AMDAP™ series for 3D-printing

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

High Thermal Conductivity Metal Powder AMDAP™ HTC45 and AMDAP™ HTC40

AMDAP^{TM} HTC45 and AMDAP^{TM} HTC40

Characteristics

1. H13-based powders with good flowability suitable for additive manufacturing.
2. Cracking of die casting-molds can be prevented by high thermal conductivity.
3. Cracking during additive manufacturing can be reduced by modifying chemical composition.

Chemical composition and range of hardness

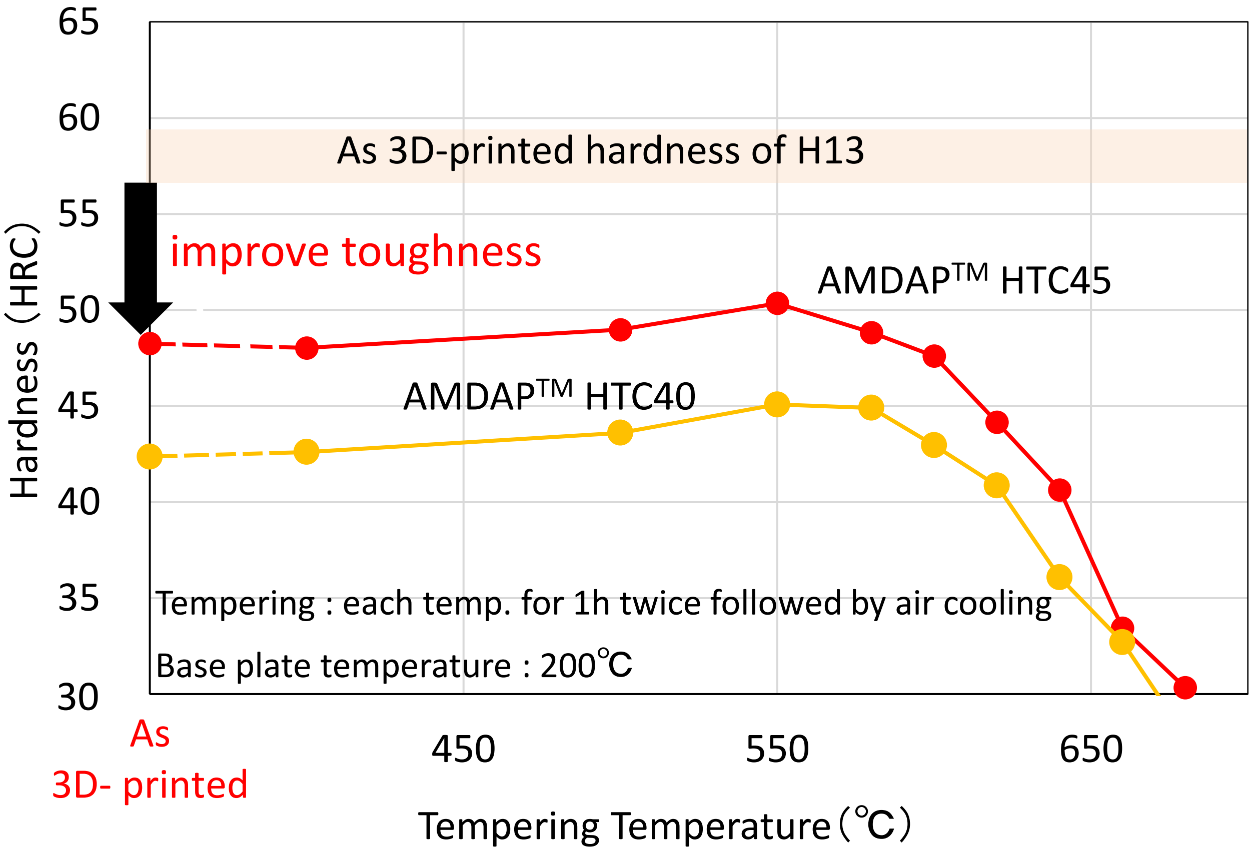
AMDAP^{TM} Series	Equivalent Steel	Range of hardness(HRC)	Chemical Composition (mass%)					Application
			C	Si	Cr	Mo	V	
AMDAP^{TM} HTC45	Type of H13	40~50	0.23	0.1	5	1.2	0.4	Die Casting Mold
AMDAP^{TM} HTC40	Type of H13	35~45	0.13	0.1	5	1.2	0.4	Die Casting Mold Plastic Mold

