H13 Modified High Thermal Conductivity Powder for 3D Printing

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DAIDO STEEL

INTERNATIONAL MOLD STEEL, INC.

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Material Development in Daido

Advanced die casting die steels

High hardenability and toughness steel
NADCA Grade F & NADCA Grade C
(Presented in NADCA 2013)

NADCA Grade F

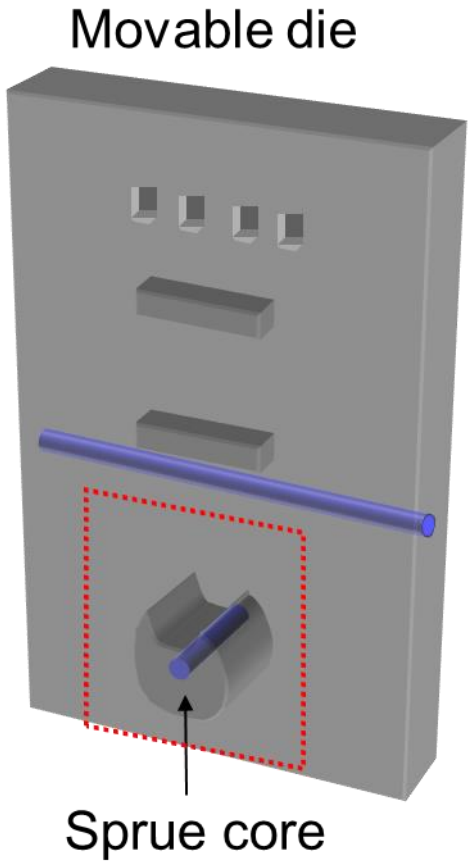
NADCA Grade C

Alloy powders and AM techniques

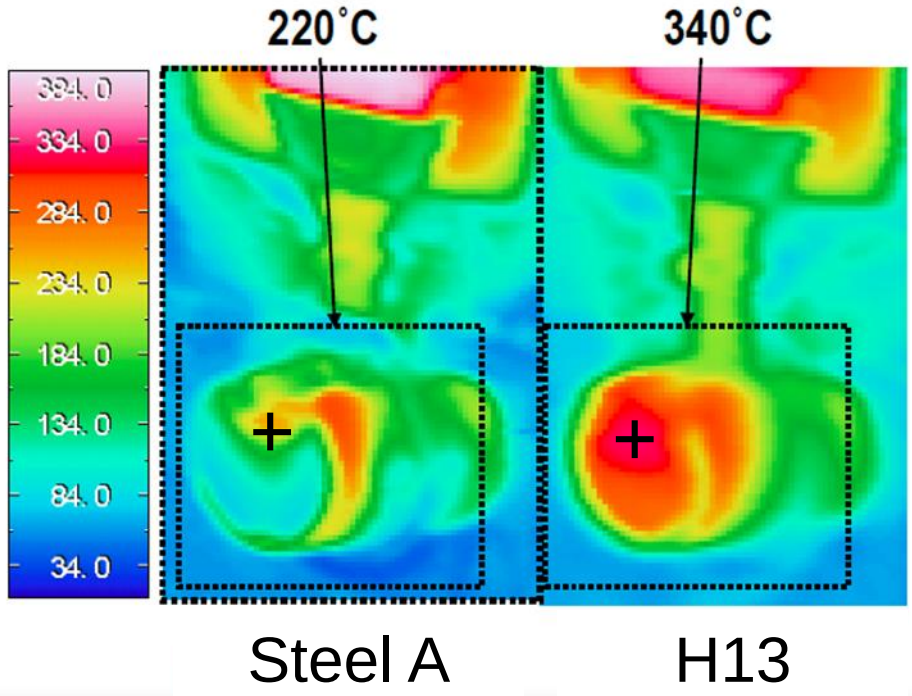
DAP™(Daido Alloy Powder)

Introduction

Die steel with high thermal conductivity contributes to faster cooling in die casting dies.



Surface temperature of sprue core



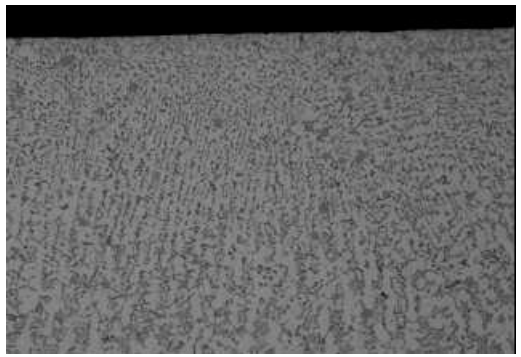
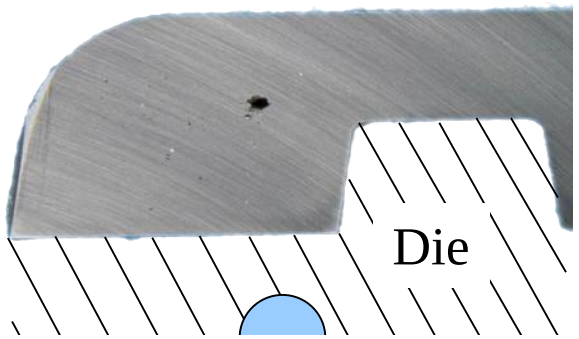
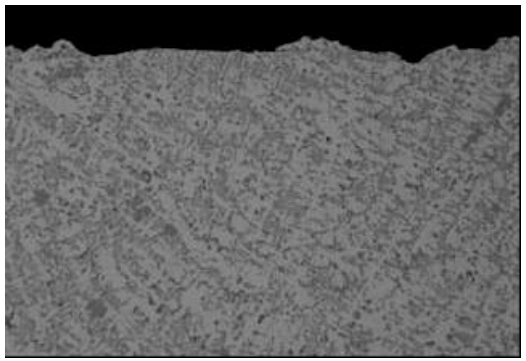
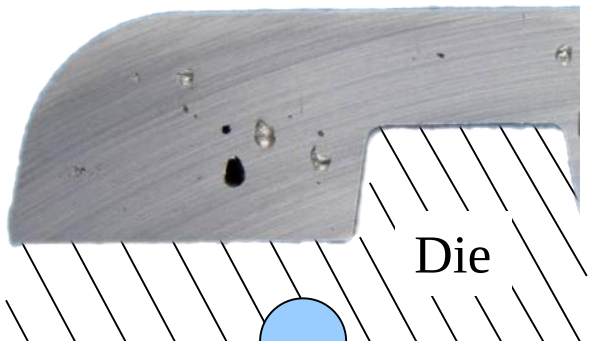
Lower die temperature

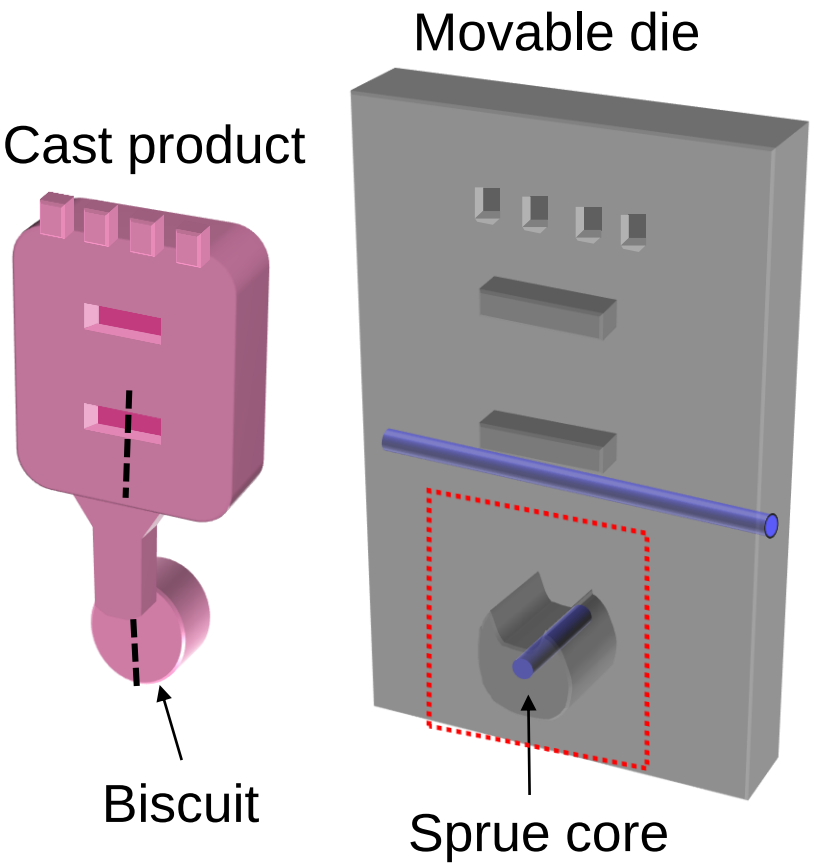
✓Shorter cycle time
✓Less thermal damage

Steel A;1.6 times higher thermal conductivity than H13.

