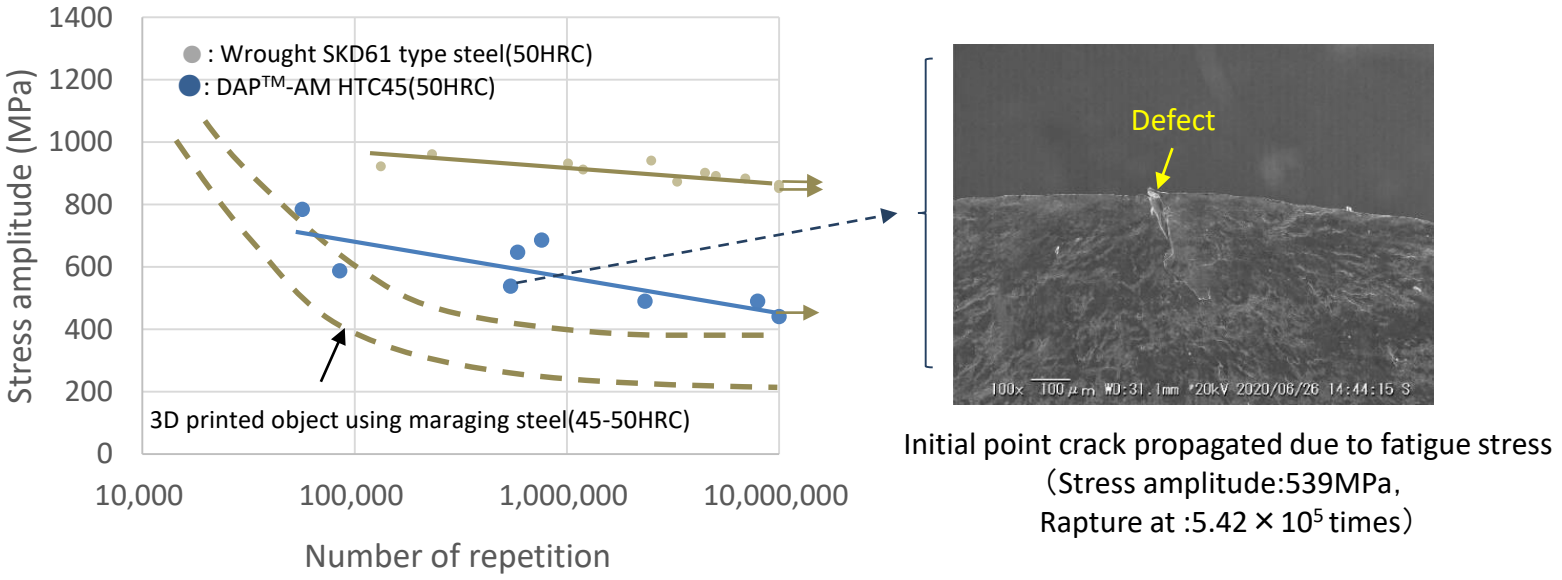


Figure.4

Relationship between hardness and impact value of DAP™-AM HTC.

◆Fatigue Strength of 3D print is lower than that of same type of steel because the density of 3D print is lower than density of steel. Potential for crack.

◆However, it is possible to increase the fatigue strength of HTC by optimizing the printing parameters. (Skill of printer)



Initial point crack propagated due to fatigue stress
（Stress amplitude:539MPa,
Rapture at :5.42 × 10^5 times）

Figure.5
Fatigue strength and typical fatigue fracture surface of DAP™-AM HTC.

Table.1
Expected improvement by increasing thermal conductivity compared to that of maraging Steel
Calculated by FEM analysis.

Calculated content	Result	Expected improvement
Reduction of the max temp. on point A (Surface of mold)	-17℃ (-62F)	Restrain mold from seizing. Improving cycle time.
Stress amplitude on point B (surface of cooling line)	-10%	Prolonging die life by improving cracking from cooling lines.