Typical Particle size

Particle Size（μm）
-53/+25

Hardness of AMDAP™ HTC45 and HTC40

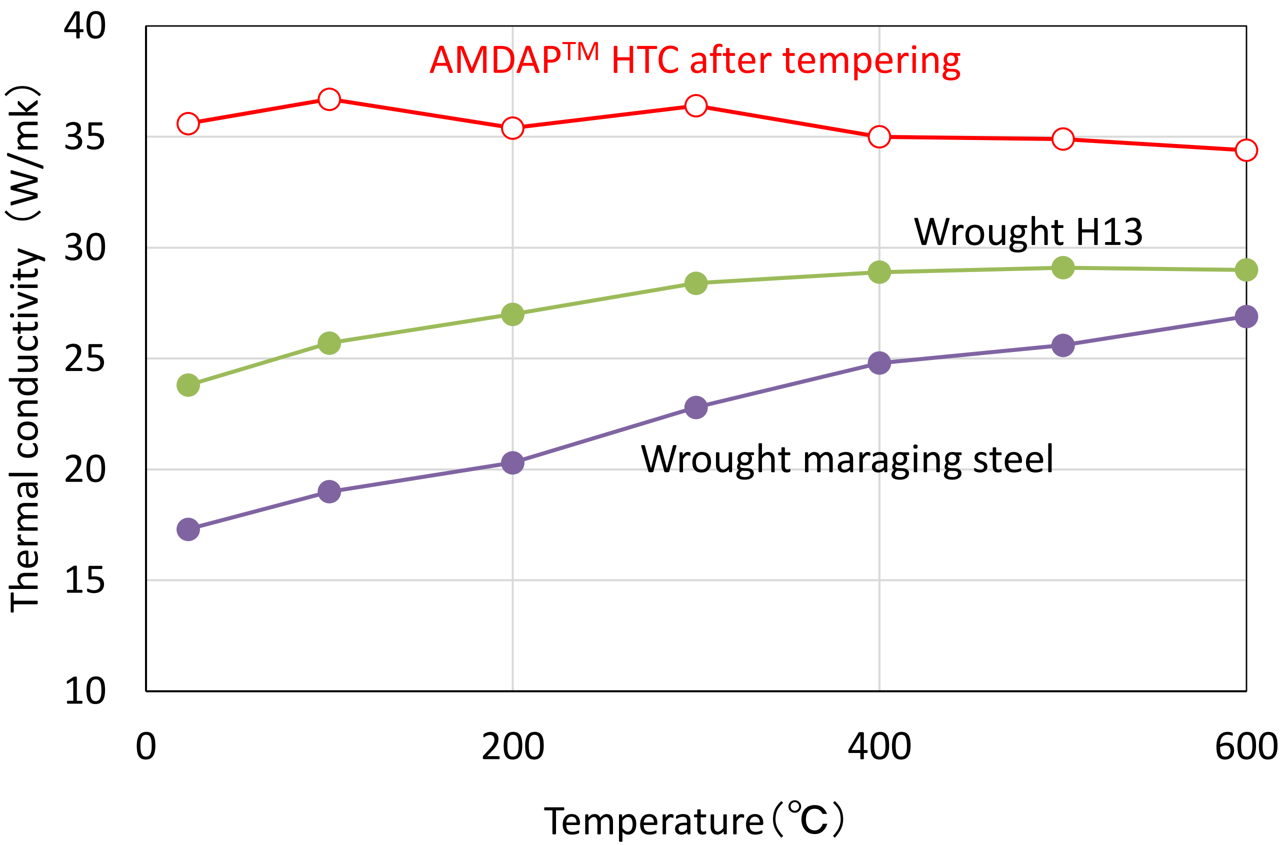
- Prevent cracking during 3D-printing, because of lower hardness than H13 as-3D printed.
- Tempering followed by 3D-printing make it possible to adjust hardness of die-casting molds.
- 550℃ or higher of tempering is recommended, because of the release of residual stress.



Thermal conductivity of AMDAP™ HTC

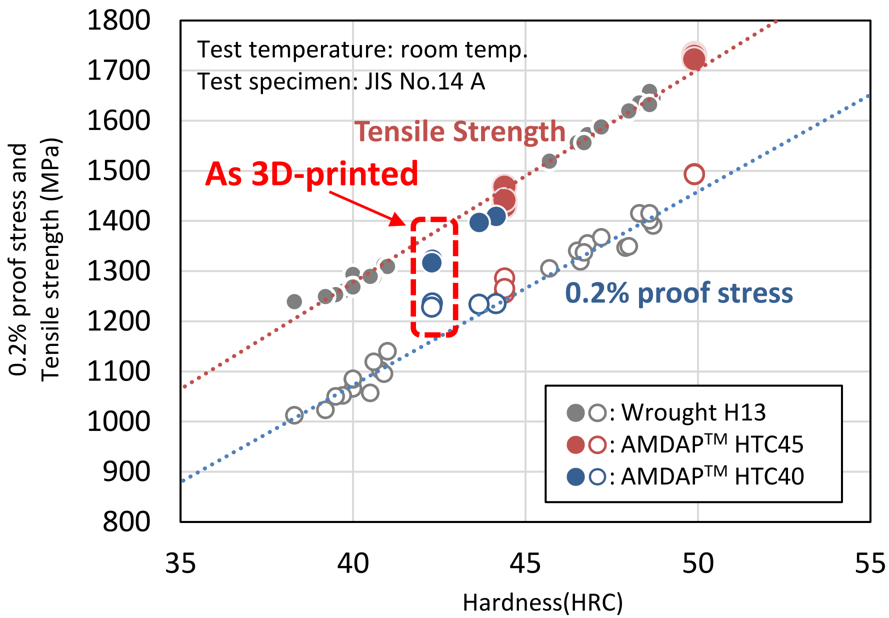
Thermal conductivity of AMDAP™ HTC series are higher than that of wrought H13.