Introduction

Die steel with high thermal conductivity contributes also to improve a product quality.

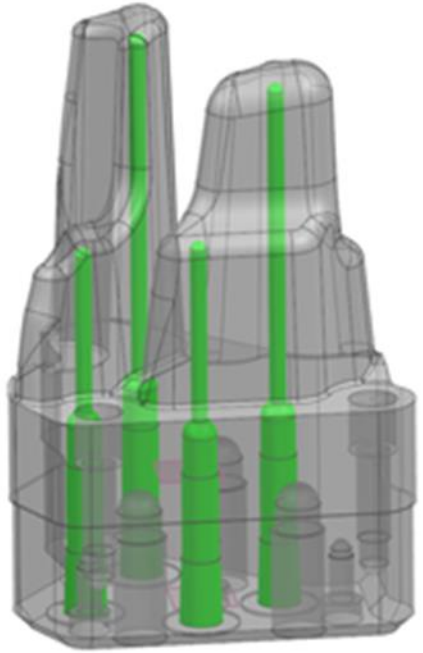
	Cross sectional microstructure of the biscuit surface	Cross section of the cast products
Steel A 35~37 W/(m·K)		
H13 24~27 W/(m·K)		
After 5,000 shots	100μm	10mm



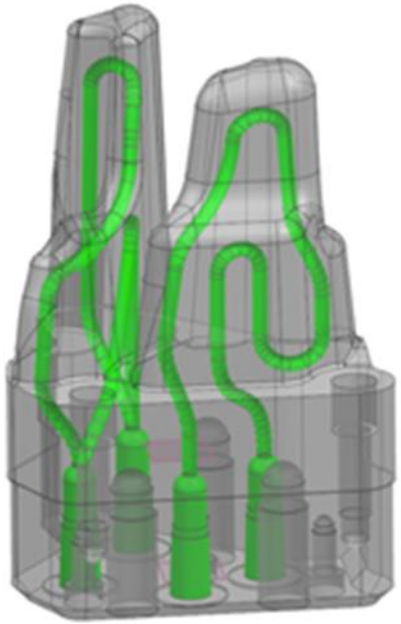
Additive Manufacturing of Dies

Conformal cooling channels made by additive mfg. is now available to enhance the internal cooling.

Linear cooling channel

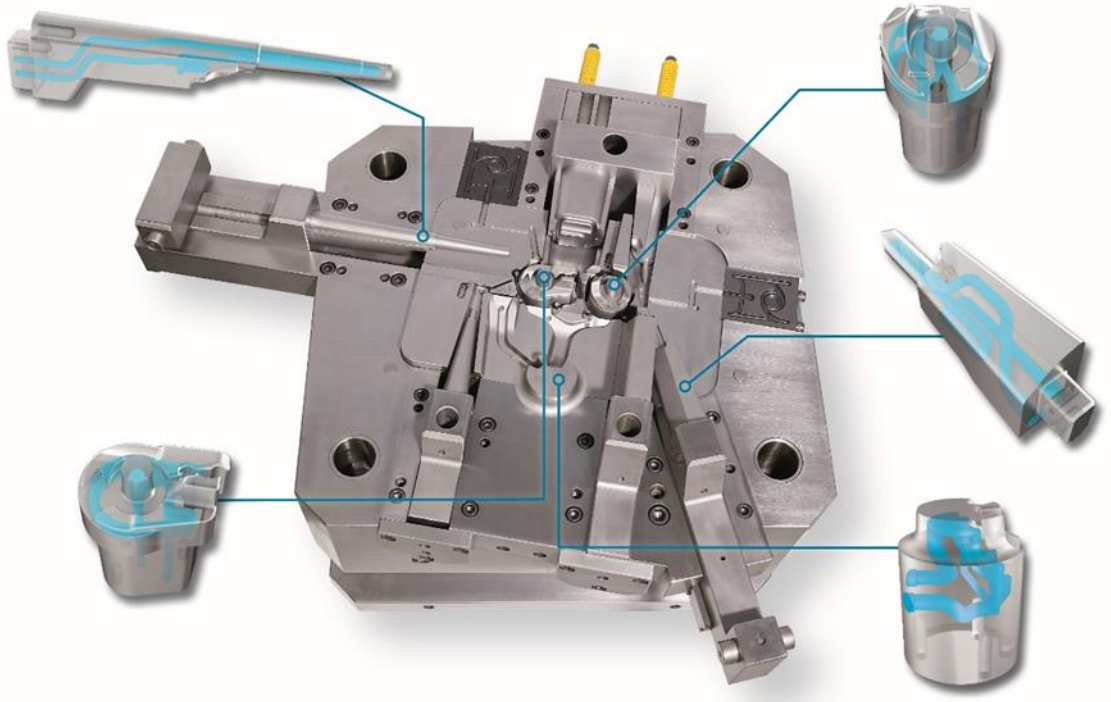


Conformal cooling channel



https://www.additivemanufacturing.media/articles/in-automotive-is-additive-manufacturing-an-answer-for-die-cast-tooling

The inserts of die casting dies made by the SLM

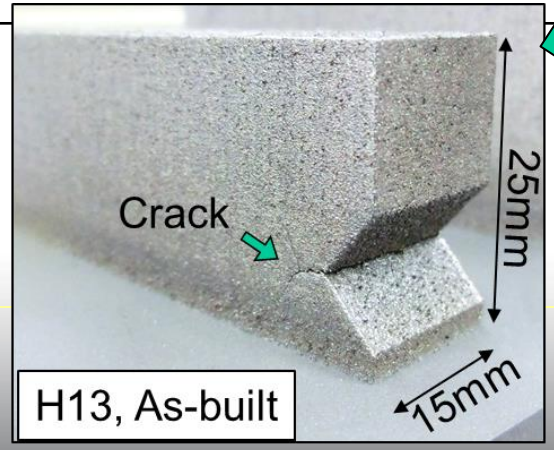


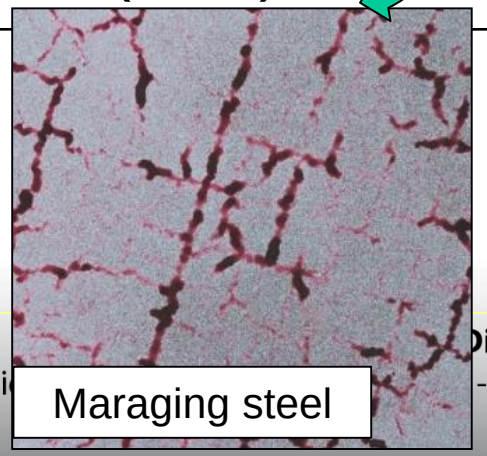
https://www.metalworkingworldmagazine.com/additive-manufacturing-technologies-extend-service-range-of-die-casting-foundries/

Conventional Powder for AM

H13 and 18%Ni Maraging steel powders are mainly used,
but each has its own problems.

