

P2X Material Performance Study

TABLE OF CONTENTS

Tool Modification Performance.....	2	Surface Finish Operations Performance	6
Milling and Drilling Operations.....	2	Texture and Polishing	6
Machining and Grinding.....	3	Hardness, Thermal Conductivity, and Corrosion Resistance	7
Welding Operations.....	4	Low Volume Production Run with Abrasive Material	8
EDM Operations.....	5	Conclusion	9

Overview

Toolmakers and molders must understand tool material behavior to ensure that the hard tool steel they use will deliver manufacturing performance over the lifetime of production cycles. While Mantle's TrueShape™ technology delivers precision parts with excellent surface finish, toolmakers may still need to modify the tools because of engineering changes. The tooling needs to be repairable and the response to polishing, milling, EDM burning, and welding operations needs to be well-understood. Mantle's printable P2X material has been formulated to deliver machinability and material properties that are equivalent or superior to industry-standard P20 tooling steel. P2X ensures that users can continue to use established machining processes and equipment to maintain or repair tooling without any additional investment or process development.

Background

Mantle partnered with toolmakers to collect data and characterize the Mantle P2X material. This white paper compares the performance of Mantle P2X to that of standard P20 tooling steel for machining processes and for its behavior during production molding processes with a highly abrasive nylon material (40% GF plus 25% Mineral filled Nylon).



TOOL MODIFICATION PERFORMANCE

Milling and Drilling Operations

Milling, drilling, tapping, and grinding operations were performed with identical machine settings on Mantle’s P2X material and standard P20 tooling steel.

The following results were noted:

Tooling Operation	Variables	Mantle P2X
Machining	Speed & Feed	Equivalent
Tapping	Speed & Feed	Equivalent
Drilling	Speed & Feed	Equivalent
Grinding	Speed & Depth	Equivalent
	Cutting Fluid	Use WD-40
Cutters	Type of cutter	Use Carbide
Coolant	Type of coolant	Equivalent

Mold inserts machined side by side



Fig: Mold inserts machined side by side

CONCLUSION

The milling and drilling performance was equivalent between Mantle P2X and standard P20 tooling steel. When grinding P2X material, it is advised to apply WD-40 to avoid loading the wheel. When cutting, it is recommended to use a carbide cutter.



TOOL MODIFICATION PERFORMANCE

Machining and Grinding

Mantle’s P2X material remained extremely stable during the process of machining and grinding the mold inserts and plates. When removing heavy stock, the Mantle P2X material did not move and warp like mold inserts and plates made with other additive manufacturing methods. The printed test block had several machining operations done and was measured for flatness throughout the entire process.

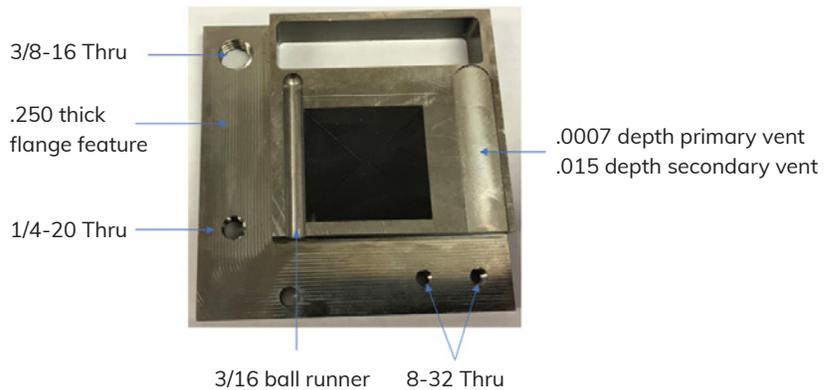
Measurables at the end of all milling operations

Flatness of each surface (final block):

1. -.0005 - 0
2. -.0004 - +.0003
3. -.0002 - 0
4. -.0002 - 0
5. -.0001 - +.0004
6. -.0002 - 0

Mantle part after machine operations

Block dimensions of 2.883” x 2.886” x .477”



CONCLUSION

The Mantle P2X material held a flatness range of 0.0007” throughout the entire process.

“The stability of this material is amazing. I was expecting it to constantly move around like laser-based additive parts do. Machining operations with this material are very predictable.”

–RAY COOMBS, WESTMINSTER TOOL



TOOL MODIFICATION PERFORMANCE

Welding Operations

To evaluate the welding performance of Mantle’s P2X material, laser and TIG welding operations were performed on P2X and standard P20 tooling steel with identical welding machines and settings.