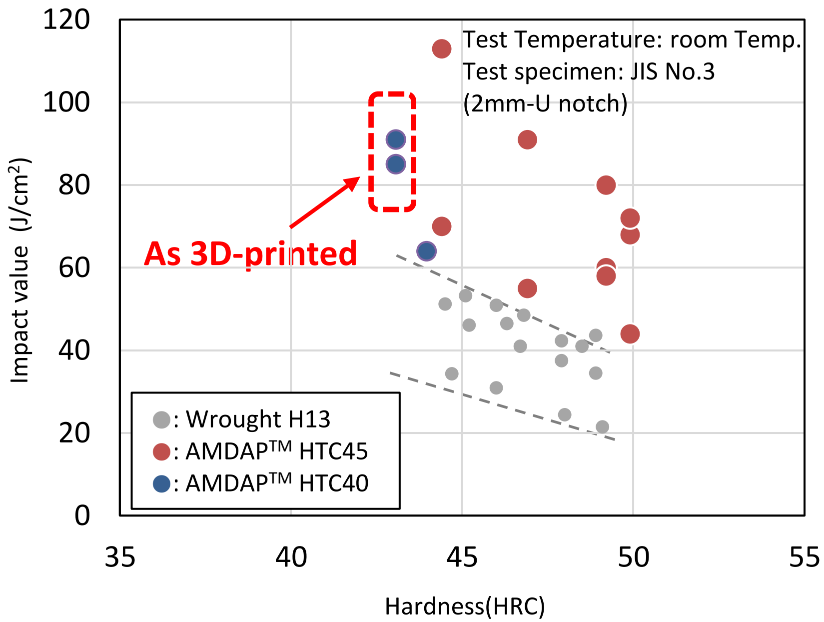
→reduce thermal stress and prevent heat cracking of die-casting molds.



Tensile strength and charpy impact value of AMDAP™ HTC series

- Tensile strength and 0.2% proof stress are equivalent to H13.
- Charpy impact value is much higher than wrought H13.





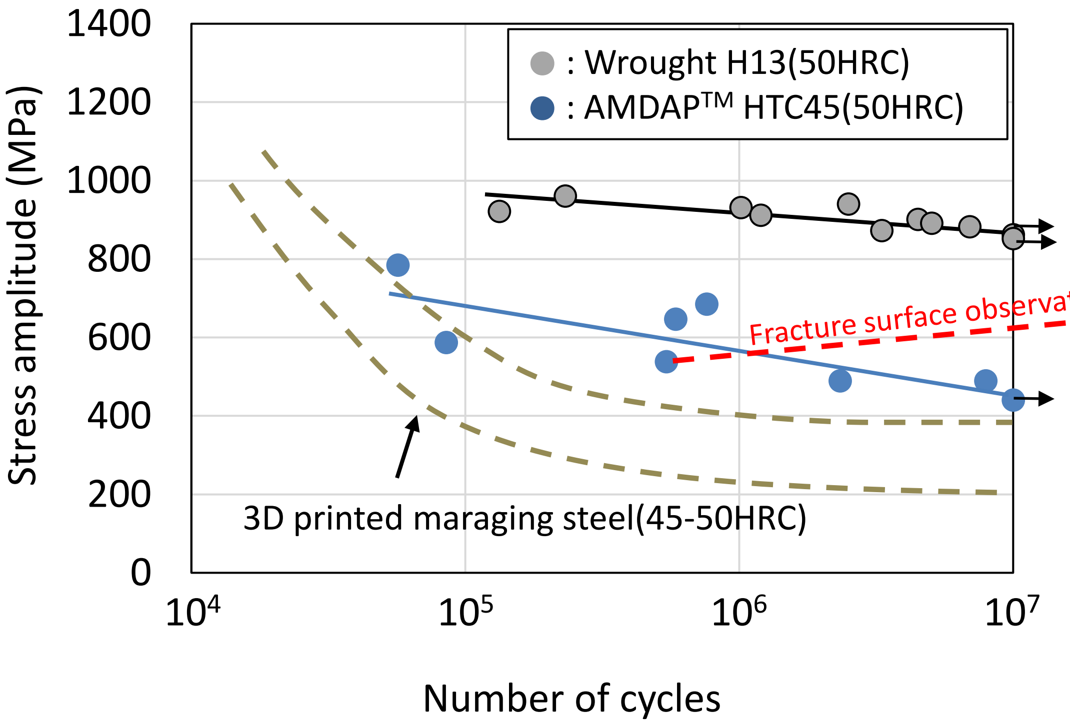
Test temperature: room temp.
Test specimen: JIS No.14 A