Steel grade	Cracking during build	Thermal Conductivity	Mechanical Properties
18%Ni maraging steel	Great No cracking	Low 17 W/(m·K)	Good
H13 / H11	Bad Easy to crack	High 24 W/(m·K)	Good

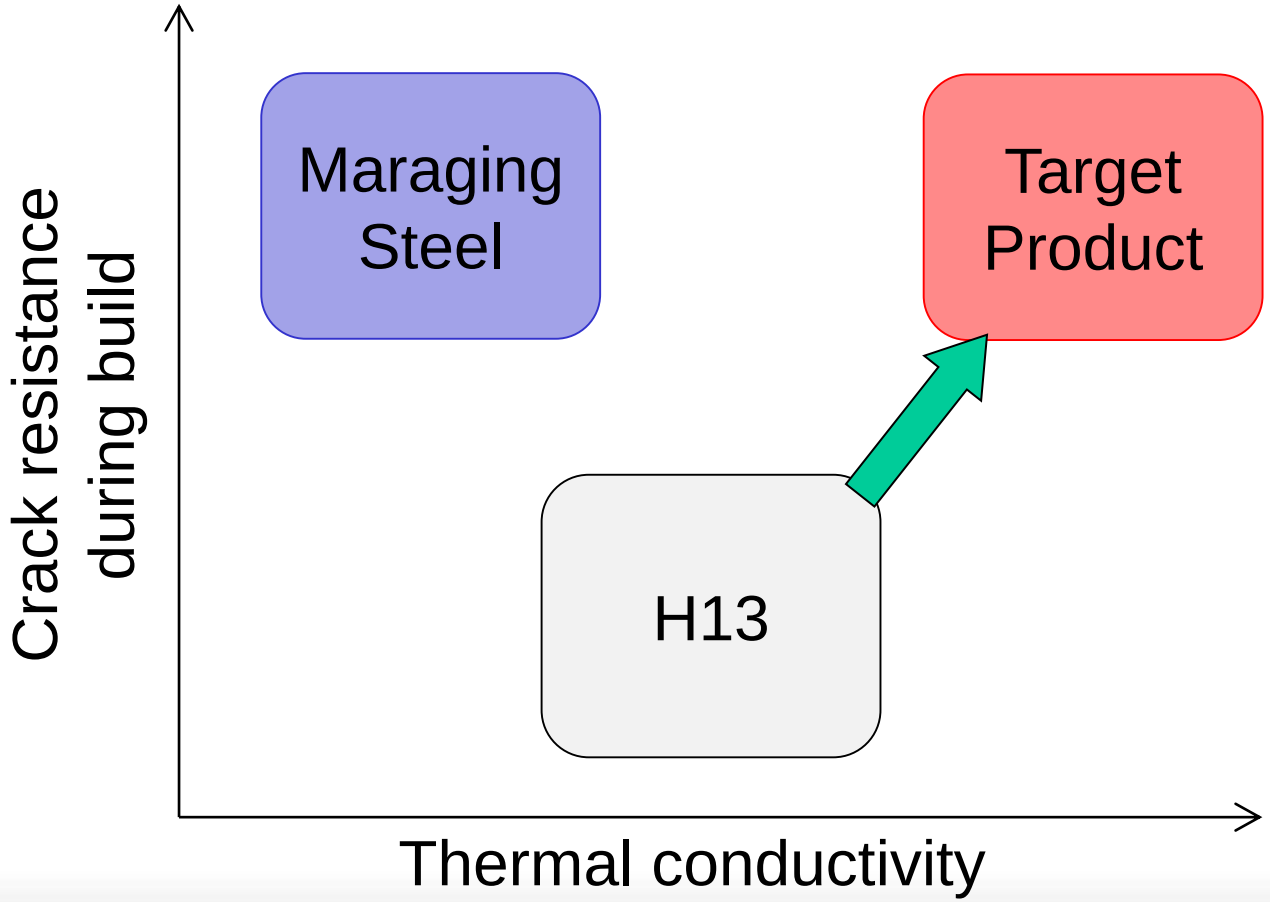




Heat checking

Concept of Powder Development

High crack resistance during build and high thermal conductivity.



