Precision Industrial Additive Manufacturing

H13 Material Performance Study

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Overview

Mantle partnered with third-party experts to collect data and characterize Mantle’s printed H13 tool steel. This material performance study compares the performance of Mantle’s H13 tool steel with traditional wrought H13 tool steel during standard toolmaking operations and during injection molding runs. It demonstrates that Mantle's H13 tool steel performs at the same high level as traditional wrought H13 tool steel. Toolmaking operations such as machining, EDM, welding, heat treating, polishing, and coating can be performed on Mantle's H13 tool steel without causing warp or distortion. Furthermore, Mantle's H13 tool steel can be used to successfully mold a wide range of plastics, including heavily filled and abrasive materials, with aggressive molding conditions.

Background

Mantle partnered with tool makers to collect data and characterize Mantle’s printed H13 tool steel. This white paper compares the performance for Mantle’s printed H13 tool steel and standard wrought H13 tool steel for standard machining processes as well as behavior during production molding with a highly abrasive material, high temperature material (30% glass filled PEEK).

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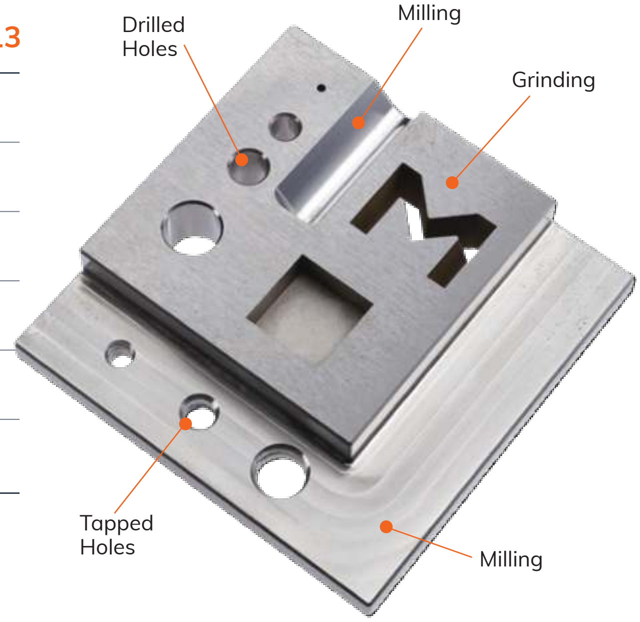
TOOL MODIFICATION PERFORMANCE

Milling, Grinding, and Drilling Operations

Milling, drilling, tapping, and grinding operations are the same with Mantle's H13 tool steel as with traditional wrought H13 steel.

The following results were observed:

Tooling Operation	Variables	Mantle Printed H13
Machining	Speed & Feed	Equivalent
Tapping	Speed & Feed	Equivalent
Drilling	Speed & Feed	Equivalent
Grinding	Speed & Feed	Equivalent
Cutters	Type of Cutter	Equivalent
Coolant	Type of Coolant	Equivalent



CONCLUSION

Equivalent milling and drilling operational performance were observed applying the same setting as for traditional wrought H13 tool steel.

TOOL MODIFICATION PERFORMANCE
Flatness

During the machining and grinding of the inserts and plates, it was found that the material remained extremely stable. When removing material, it did not move and warp like other metal 3D printing methods tend to do. This block had several machining, drilling, grinding, and EDM operations done and was measured for flatness throughout the entire process.

CONCLUSION

Mantle's printed H13 tool steel held a .0007" flatness range throughout all secondary processing.

TOOL MODIFICATION PERFORMANCE
Welding Operations

Standard mold shop welding methods were evaluated. Both Laser and TIG operations were performed on Mantle's printed H13 tool steel and traditional wrought H13 using 0.10" diameter H13 filler rod with identical welding machines, and settings and the following observations were recorded.**The following results were observed:**

Welding Operation	Process	Mantle Printed H13
Welding	Laser	Equivalent
	TIG	Equivalent

Laser welding of the Mantle printed H13 part

Mantle's printed H13 part post laser welding

The Mantle printed H13 part post laser welding and grinding

PLT Precision Laser Technology

(Images courtesy of PLT, Precision Laser Technology)

CONCLUSION

The Mantle printed H13 part took filler and welded as well as the conventionally manufactured H13 tool. No halo effect from the welding was visible post grinding.