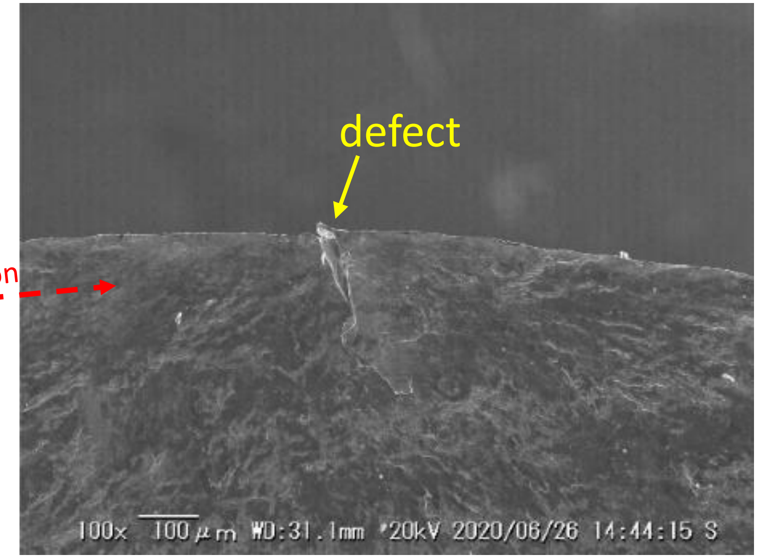
Test Temperature: room Temp.
Test specimen: JIS No.3 (2mm-U notch)

Fatigue strength

- Fatigue strength of 3D-printed specimen is lower than that of wrought specimen, because of defects occured during 3D-printing.

- To increase the fatigue strength of AMDAP™ HTC45, optimizing printing parameters is effective.





Initial point of crack propagated due to fatigue stress
(Stress amplitude:539MPa, Fatigue life:5.42x10^5 cycle)

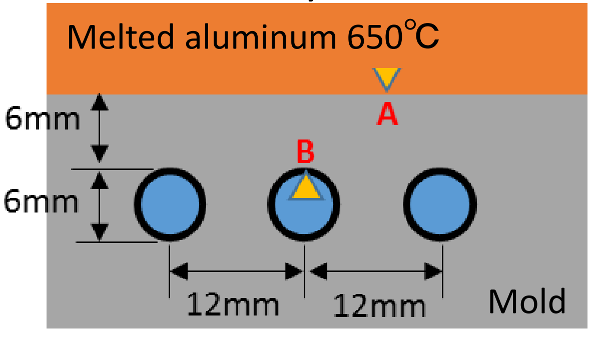
Expected improvement of molds by increasing thermal conductivity

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

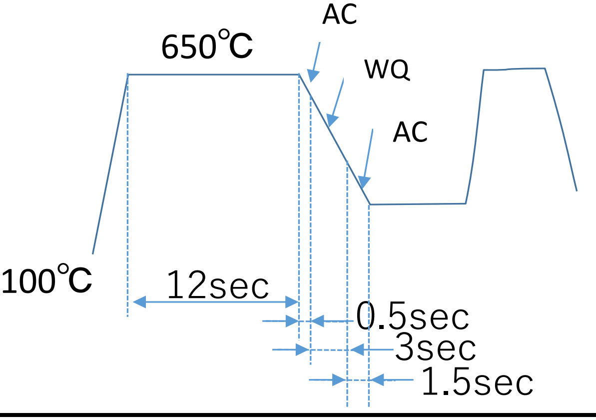
- Higher thermal conductivity contributes to prevention of cracks from cooling lines by reducing any stresses on the surface of it.
  →mold life can be expected to be prolonged.

