National Aeronautics and Space Administration

Additive Design & Development of 3D Printed Magnetically Shielded Hall Thrusters

Principal Investigator: Robert “Peter” Dillon (357) CoI’s: Ryan Conversano (353), Samad Firdosy (357), John Paul Borgonia (357), Bryan McEnerney (353), Dan Goebel (353)

Program: Topic

Project Objective:

Demonstrate cost, schedule, rapid prototyping, and performance improvements through the incorporation of additive manufacturing in the design and fabrication of a Magnetically Shielded Miniature (MaSMi) Hall thruster.

(1) 50% fabrication schedule reduction

(2) 10% total cost reduction

(3) Equivalent functional performance

(4) Incorporation of thermal management and/or light-weighting

(5) Potential for improvement of a Hall thruster by the fabrication of a metallurgical gradient from VIMVAR iron or equivalent to Hiperco as a means to fabricate a monolithic structure and eliminate bolted joints.

FY19 Results:

The team used the requirements for the latest MaSMi thruster design, which incorporates thermal control features and reduced mass, developed the process flow for the MaSMi thruster, optimized 3D printing parameters by building test coupons, fabricated the components to near-net shape, finish machined and heat treated those components, and completed preliminary testing of the component stack.

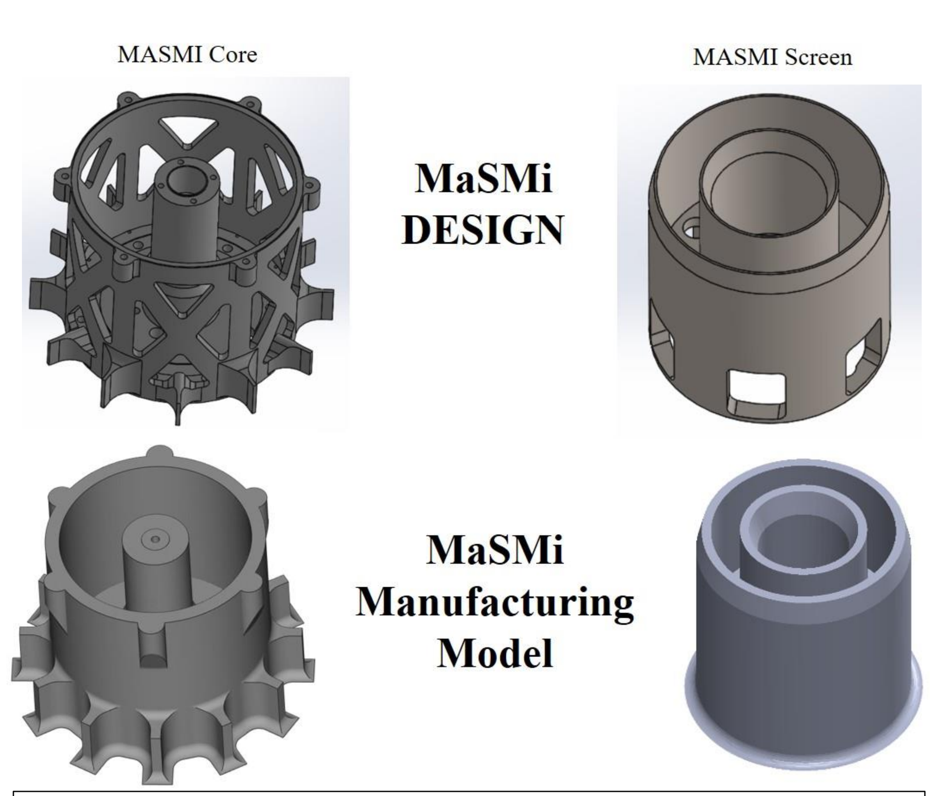
Printing of 4 Hiperco®50 thruster components (core, screen, and pole pieces) took ~100 hours to print by DED. Total post-print machining time was ~200 hours. This demonstrates the capability to go from powder to heat treated components for a thruster in ~1 month, a 50% reduction from the baseline. A cost reduction was not realized in this study. It is estimated this prototype cost ~4x that of a traditionally machined thruster; however, there is an expected efficiency gain as the number of units produced increase from 1 and recycled powder is used. Further efficiency is expected in moving the technology to laser powder bed fusion, L-PBF, allowing fabrication of a higher fidelity manufacturing model that is closer to net-shape and requiring less finish machining time.

Testing of the component stack will be completed in the next FY, but preliminary results indicate the magnetic performance is in family with a traditionally fabricated thruster of the same design. In addition to fabricating the thruster components, fabrication of a metallurgical gradient (Hiperco®50 to 316 stainless steel) was demonstrated. This coupon was fabricated crack free.