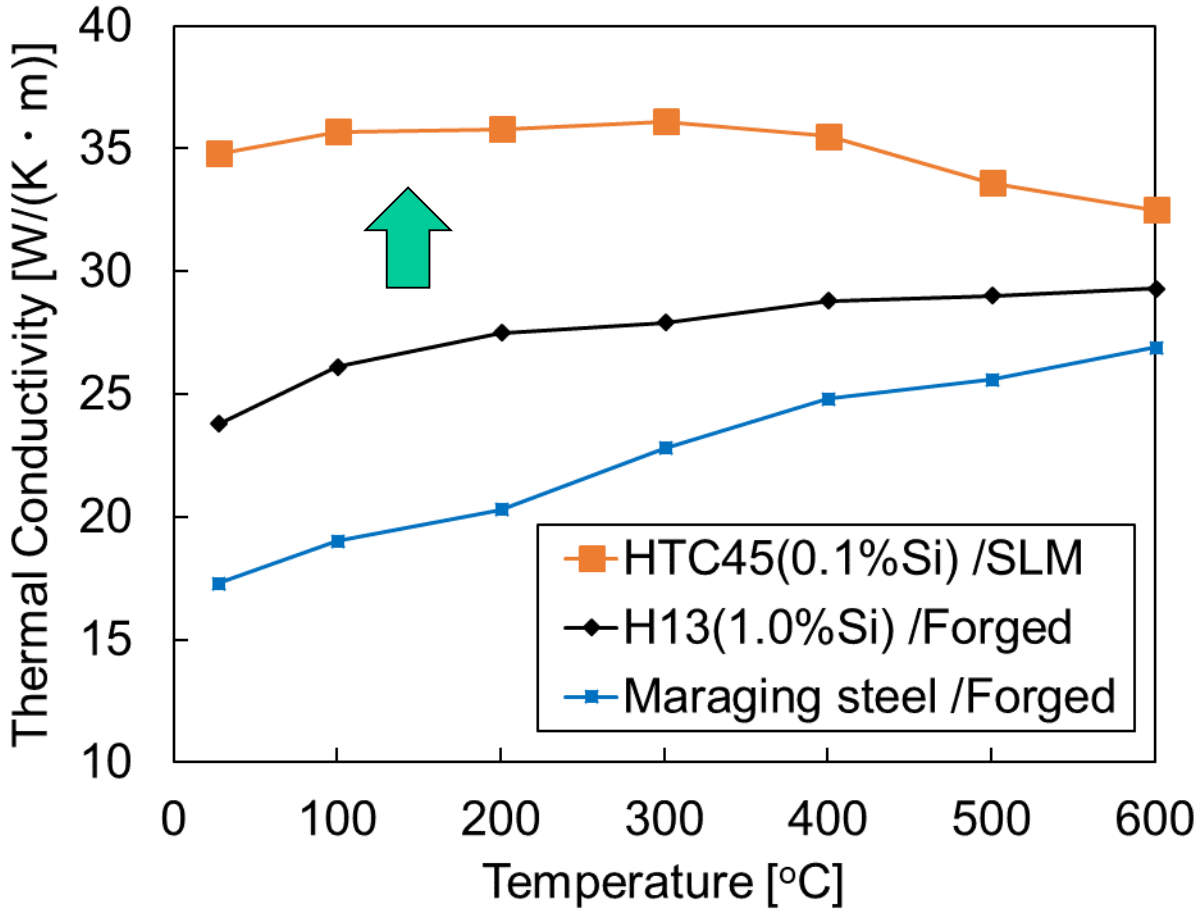
New Powder Material DAP™-AM HTC

Daido Alloy Powder – for Additive Manufacturing High Thermal Conductivity

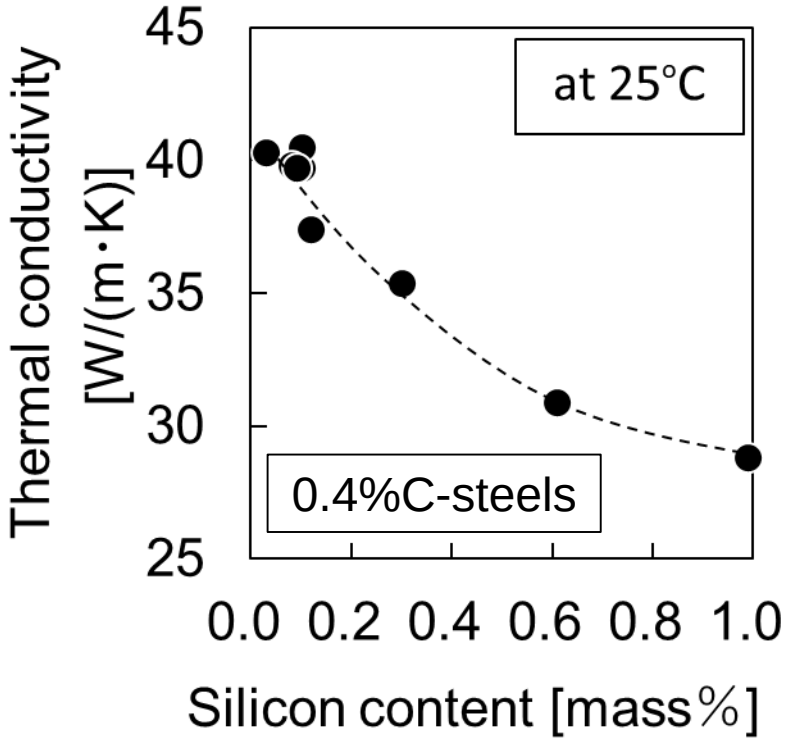
Steel grade	Cracking during build	Thermal Conductivity	Mechanical Properties
18%Ni Maraging steel	Great No cracking	Low 17 W/(m·K)	Good
H13 / H11	Bad Easy to crack	High 24 W/(m·K)	Good
"DAP™-AM HTC"	Good Hard to crack	Great 35 W/(m·K)	Good

Thermal Conductivity

The built specimens with HTC powder has high thermal conductivity.
Because HTC is lower Silicon content than H13.



Effects of Si content on thermal conductivity of die steel



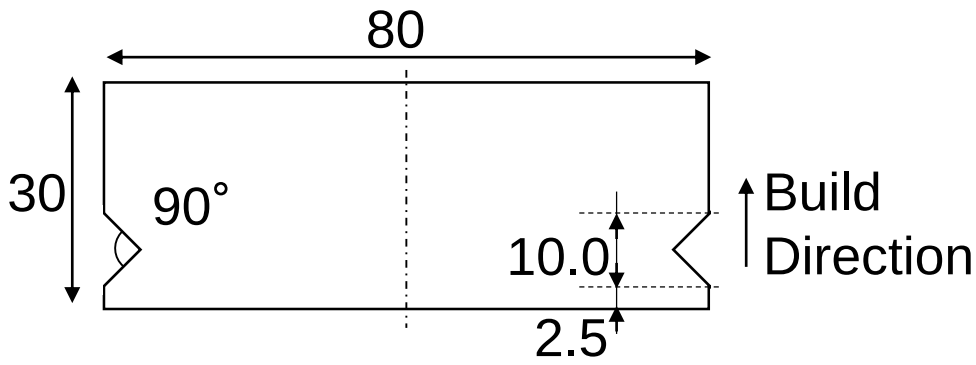
Formability / Cracking during Build

Cracking was suppressed due to the reduction of hardness during build.

0.23%C
HTC45 / 48 HRC

0.37%C
H13 / 54 HRC

Notched Specimen



Built with preheating at 200 °C

Alloy Design of Modified Powder

Our new powder grades HTC40 and HTC45 are alloy-designed based of H13.

Composition (mass%)

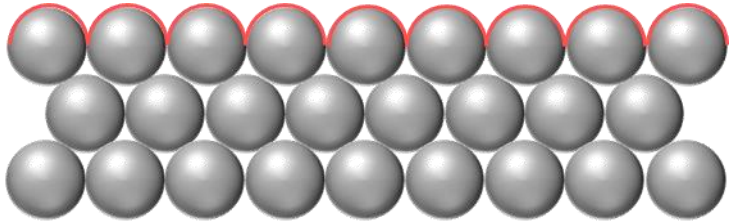
	C	Si	Mn	Ni	Cr	Mo	V	Co	Hardness HRC	Applications
HTC45	**0.23**	**0.1**	0.4	-	5.3	1.2	0.4	-	45-50	Thin tools e.g. Core pins
HTC40	**0.13**	**0.1**	0.4	-	5.3	1.2	0.4	-	40-45	Thicker tools e.g. Insert
H13	0.40	1.0	0.4	-	5.3	1.2	1.0	-	45-53	
18%Ni Maraging steel	-	-	-	18.5	-	4.8	-	9.0	35-55	

Flow & Density

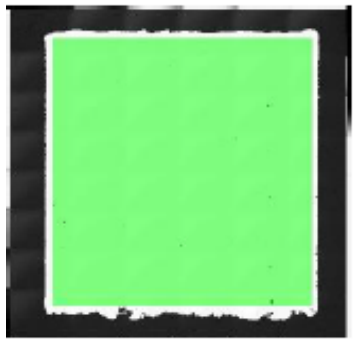
HTC powders have good flow, which makes it possible to form dense parts.

Selective Laser Melting(SLM) process requires powder flow-rate to achieve high density.

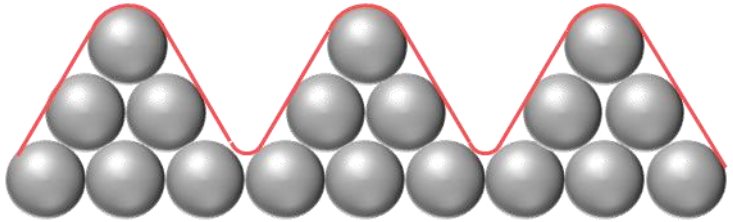
Good flow



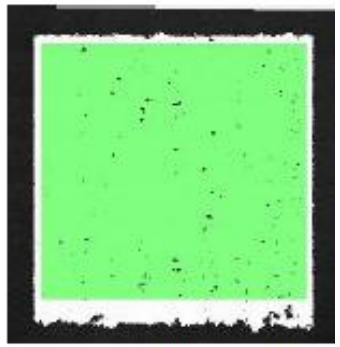
Smooth powder bed



Poor flow



Rough powder bed



Concept Laser M2

Building Condition

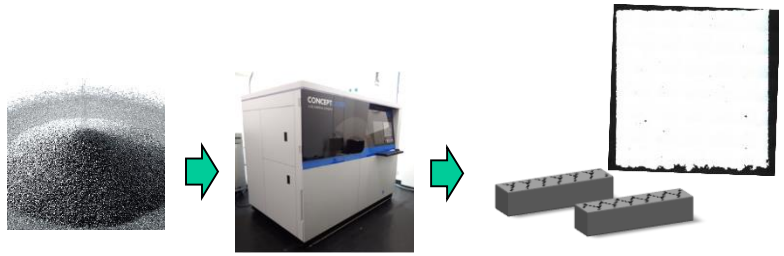
Laser Power	300 W
Scan Speed	600 mm/s
Hatching Distance	0.13 mm
Laser Spot Diameter	180 μm
Layer Thickness	50 μm
Preheating Temperature	200 °C