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

FEM analysis model



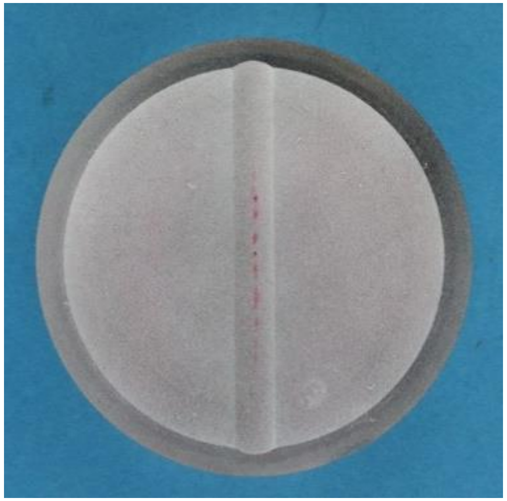
Thermal history used for FEM

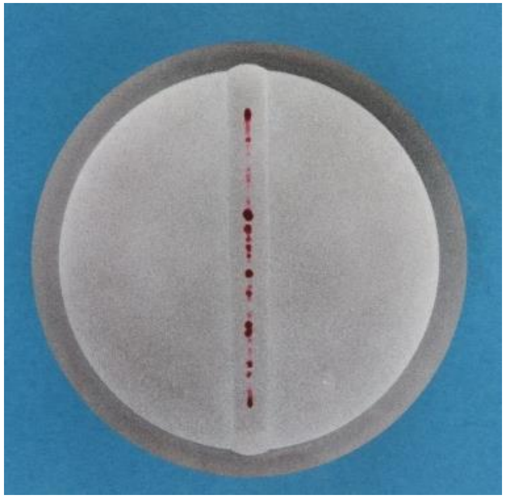


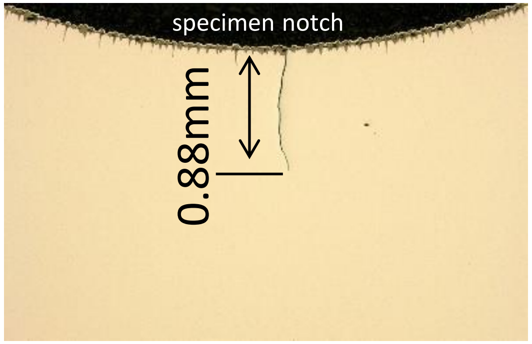
Comparison of heat cracking

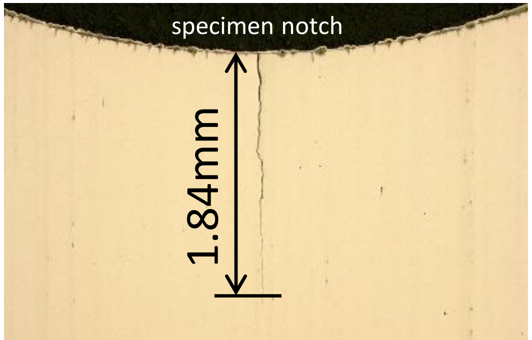
Having high thermal conductivity, AMDAP™ HTC shows less heat cracking than wrought H13.

AMDAP™ HTC45(48.9HRC) Wrought H13(47.6HRC)

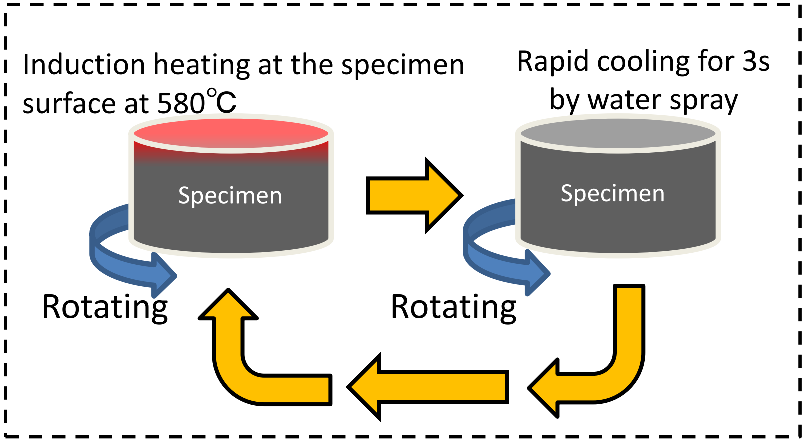








specimen notch : R=6mm, depth=1mm



4000 cycles

Recommended 3D-printing process parameters of AMDAP™ HTC

The process parameters shown below are for GE Additive's Concept Laser M2 machine.
When using other 3D printers, please refer to the table for optimizing conditions.

Please feel free to ask our Metal Powder Department about the process parameters.

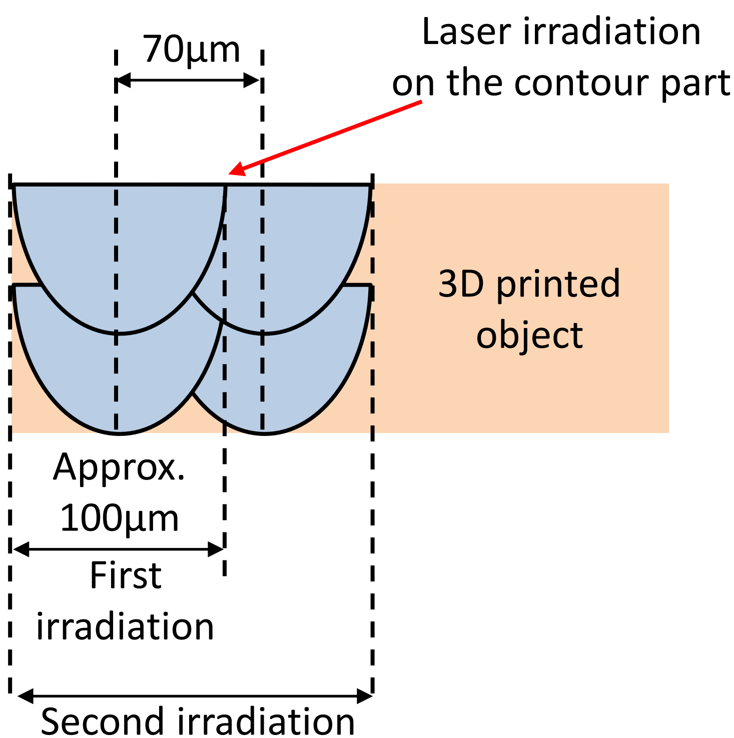
Part		Laser power (W)	Laser spot diameter (μm)	Scanning speed (mm/s)	Hatching distance (mm)	Layer thickness (μm)
Product	Inside	300	180	600	0.13	50
	Contour	150	100	300	—	50
Downskin		380	180	950	0.13	50
Supporting part		150	100	700	—	50