The following observations were recorded:

Welding Operation	Process	Mantle P2X
Welding	Laser	Equivalent
	TIG	Equivalent
	Filler Rod	420

CONCLUSION

The welding performance of Mantle P2X was equivalent to that of standard P20 tooling steel. The local area was slightly harder from the welding process than the area not affected by the weld, which is consistent with standard P20 tooling steel.

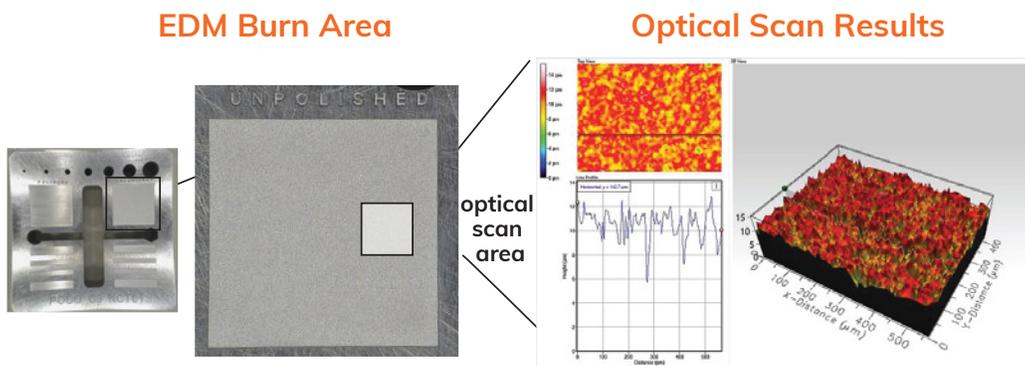


TOOL MODIFICATION PERFORMANCE

EDM Operations

To evaluate the performance of Mantle P2X material during and after EDM operations, sinker EDM and wire EDM operations were performed. The EDM operations performance of Mantle P2X is equivalent to that of standard P20 steel using the same operations parameters. One note of interest is that no wire breakage was observed with P2X; standard P20 tooling steel often breaks wires.

EDM Operation	Variables	Mantle P2X
Sinker EDM	Graphite (C3) Electrode	0.6-0.8 $\mu\text{m Ra}$ - Equivalent
	Copper Electrode	0.6 $\mu\text{m Ra}$ - Equivalent but with minor pitting
	Feed	Equivalent
	Overburn	Slightly less than P20
Wire EDM	Amperage	Equivalent
	Wire Diameter	.010"
	Wire Breakage	None
	Speed and Feed	Equivalent



Surface roughness after graphite burning shows a similar finish compared to P20 Steel.

CONCLUSION

EDM operations performance of Mantle P2X is comparable to the performance of standard P20 steel using the same operating parameters.



SURFACE FINISH OPERATIONS PERFORMANCE

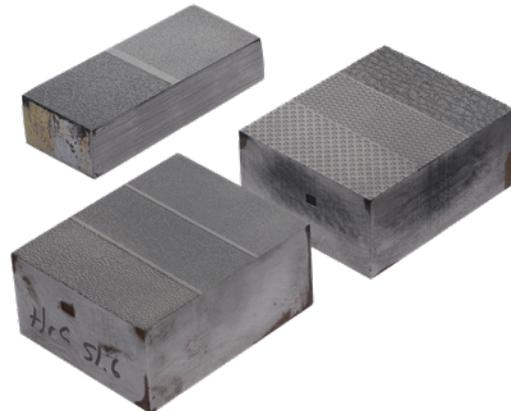
Texture and Polishing

Mantle's P2X material has a surface finish of 1.6 to 3.0 $\mu\text{m Ra}$ after sintering; often, no surface finishing is required prior to molding. However, in some cases, it may be advantageous to perform additional texturing and polishing steps. To evaluate different surface finishes, as-printed samples were subjected to various texturing and polishing operations.

Surface Finish	Capabilities	Mantle P2X
As Machined		Similar
Polish	Paste / Water	Plant-based mineral oil
	Diamond	1200 grit
	Stone	600 grit
	Polish Level Achieved (A, B, C)	A2
Grain/Texture	Acid Etch	Similar
	Laser Etch	Similar
	Horizontal	Similar
	Vertical	Similar



A2 Polish



Various Etched Texture Samples

CONCLUSION

The surface finish performance of P2X was equivalent to the surface finish of P20 steel. Achieving an A2 polish is possible with P2X.