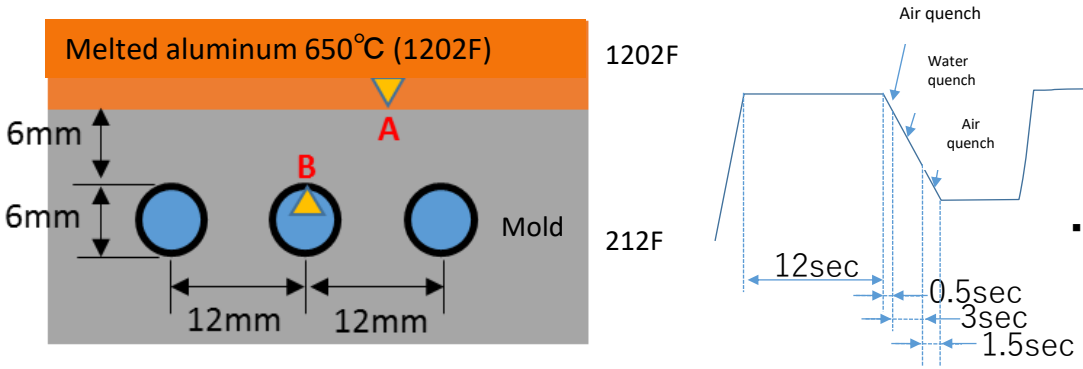


Figure.6
FEM analysis model and thermal history.

- Improved thermal conductivity can keep the mold temp. lower and prevent casted aluminum product from seizing.

- Better thermal conductivity contributes to prevention of cracks from cooling lines by reducing any stresses on the surface of it.

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You can prolong mold life as the above.

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

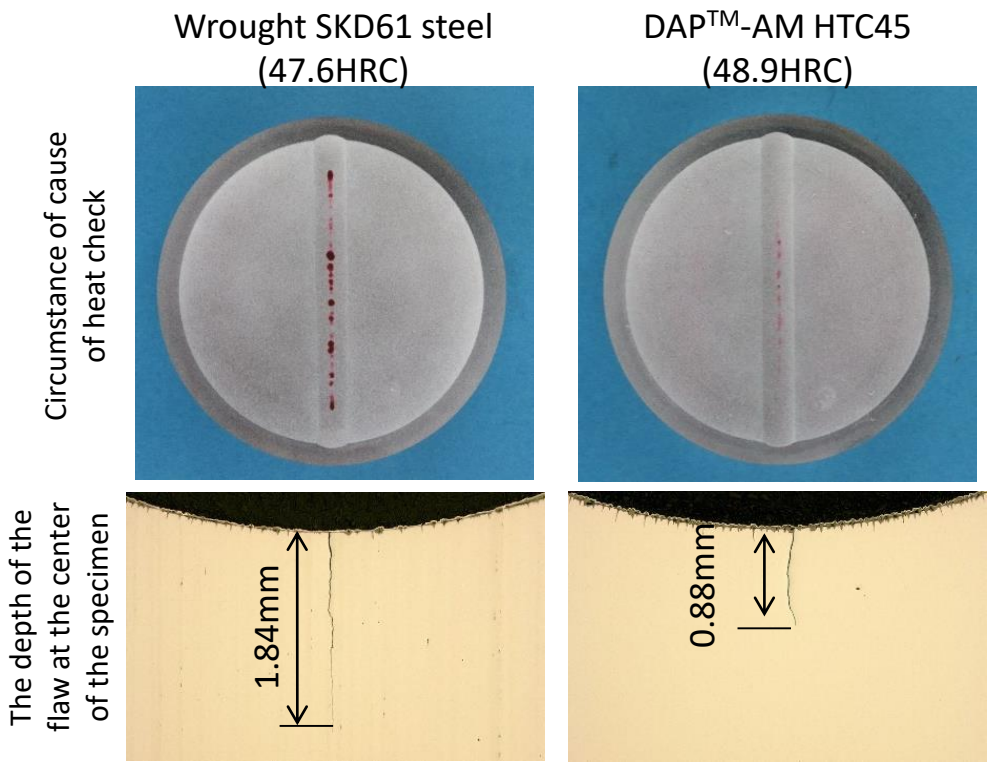


Figure.7
Fig. 7 Heat checking test results.*3
(Shape of notch：R=6mm,depth=1mm)