"It was a seamless experience, and didn't disrupt any of the processes in our shop. There were no requirements for special tooling or alterations to the process because of the material. Performance was consistent with conventional H13 across all machining and welding processes and outcomes, including surface appearance, machinability, and performance."

– RON NATALE, PLT CO-OWNER

TOOL MODIFICATION PERFORMANCE

EDM Operations

Equivalent wire and sinker EDM operations performance was observed with Mantle's printed H13 tool steel using the same operations parameters as traditional wrought H13 tool steel.

The following results were observed:

EDM Operation	Variables	Mantle Printed H13
Sinker EDM	Copper Electrode	Equivalent
	Feed	Equivalent
	Overburn	Equivalent
Wire EDM	Amperage	Equivalent
	Wire Diameter	.010"
	Wire Breakage Typical	None
	Speed and Feed	Equivalent

CONCLUSION

Surface roughness after burning: a value of ~0.6-0.8 micron was achieved with graphite (C3) electrode - similar performance as a traditional H13 tool steel.

Fathom tool after Mantle's TrueShape process

Fathom tool after sinker EDM and polishing operations

FATHOM

DIGITAL MANUFACTURING REIMAGINED

Application example: Fathom Manufacturing

While Mantle's TrueShape process is able to produce fine features that would generally require EDM operations with traditional manufacturing, occasionally printed tools still require EDM work to further refine details that can't be printed.

In this example, Fathom printed a few features slightly oversized because the features were too small to be printed and then used sinker EDM to achieve their final geometry. Although the tool required EDM work, Mantle still enabled Fathom to **reduce their lead time on the tool by 40%**, the largest savings coming from the reduction of overall EDM time from 100 hours to 27 hours.

SURFACE FINISH OPERATIONS PERFORMANCE
Texture and Polishing

Surface Finish	Capabilities	Mantle Printed H13
Polish	Paste / Water	Plant-based mineral oil
	Diamond	1200 grit
	Paper	600 grit
	Stone	600 grit
	Polish Level Achieved (A, B, C)	A2
Grain/Texture	Acid Etch	Similar
	Laser Etch	Similar
	Horizontal	Similar
	Vertical	Similar

Part after the Mantle TrueShape process

Part after being hand polished to A2 finish

Example of chemical and laser texturing performed to Mantle's printed H13

CONCLUSION

Equivalent surface finish performance was observed for Mantle's printed H13 tool steel using the same operating procedures compared to a traditional H13 tool Steel. Achievement of A2 polish is possible with Mantle's printed H13, no pitting was observed.

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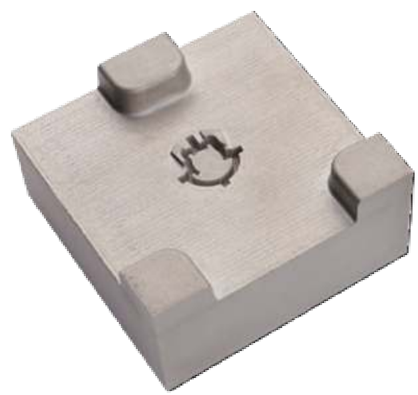
SURFACE FINISH OPERATIONS PERFORMANCE

Coating and Plating

Mantle's printed H13 underwent coating operations for nickeless teflon, DLC coating, and baked on hard chrome. The coating operations were consistent with the standard operations for a traditional H13 tool steel.

The following results were observed:

Operation	Coating Type	Mantle Printed H13
Coating	Nickeless teflon	Equivalent
	DLC coating	Equivalent
	Baked on hard chrome	Equivalent



CONCLUSION

Equivalent coating ability was observed for Mantle's printed H13 tool steel using the same standard operating procedures for a traditional H13 tool steel and showed no signs of flaking.

HEAT TREATMENT

Mantle's printed H13 was heat treated using conventional heat treatment equipment with the goal to raise the hardness to 52 HRC.