“This material took texturing just like P20 with the same settings. We could polish it to an A2 finish.”

– CHRIS, MOLD-TECH



HARDNESS, THERMAL CONDUCTIVITY, AND CORROSION RESISTANCE

Mantle tested the P2X material according to the Rockwell C procedure and compared the results to typical P20 tooling steel. In general, the observed hardness of P2X is slightly higher than the hardness of P20 tooling steel. Mantle also compared thermal conductivity between the materials. The thermal conductivity of P2X is slightly lower than the thermal conductivity of P20. However, Mantle’s TrueShape™ process allows for the flexibility to incorporate conformal cooling for thermal management. For detailed material properties, see the P2X Material Data Sheet.

A water submersion corrosion test was also performed. Test blocks of P2X and standard P20 steel were submerged in tap water for 4 days to assess corrosion. Only minor corrosion occurred with the P2X material; significant corrosion occurred with P20 tooling steel.

Material Properties		Mantle P20	P20 Steel
Hardness (HRC)	Horizontal	32	30
	Vertical	32	30
	Center (after cut)	35	28
	Edge (after cut)	32	30
Thermal Conductivity		20 W/mK	30 W/mK
Corrosion	4-day water submersion	Minor	Significant

Mantle P2X after Corrosion Testing



P20 Tool Steel after Corrosion Testing



CONCLUSION

Material tests show that P2X has exceptional corrosion resistance and is slightly harder than standard P20 tooling steel. Thermal conductivity is lower than standard P20 tooling steel but can be addressed with conformal cooling if desired.



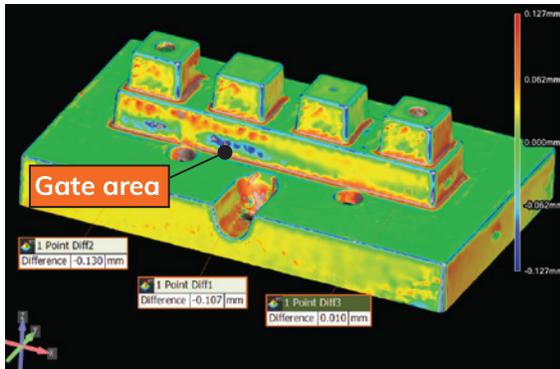
LOW VOLUME PRODUCTION RUN WITH ABRASIVE MATERIAL

A low volume production run was performed using one insert made with Mantle’s TrueShape™ technology and P2X material and another insert made with conventional manufacturing and standard P20 tooling steel. The molding conditions were identical.

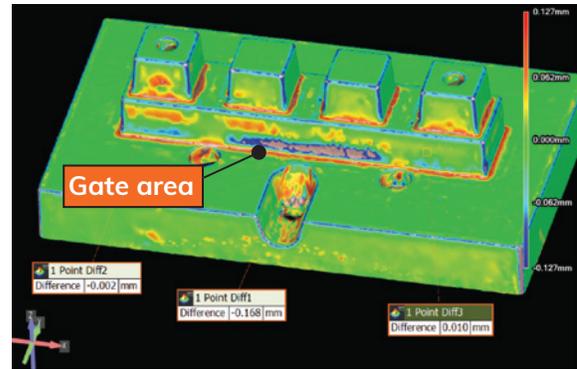
The following results were observed:

Molding Operations and Observations	Mantle P2X	P20 Steel
Cycling conditions		
Press Tonnage	40T	40T
Plastic Pressure	12,000psi	12,000psi
Plastic material used	40% glass filled + 25% mineral filled nylon	
Obvious signs of wear		
Venting (gas burning)	No signs	After 2500 shots
Impingement (near gate)	.004” groove developed	.007” groove developed

Mantle P2X



P20 Steel



These 3D scans were obtained with Keyence VL series 3D scanner and compared to new inserts after 2500 parts.

CONCLUSION

Inserts made with Mantle P2X showed 42% less wear than standard P20 tool steel over the same number of shots.

CONCLUSION

Mantle's P2X material is compatible with all standard machining operations with little to no modification of process parameters. In all operations and in molding results, P2X achieved results equivalent or superior to standard P20 tooling steel. The Mantle P2X material with TrueShape™ technology is an excellent choice for tooling applications for both prototyping and production.

“This stuff is better than P20 tooling steel.”

– CHRIS SCHRECK, SAMTEC

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.