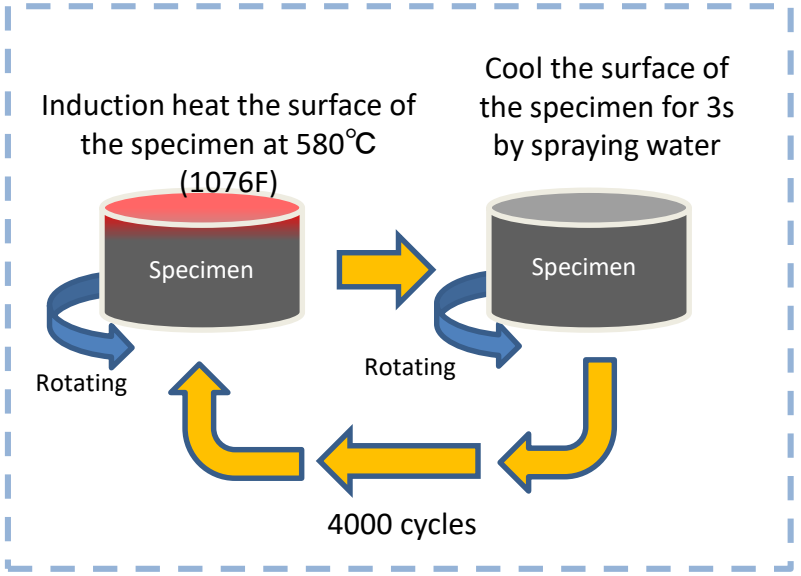


Figure.8
Overview of heat checking test.

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

Stipulations for 3D printing

The stipulations shown on table.2 is the condition established with the equipment produced by concept laser company (under GE).

Please feel free to ask Daido's powder metal department about the stipulation if you use different equipment.

Table.2
Recommended stipulation for 3D printing*4

Position		Laser output (W)	Laser spot (μm)	Scan Speed (mm/s)	Hatching range (mm)	Thickness of lamination (μm)
Product	Inside part	300	180	600	0.13	50
	Outline part	150	100	500	—	50
Support part		150	100	700	—	50

We recommend
- Chess board type for laser scanning.
- 200℃ (392F) temperature for base plate.

*4 Recommendations are for reference only and do not guarantee the quality of mechanical property and fatigue strength.

Condition of 3D printing for contour part

You can reduce a risk of cracks existing between contour and inside of 3D printed object by hitting laser twice so that the both tiers overlap in 70µm.