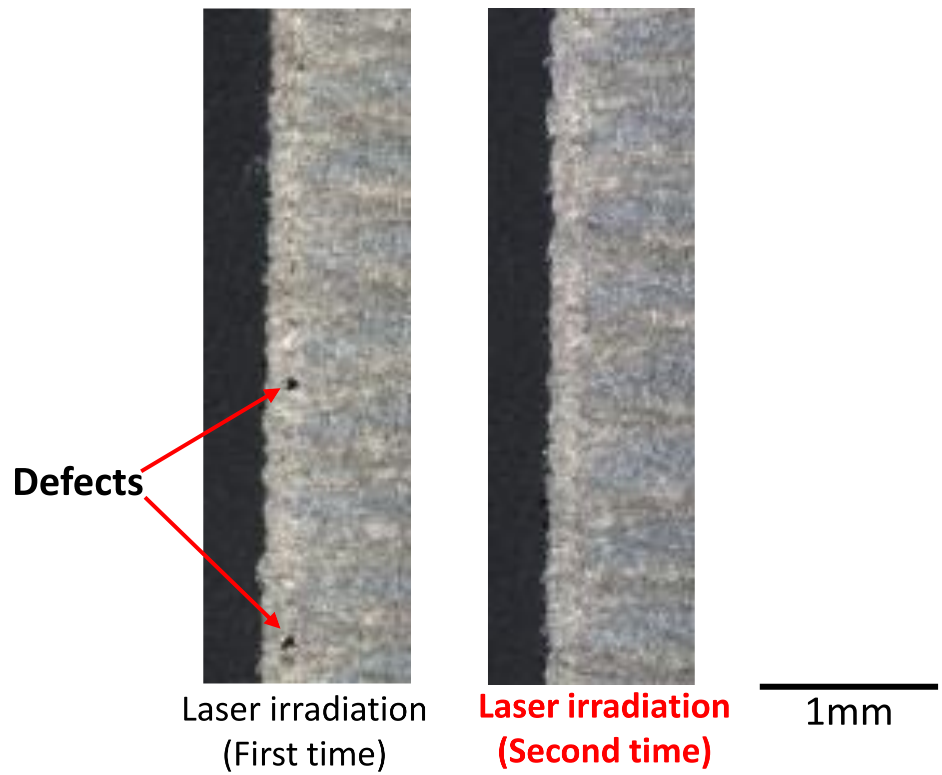
The recommended laser scanning pattern is a checker-board type and the recommended base plate temperature is 200℃.

3D-printing process at a contour part

Two-time irradiating laser on the contour part can reduce defects in the border between contour part and inside part.

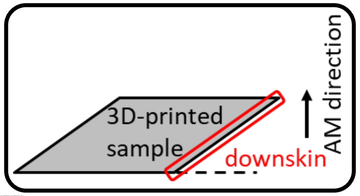
(The second time is shifted 70 µm inward from the first time.)





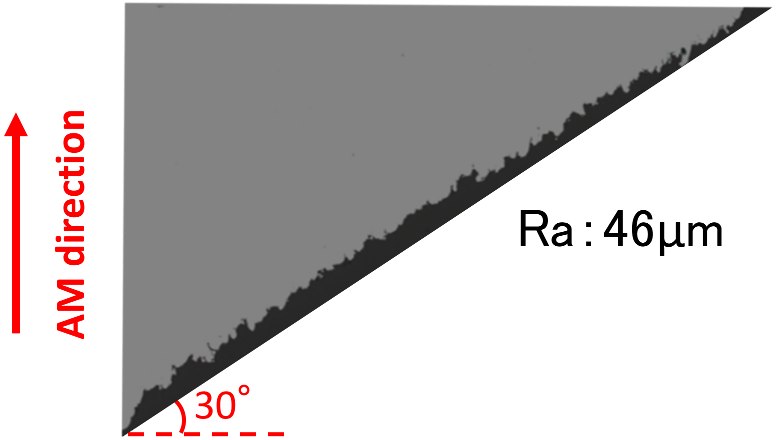
3D-printing process at a downskin part

Since the surface of the downskin part tends to be rough, the surface roughness can be reduced by applying the specific molding parameters shown in Table 1.

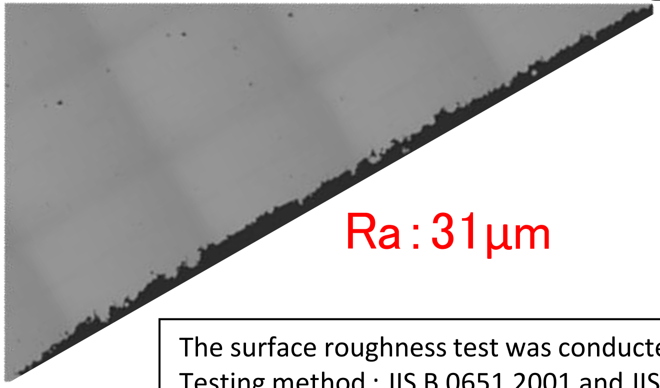


(Note : Downskin contour area should be irradiated by a single laser.)