The following results were observed:

Operation	Resulting Mantle Printed H13 Hardness	Growth
H13 Double Temper Heat Treat	52 HRC	.0012" / in.

CONCLUSION

Mantle's printed H13 was able to reach the desired hardness of 52 HRC, consistent with what would be expected from a traditional H13. The cycle did require a slight change in the double tempering temperature (full heat treatment schedule available upon request). Mantle's H13 experienced growth of .0012" / in. after heat treatment and experienced no warping, resulting in a flat, thermally stable part.

MATERIAL PROPERTIES

For detailed material properties see the material data sheet. A few key properties, and their comparison to traditional H13 are listed below. As seen below, Mantle's printed H13 tool steel's properties are consistent with those of a traditional H13 tool steel.

Mechanical Property	Standard	Mantle Printed H13 (as sintered)	Mantle H13 Heat Treated (double tempered @ 525C)	Mantle H13 Heat Treated (double tempered @ 575C)	Standard H13 Heat Treated (double tempered @ 575C)
Ultimate Tensile (MPa)	ASTM E8	1,430	2,070	1,720	1,770
Tensile Yield (MPa)	ASTM E8	830	1,620	1,410	1,585
Elongation (%)	ASTM E8	6	3.6	5.8	7.4
Hardness (HRC)	ASTM E18	42	52	45	49
Density (g/cm3)	ASTM B311-17	7.47	7.47	7.47	7.78
Relative Density (%)	ASTM B311	96	96	96	100

Thermal Property	Standard	Mantle Printed H13 (as sintered)	Mantle H13 Heat Treated (double tempered @ 525C)	Mantle H13 Heat Treated (double tempered @ 575C)	Standard H13 Heat Treated (double tempered @ 575C)
Thermal Conductivity (W/m-k)	ISO 22007-2	18.25	21.48	21.48	24.3

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DURABILITY

Mantle's printed H13 performs consistently with wrought H13 tool steel during molding, including tool lifetime and durability. Mantle's H13 has a hardness of 42 HRC as printed and can be heat treated to 52 HRC, giving it the required hardness for sustained durability in even the most demanding molding environments.

Application Example:
Tessy Plastics has run Mantle's metal 3D printed inserts for over 1.4 million cycles and counting.

Tessy is currently running a 32 cavity tool that produces 6,500 deodorant stick thumb wheel screws per day in polypropelene. Two of the cavities include Mantle-printed inserts: one printed with Mantle's H13 tool steel and one printed with Mantle's P2X (P20 comparable) tool steel.

After 1.4 million cycles, Mantle's 3D printed inserts in H13 and P2X tool steel have proven to have the durability required for high volume production. The inserts have not shown signs of unexpected wear, even on shut off surfaces that are being shut off with S7 slides. All 2.8 million parts molded with Mantle's inserts have passed Tessy's internal quality control checks and have been shipped to their customer.