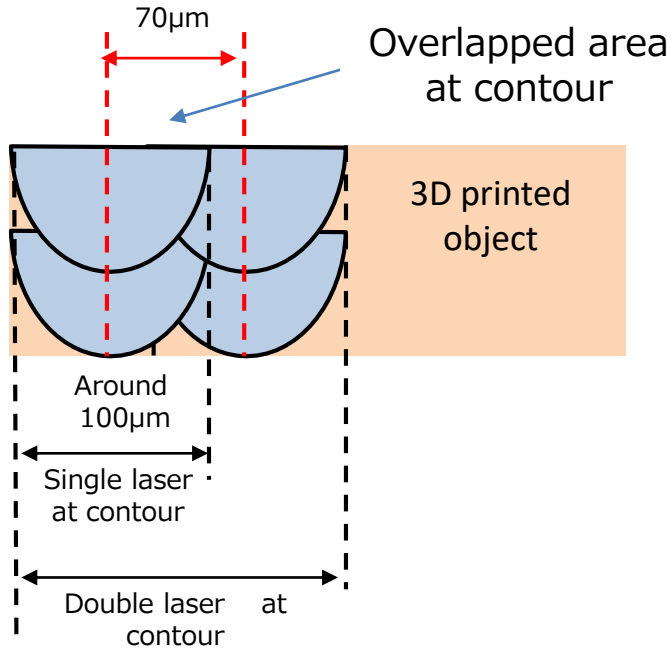
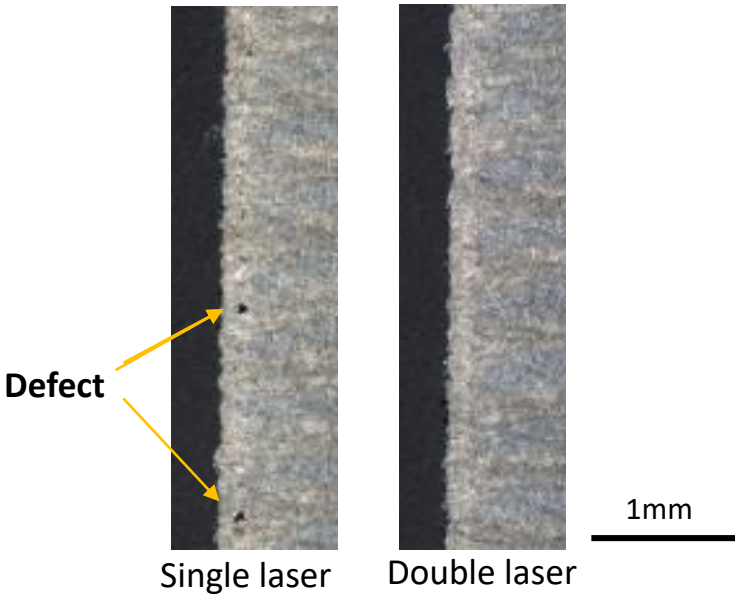


Image regarding doubled laser



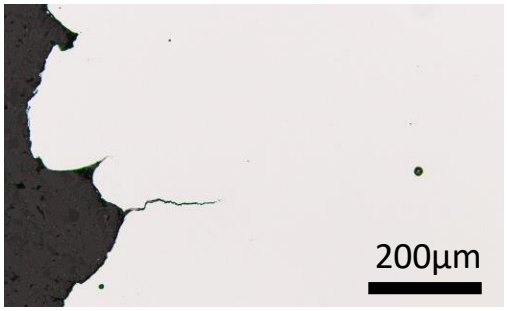
Improvement of surface quality by double laser at contour

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 is performed.
Distortion after removal from the base plate is reduced if heat treating is performed without detaching it form the base plate.

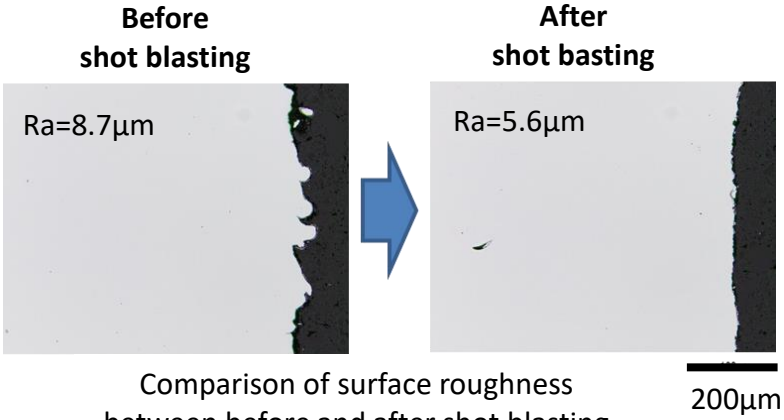
3D Printing → Shot basting → Heat Treatment Tempering/Stress relieving → Removing from Base plate → Machining

Typical mold manufacturing process using DAP™-AM HTC.

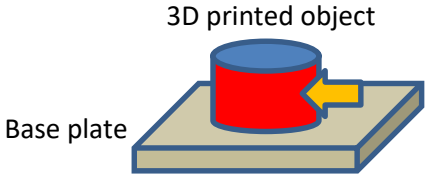


Initial cracks caused by tempering after 3D printing.

Crack on 3D printed object is caused by concave and convex existing on the face vertically running against base plate. Making the surface smooth by shop peening contributes to dramatically decreasing a risk that crack happens.