Relative Density 99.96 %

Mechanical properties evaluation

Built specimens with HTC powder

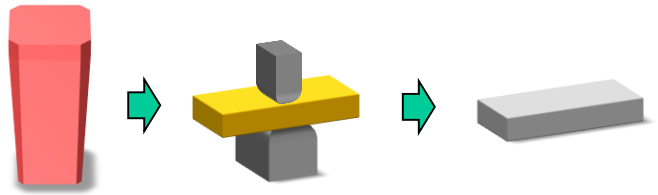
HTC / SLM



Atomized Built Heat treated

Conventionally cast and forged H13

H13 / Forged

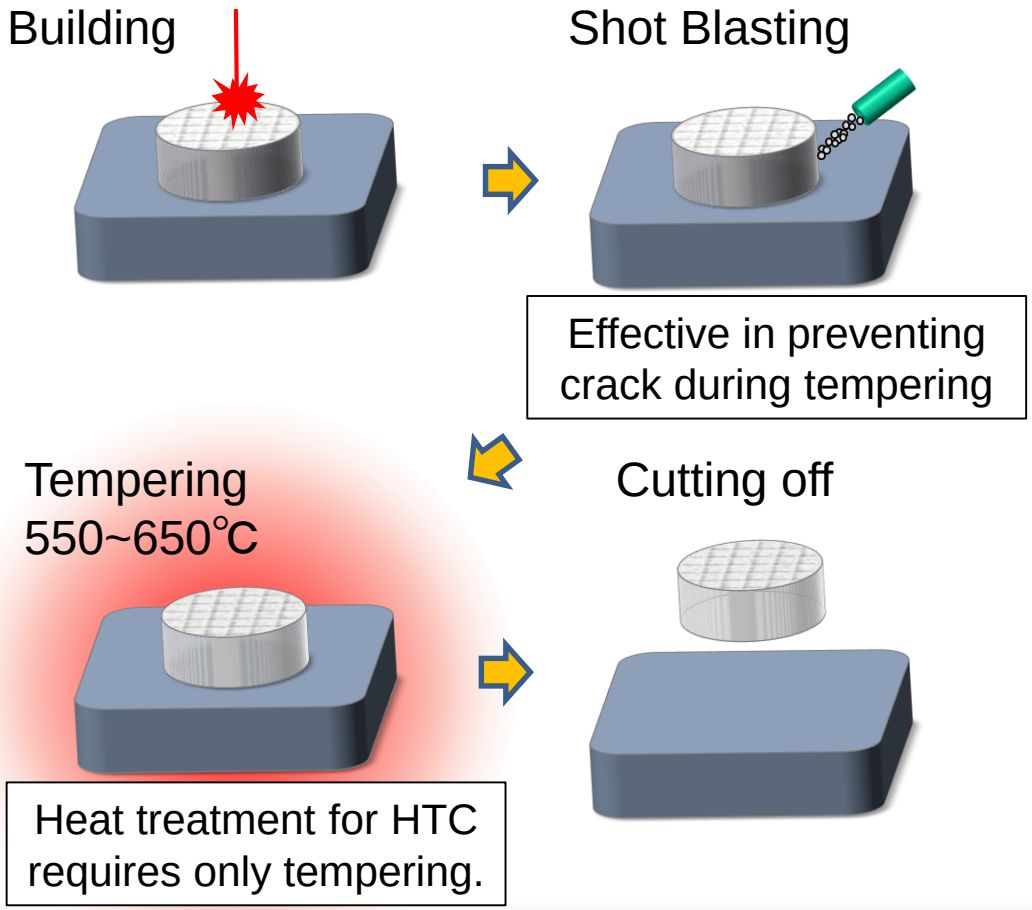


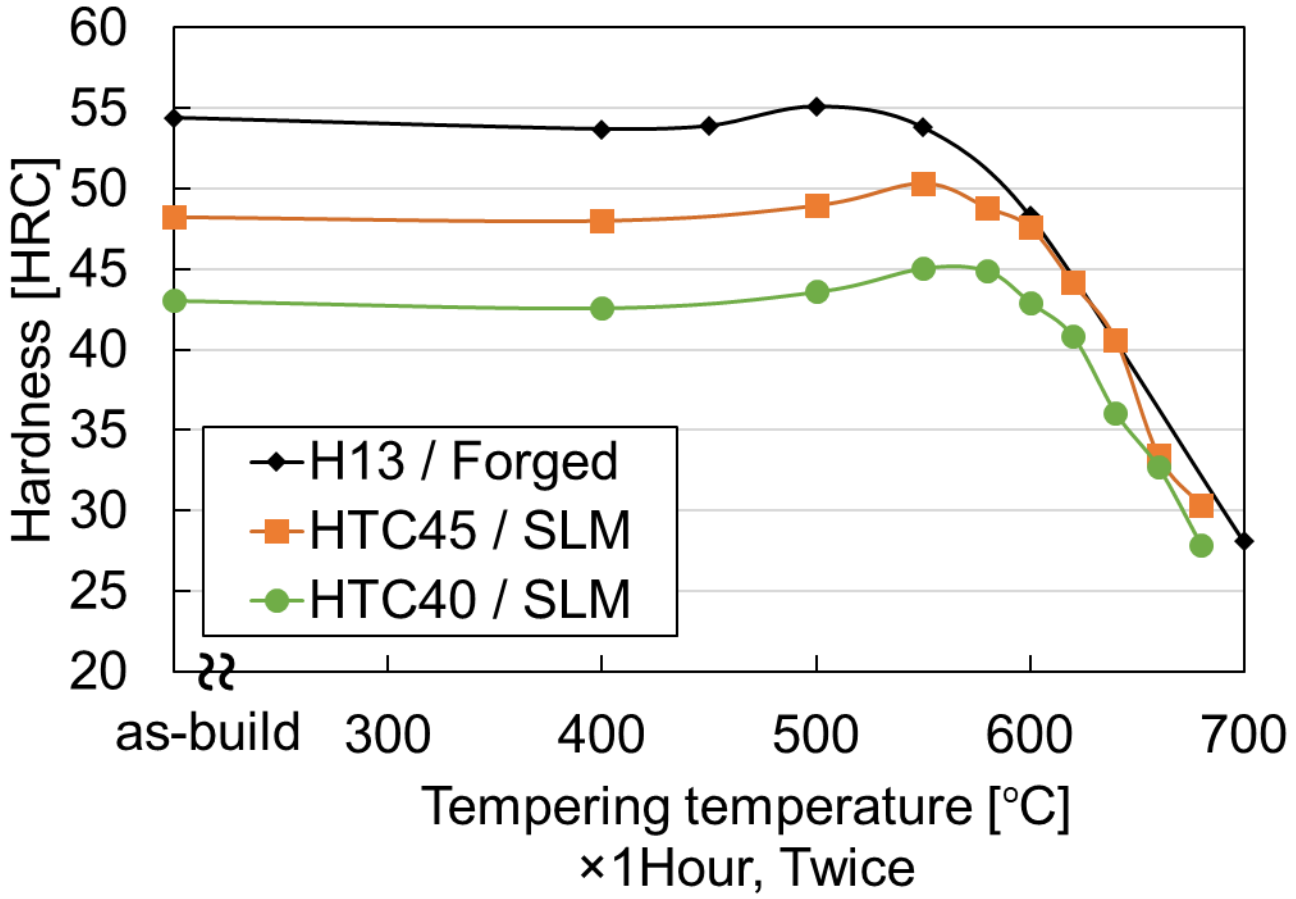
Cast Forged Heat treated

- ◇ **Heat treatment / Hardness**
- ◇ **Nitriding hardness**
- ◇ **Impact Toughness**
- ◇ **Tensile Strength, Elongation**