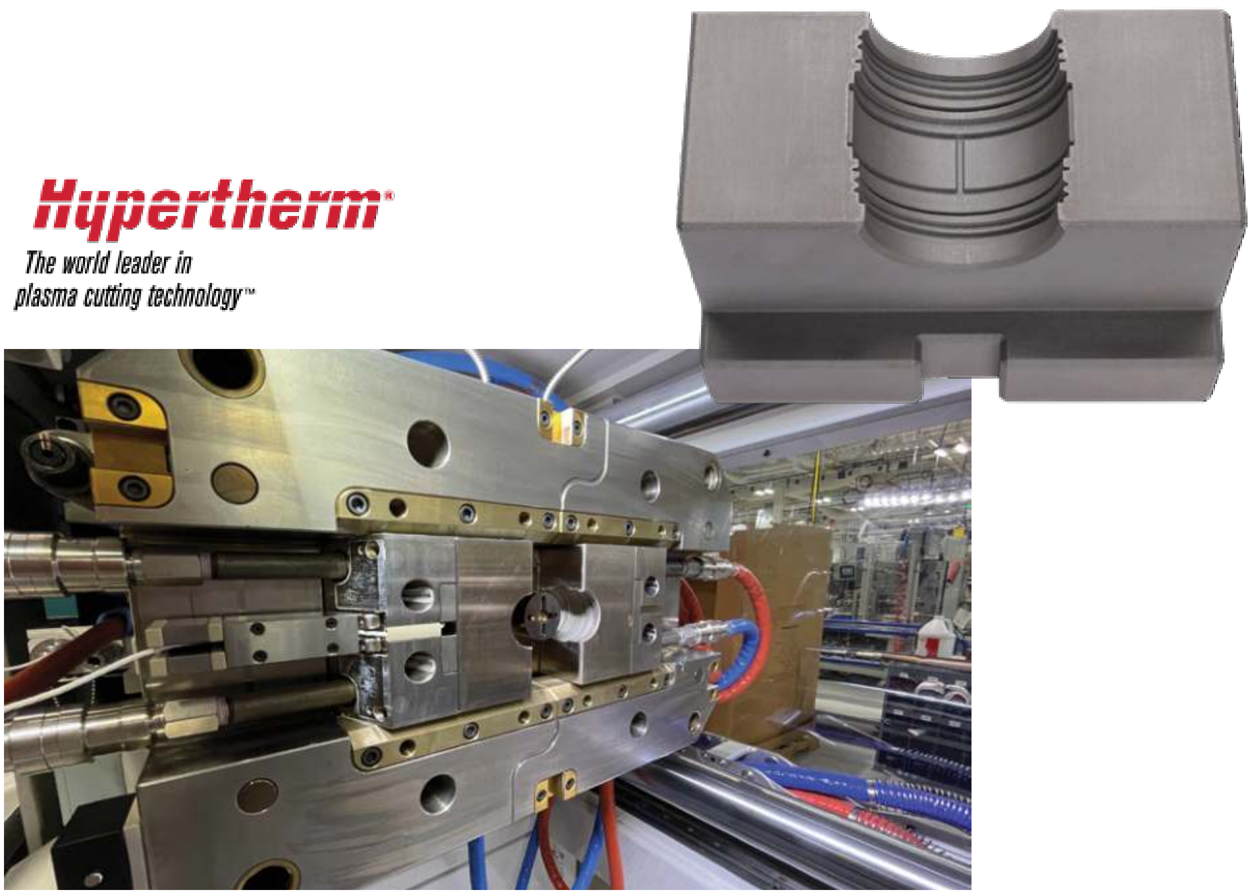
Shut off surfaces showed no signs of wear

MOLDING EXAMPLE

Hypertherm associates used a Mantle printed H13 tool to mold a highly abrasive, high-temperature, 30% glass filled PEEK. The plastic was injected at 720°F, and the tool was heated to 355°F during the molding process. After injection molding, Hypertherm saw no unusual wear on the Mantle printed H13 tool compared to a traditional H13 tool.

Key tool metrics:

- 75% lead time reduction
- 75% cost reduction
- The printed tool was used with no post processing to part detail
- Successfully injected 30% glass filled PEEK resin at 720°F, the tool heated to 355°F



Mantle printed insert molding 30% glass filled peek plastic at 720°F and tool at 355°F.
Image courtesy: Hypertherm

CONCLUSION

Mantle's printed H13 tool steel is comparable to traditional H13 tool steel, but printing dramatically simplifies the way H13 tools are fabricated. Mantle enables toolmakers to produce precision tooling with little to no user interaction, making fabrication as easy as the push of a button. In addition, once printing is complete, Mantle's tool requires little to no post processing via CNC or EDM machining, unlike other metal 3D printing approaches.

With Mantle, steel tooling can now be made in days and is durable enough to withstand hundreds to millions of cycles. Mantle's printed H13 is an excellent choice for tooling applications and is suitable for everything from rapid prototyping to true production tooling. For more information, visit mantle3D.com

Mantle helps manufacturers bring new products to life faster, cheaper, and more easily than ever before with its patented TrueShape™ metal 3D printing technology. TrueShape™ delivers precision parts that dramatically cut the time and cost of making production-grade tools, molds, and dies. Mantle tools have produced hundreds of thousands of parts for customers - a number that grows each day. Mantle is headquartered in San Francisco, California. To learn more, visit mantle3D.com.

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