Comparison of surface roughness between before and after shot blasting



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

Distortion during 3D printing & heat treatment for stress relief

Distortion will occur by heat affect during 3D printing. Therefore, we recommend tempering at more than 550℃ (1022F) to relieve the stress generated when 3D printing.
This tempering process covers the process to adjust the hardness.

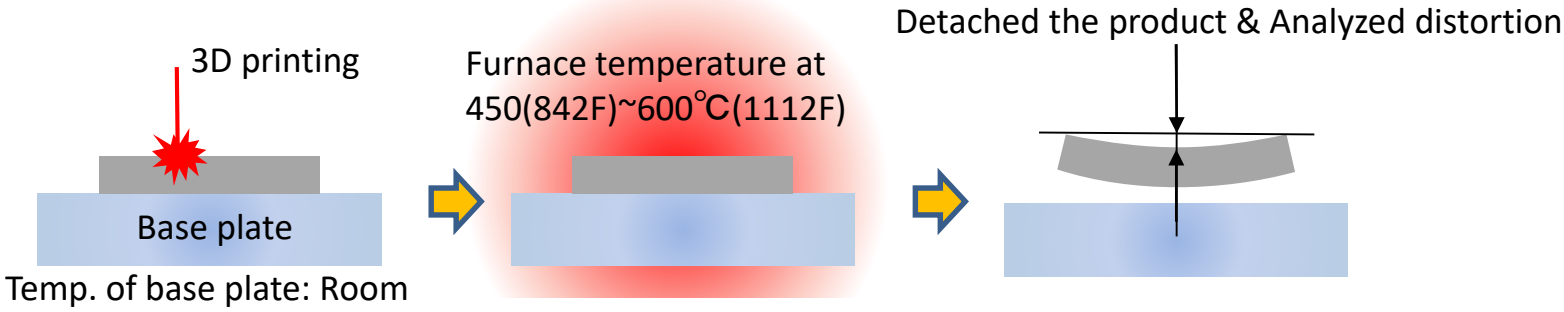


Figure.10
The method of evaluation for distortion during 3D printing & the stipulation of heat treatment for stress relief.

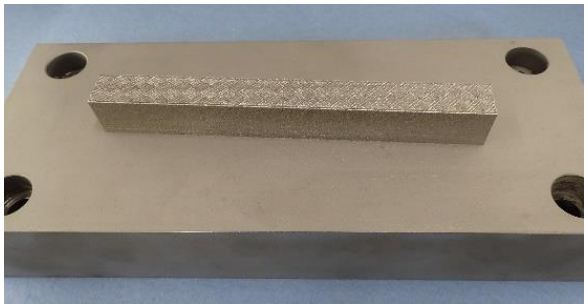


Figure. 11 Appearance of specimen.
(DAP™-AM HTC40: 15W × 17H × 150Lmm)

Table.3
Stipulations for Heat Treatment & amount of distortion.

Heat Treatment	Distortion
As 3D printed	0.24mm
450℃(842F) × 1h	0.22mm
500℃(932F) × 1h	0.22mm
550℃(1022F) × 1h	0.12mm
600℃(1112F) × 1h	0.15mm

Summary

DAP™-AM Series, DAP™-AM HTC45 and DAP™-AM HTC40･･･

- Thermal conductivity of DAP™-AM is 2X better than maraging steel ,and it makes mold cooling easier and contributes to improvement of mold life by prevent cooling lines from cracking.
- Reduced occurrence of cracks when controlling the max hardness as 3D printed.
- Mechanical properties are equal or better than SKD61, except fatigue strength.
- Please pay attention to fatigue strength because the property is inclined to be lower than that of “actual steel” due to the defect during 3D printing.
- You can reduce the stress generated during 3D print by carrying out tempering at over 550℃(1022F).
- There is a possibility that crack occurs from concave and convex on 3D printed object’s surface by low toughness due to secondary hardening after tempering. In this case, removing those concave and convex areas by shot peening after 3D printing to make the surface flat contributes to preventing the crack.