Heat treatment / Hardness

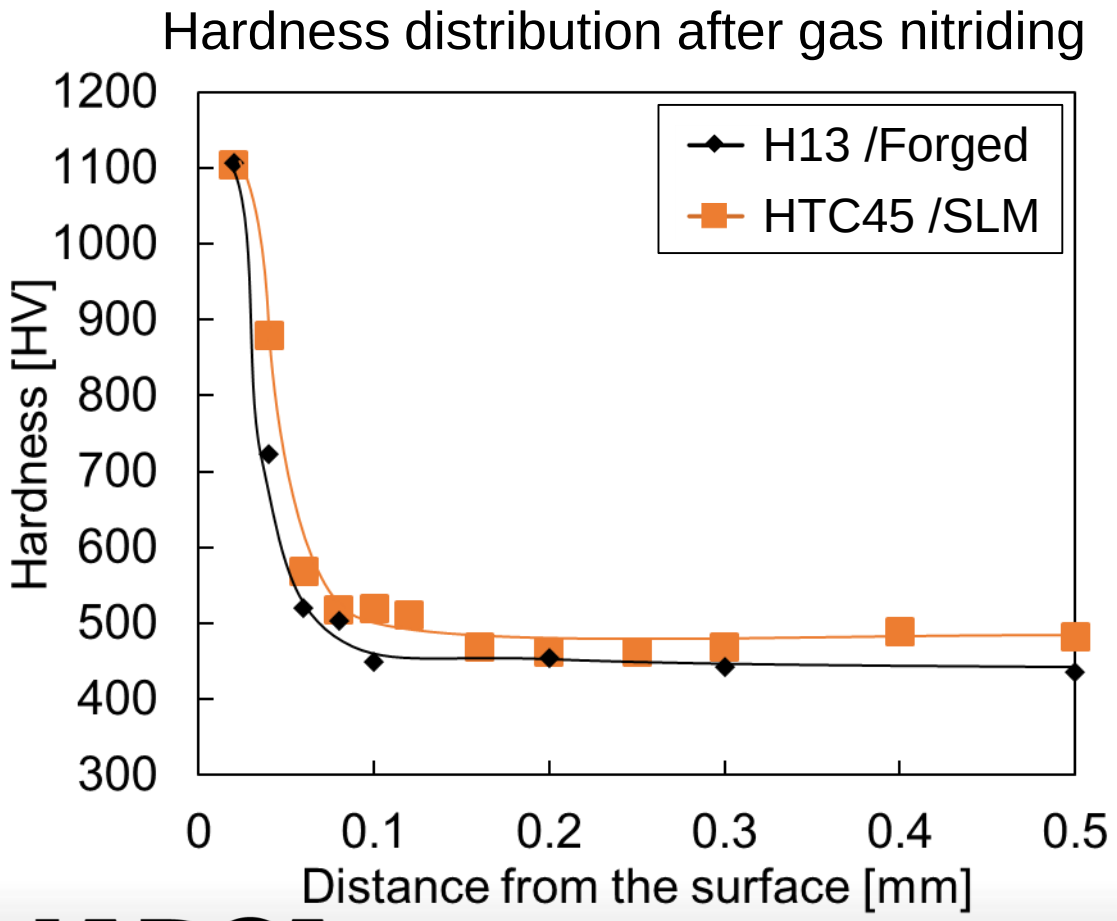
The hardness of HTC can be adjusted by tempering as same as the forged H13.





Nitriding hardness

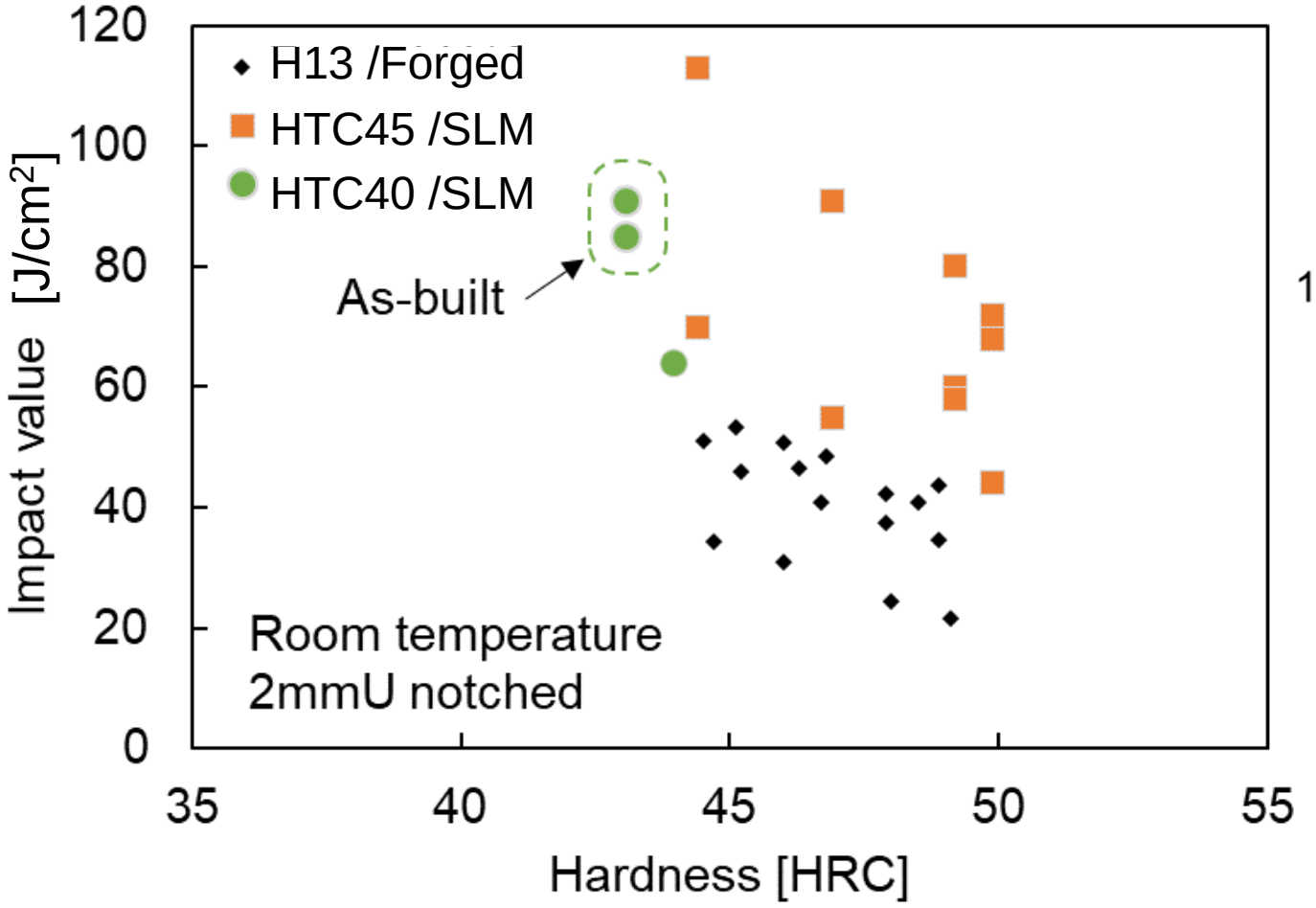
The nitriding hardness of the HTC is same as one of the forged H13.

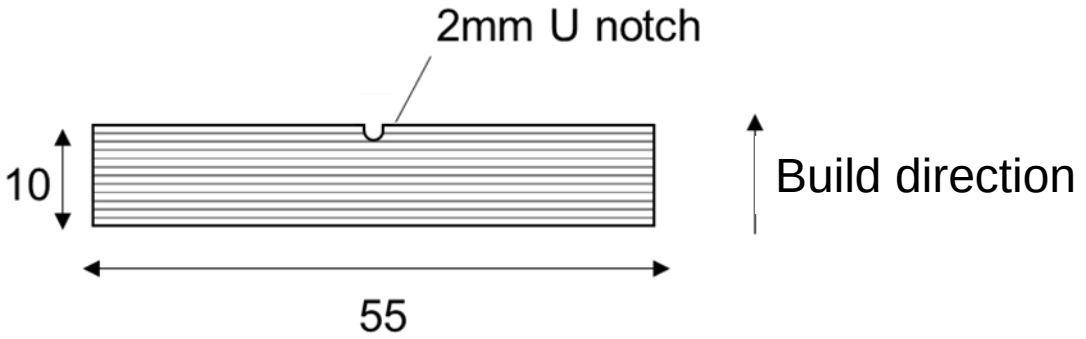


	HTC45 SLM	H13 Forged
Maximum Hardness /HV	1103	1106
Initial Hardness /HV	450	440

Impact Toughness

The impact toughness of the HTC is higher than that of the forged H13.