The same 3D-printing conditions as product inside

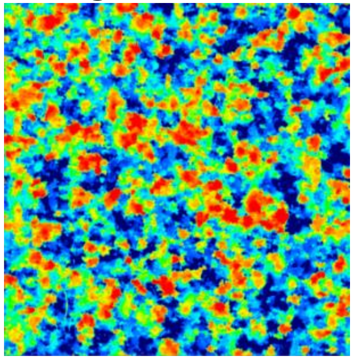


Recommended conditions

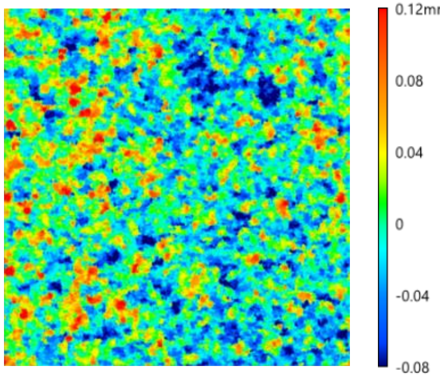


The surface roughness test was conducted by stylus method.
Testing method : JIS B 0651 2001 and JIS B 0601 2001 Standard
Touch needle : DM47501(conical shaped diamond, 2µmR, 60°)

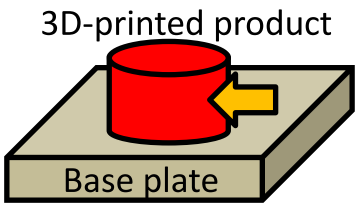
The same 3D-printing conditions as product inside



Recommended conditions



Mold manufacturing process of AMDAP™ HTC



Smoothing the surface perpendicular to the base plate

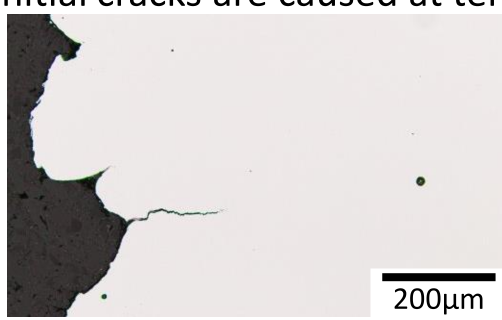
In order to prevent cracking during tempering, the surface of 3D-printed product should be smoothed by shot blasting.

Tempering should be carried out to adjust the hardness and to relieve internal stress.

quench-hardened → **3D Printing** → **Shot basting** → **Tempering (at550℃ or higher is recomenned)** → **Removing From base plate** → **Machining**

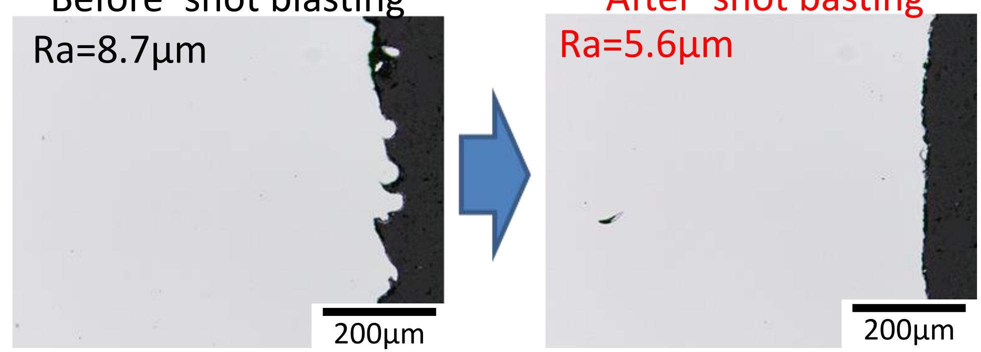
- 3D Printing (quench-hardened)
- Shot basting
- Tempering (at550℃ or higher is recomenned) — Adjust hardness and relieve stress
- Removing From base plate — Low distortion
- Machining

Without shot blasting,
Initial cracks are caused at tempering.



Before shot blasting

After shot basting

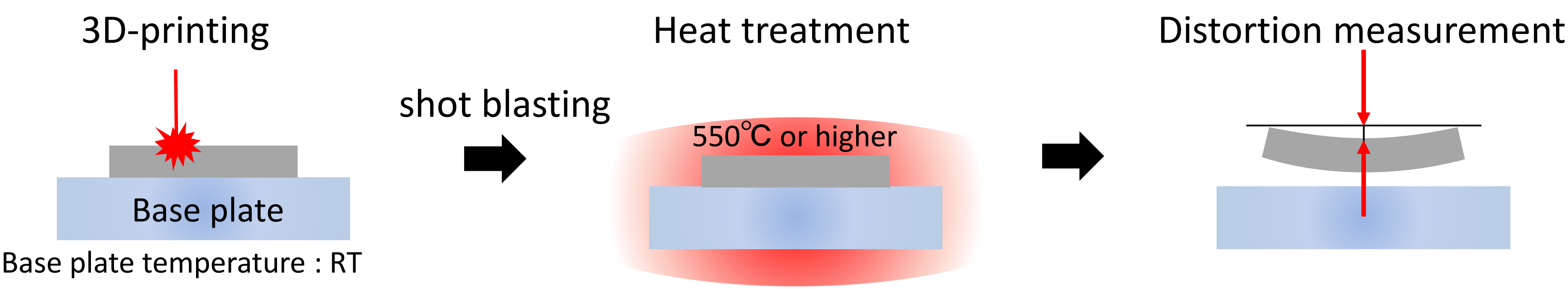


Heat treatment for stress relief

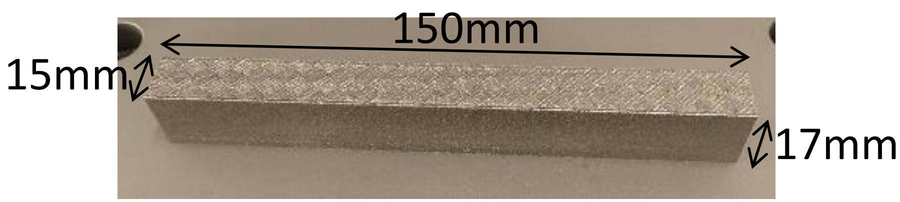
Strain occurs due to thermal effects in multilayer modeling.