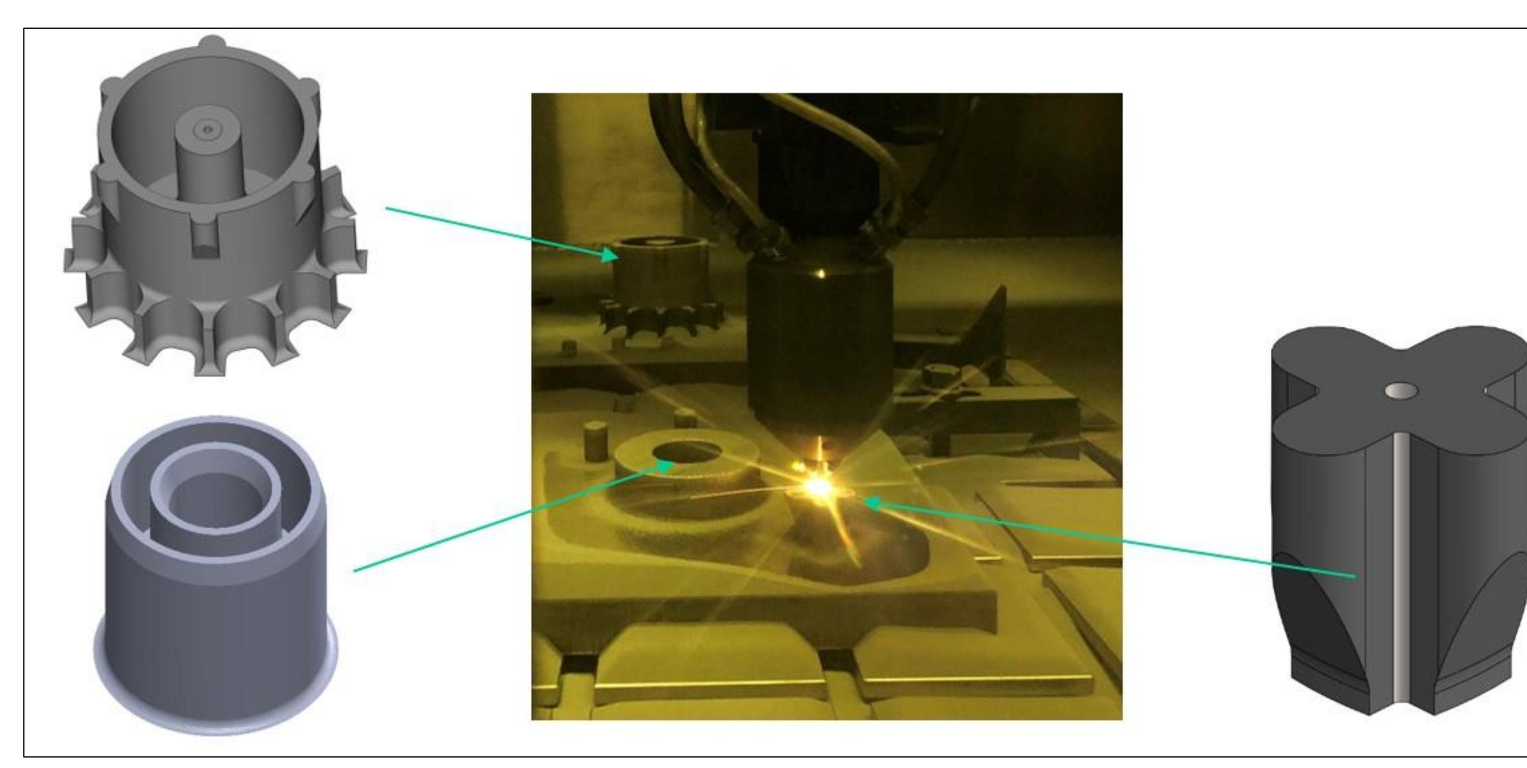
Benefits to NASA and JPL (or significance of results):

This research demonstrated that MaSMi Hall thruster Hiperco® 50 components can be additively manufactured and these components can be produced in approximately half the time as traditional machining. As the DED process is scalable (equipment with 5’ x 5’ x 7’ build volumes are available) this could have significant implications on the production of larger thrusters. For MaSMi scale thrusters, further efficiencies in cost and cost and schedule can be gained through the implementation of this technology in L-PBF, which will be demonstrated in the next FY. There is already interest in this technology by industry for use in the production of flight MaSMi thrusters and there has been some discussion on licensing. The demonstration of the compositional gradient is also significant in that it demonstrates new design possibilities using DED to join Hiperco®50 and non-magnetic structural alloys.