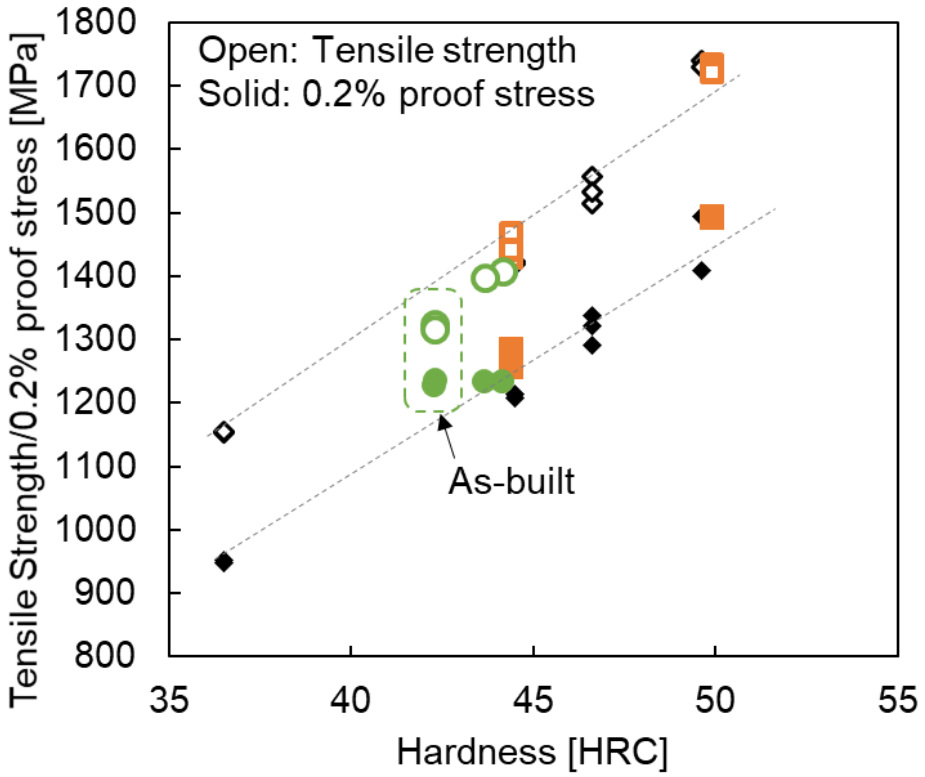


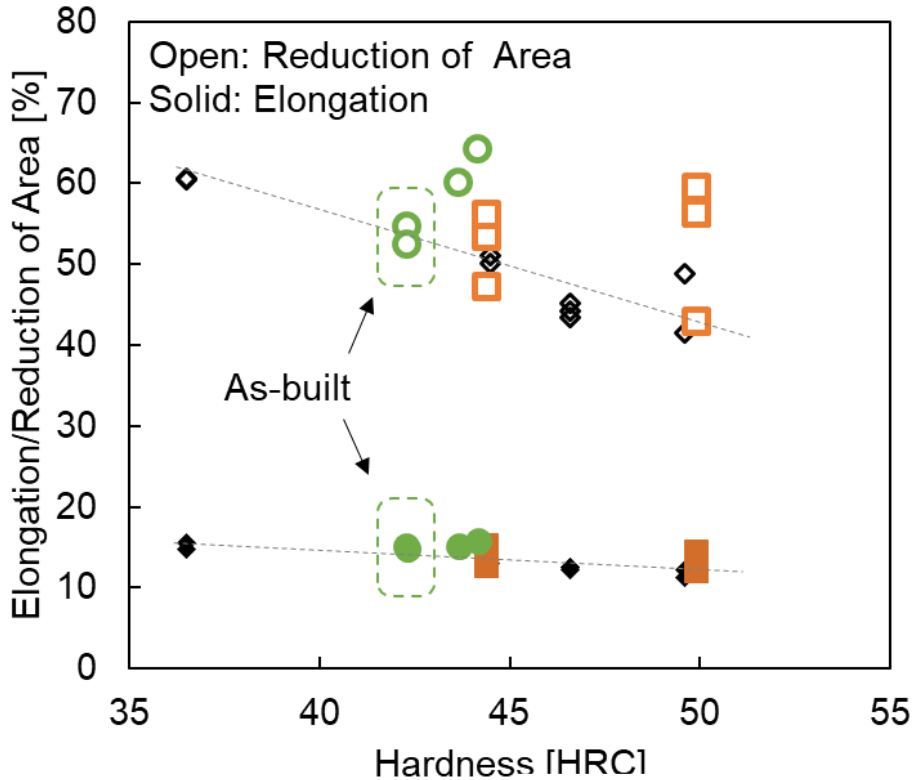


Size of built samples : 15 × 60 × 15 mm
Heat treatment Condition
HTC45 : Tempered to 45~50HRC
HTC40 : As-built(43HRC)
Tempered to 44HRC

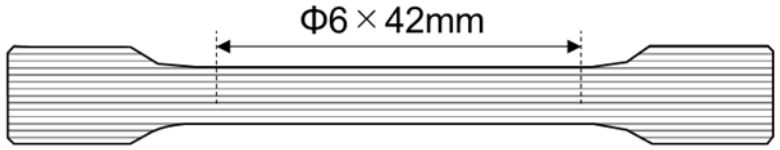
Tensile Strength, Elongation

The tensile strength and ductility of the HTC is comparable to forged H13.





- H13 /Forged
- HTC45 /SLM
- HTC40 /SLM



Build direction

Size of built samples：15 × 100 × 15 mm

Heat treatment Condition

HTC45 ：Tempered to 45~50HRC

HTC40 ：As-built(43HRC)