For this reason, Heat treatment is recommended at 550℃ or higher after modeling to remove the strain generated during 3D-printing.

This heat treatment can be performed in combination with tempering.



AMDAP™ HTC40 specimen for distortion measurment



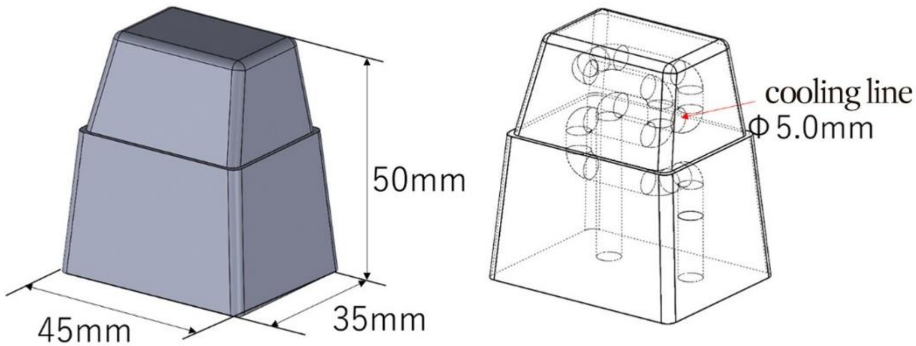
Heat Treatment pattarns and amount of distortion

Heat Treatment	Distortion
As 3D printed	0.24mm
450℃ × 1h	0.22mm
500℃ × 1h	0.22mm
550℃ × 1h	**0.12mm**
600℃ × 1h	**0.15mm**

Examples of 3D-printed samples of AMDAP™ HTC45 (after shot blasting)

Small example

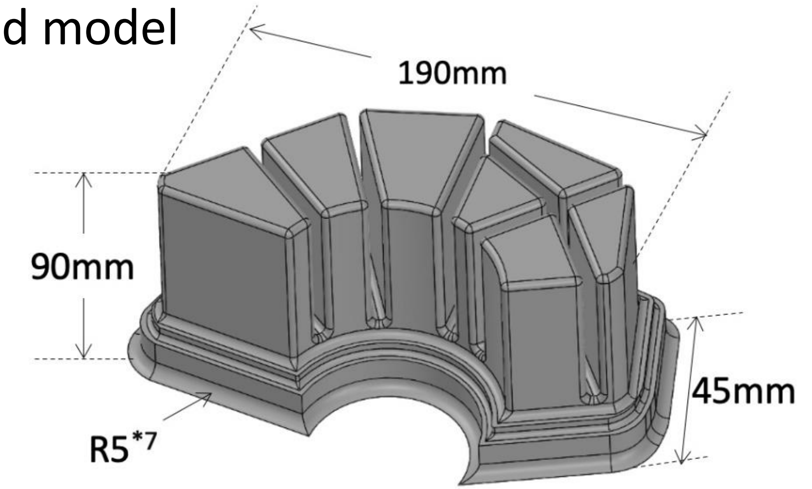
Cad model



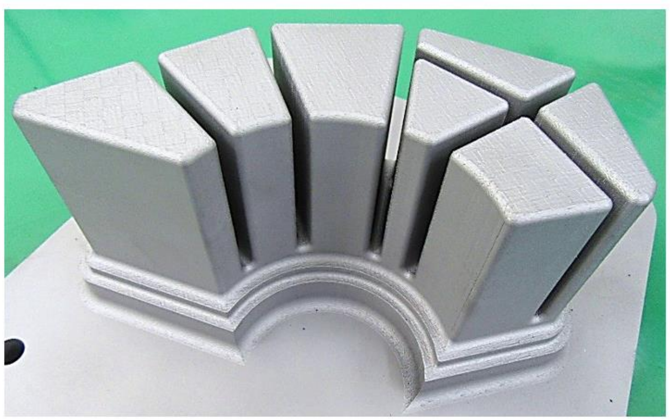
Apparance

Large example

Cad model



Apparance



Summary of AMDAP™ HTC45 and AMDAP™ HTC40

- Compared to wrought H13, the hardness in the as-molded state is reduced, making cracks less likely to occur during molding.
- Thermal conductivity is twice as high as that of maraging steel, enabling efficient cooling of molds. Also, cracking at the water-cooled holes and heat checking can be suppressd.
- Mechanical properties are equal or better than wrought H13, except fatigue strength.
- Fatigue strength is lower than that of wrought steel due to defects that occur during forming.
- Distortion generated during 3D-printing can be reduced by heating at 550℃ or higher.
- Cracking may occur in secondary hardening after tempering due to roughness of the surface. Cracking can be suppressed by flattening the surface by shot blasting after 3D-printing.