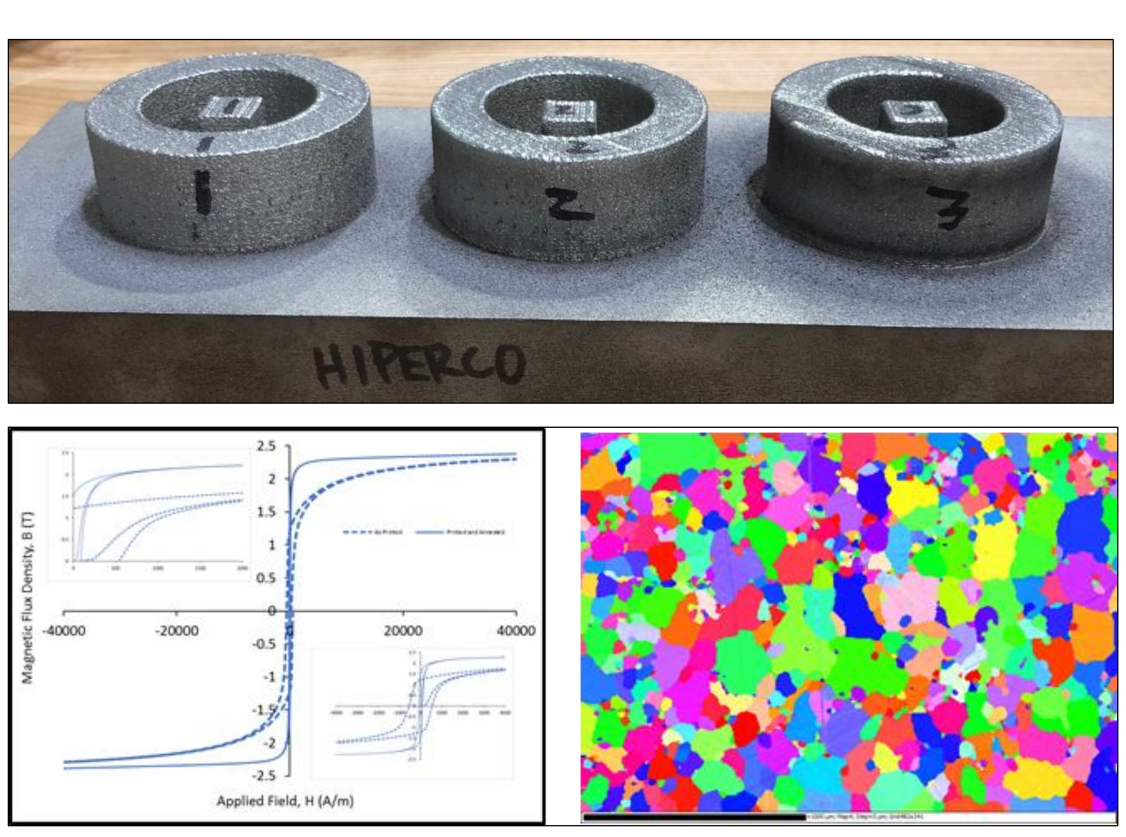
JPL’s RPM 222 Directed Energy Deposition (DED) System



MaSMi core and screen components and manufacturing models used for printing

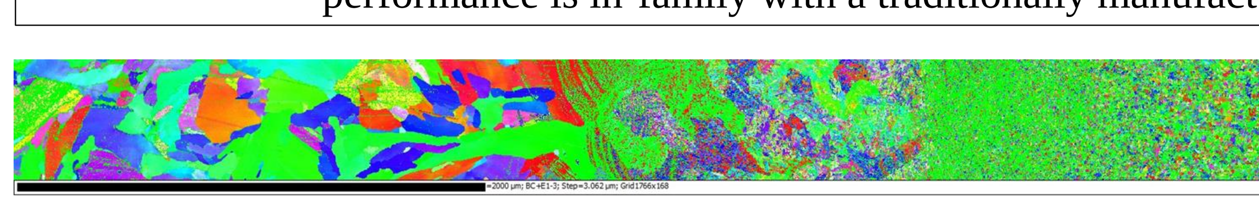


Stainless steel practice builds and geometric test coupon to evaluate printability of overhang geometries.

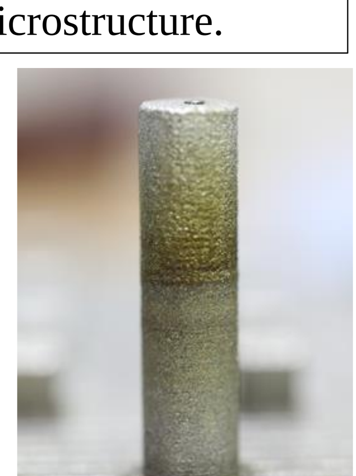


As-printed coupons for evaluating magnetic properties and microstructure as a function of process conditions. Typical magnetic test results and annealed microstructure.

Manufacturing models of the core, screen, and pole pieces were printed, machined, and heat-treated. Initial testing indicates the magnetic performance is in-family with a traditionally manufactured (fully machined) thruster of the same design.



Compositionally graded (Hiperco®50 50 to 316 stainless steel) coupon and electron backscatter diffraction image of the microstructural transition from the monolithic alloys through the gradient structure between them.



PI/Task Mgr. Contact Information:
Dr. Robert “Peter” Dillon
rpdillon@jpl.nasa.gov

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

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