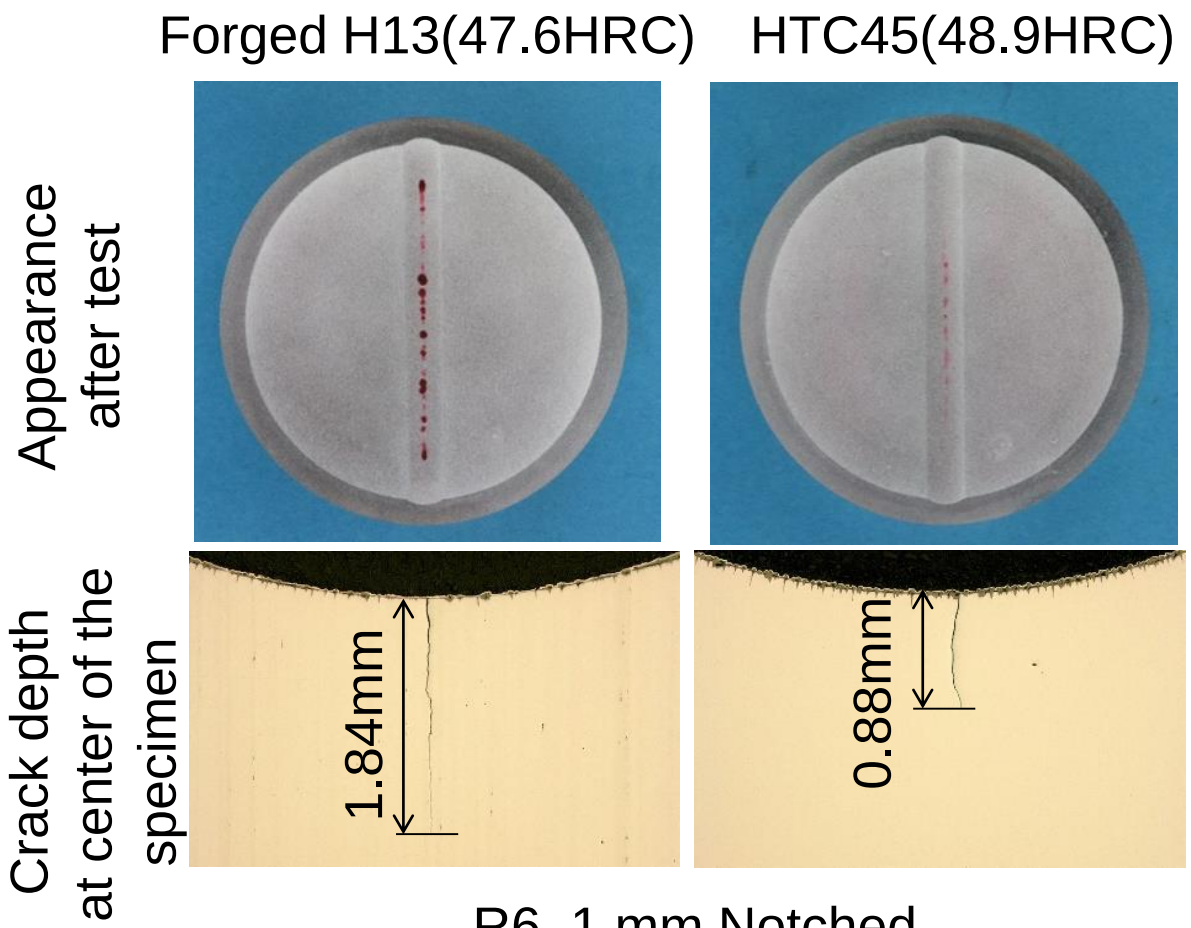
Tempered to 44HRC

Practical evaluation

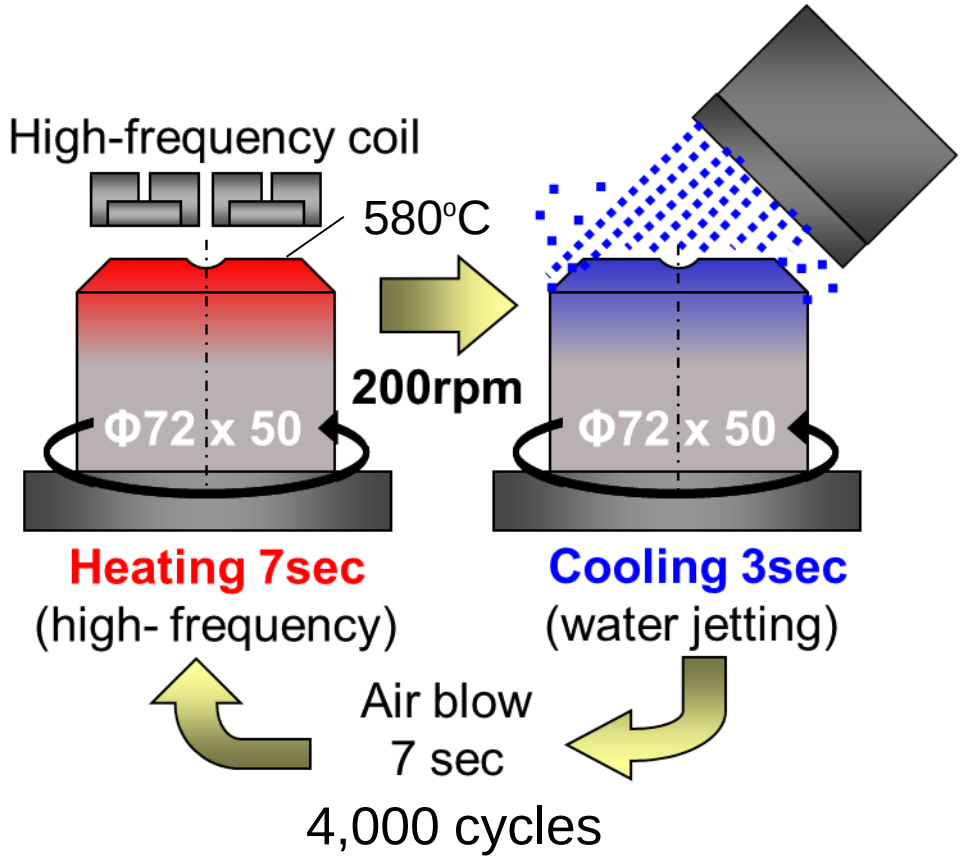
- ◇ Heat checking resistance
- ◇ Building mock-up dies

Heat checking Resistance

HTC45 has better heat checking resistance than forged H13.



R6, 1 mm Notched



Heat checking test procedures

How thermal conductivity affects heat checking resistance

Thermal stress applied on surface

$\sigma = C \times E \times \alpha \times \Delta T$

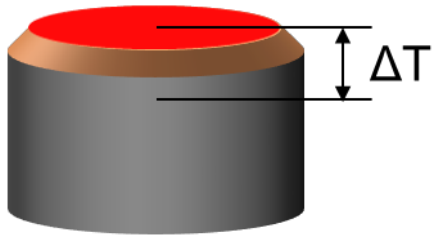
C=f(v) v: Poisson's ratio
E: Young's modulus
α: Thermal expansion coefficient

Almost same in forged H13 and SLM built HTC45

ΔT: Temperature difference between the surface and inside

ΔT=f(**λ**)

λ: Thermal conductivity

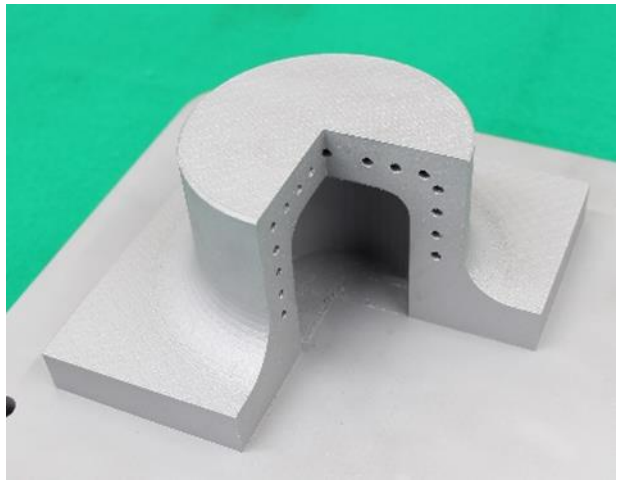


Higher thermal conductivity ⇨ Smaller ΔT
⇨ Smaller σ

N. Umemori, M. Kawano, T. Masuda, "Evaluation of Heat Checking of Molds through Flow and Solidification Simulation", *NADCA DIE CASTING CONGRESS & EXPOSITION,*2018.

Building mock-up dies

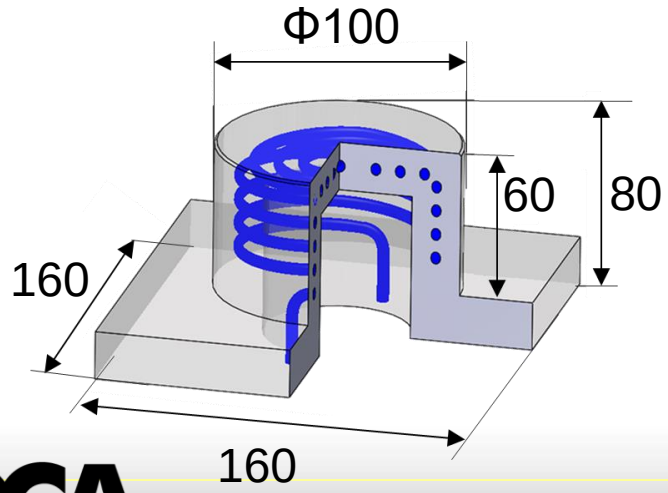
Core Insert Model of HTC40

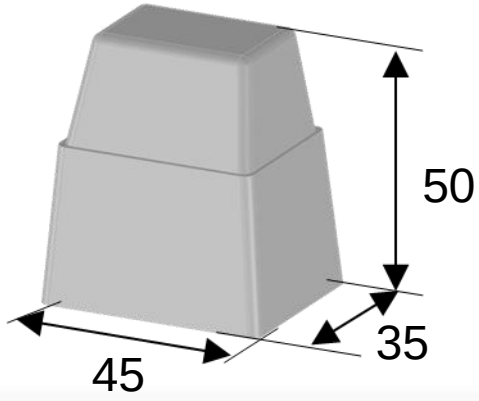


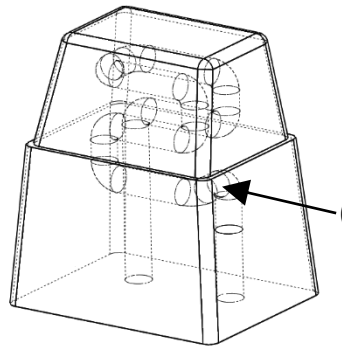
Insert Model of HTC45

3D-CAD

Unit : mm







Cooling Channel
Φ5.0

New Powder Material DAP™-AM HTC

The developed powders are suitable for additive manufacturing and are sufficiently durable as a die-casting dies after build.

Steel grade	Cracking during build	Thermal Conductivity	Mechanical Properties
18%Ni Maraging steel	Great No cracking	Low 17 W/(m·K)	Good
H13 / H11	Bad Easy to crack	High 24 W/(m·K)	Good
"DAP™-AM HTC"	Good Hard to crack	Great 35 W/(m·K)	Good

Thank you for your attention.

Please visit us at booth 817

International Mold Steel

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