National Aeronautics and Space Administration

3D Printed Actuator with Innovative Thermal Management

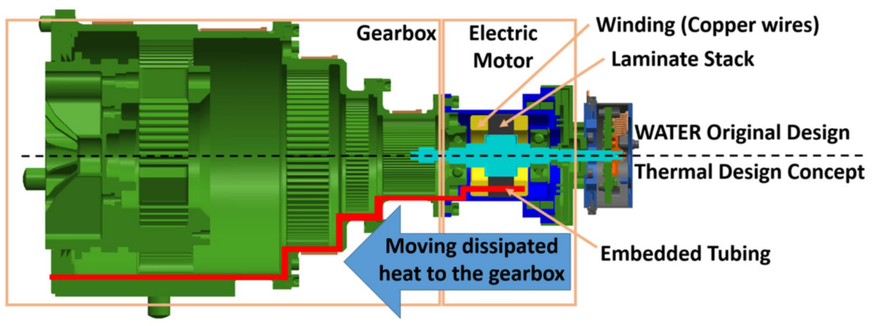
Principal Investigator: Elham Maghsoudi (353K)

Co-Is: B. Kennedy (347B), A.J. Mastropietro (353J), B. Furst (353K), J. Jasper (347M), S. Roberts (357H), R. Conversano (353B)

program: 2019 R&TD Topic Area

Project Objective:

Use additive manufacturing techniques (UAM, DED, and L-PBF) to efficiently bridge the heat source (electric motor) to the heat sink (gearbox) with thermally conductive channels.



MSL WATER: The Wrist and Turret et RSM [Remote Sensing Mast] Actuator

UAM:
Ultrasonic Additive Manufacturing
DED:
Direct Energy Deposition
L-PBF:
Laser Powder Bed Fusion

Benefits to NASA and JPL

- Increased science return from landed missions due to reduced time and energy to get the actuators to their operating conditions
- Energy efficient sampling for short duration missions to the ocean worlds such as Europa and Enceladus
- This technology may enhance JPL proposals that use actuators

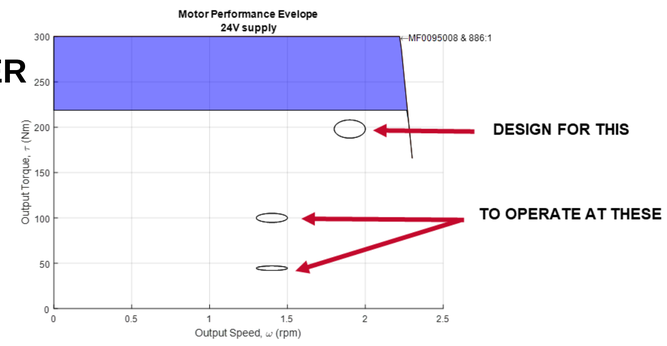
FY19 Results:

Robotics:

A baseline actuator without thermal management with an off-the-shelf motor designed and fabricated.

Approximately match WATER actuator's performance

- ≤ 3.15 kg
- ≤ 100mm diameter
- 208 Nm @ 2.0 RPM
- 28V, 3A max, 86 Nm/A

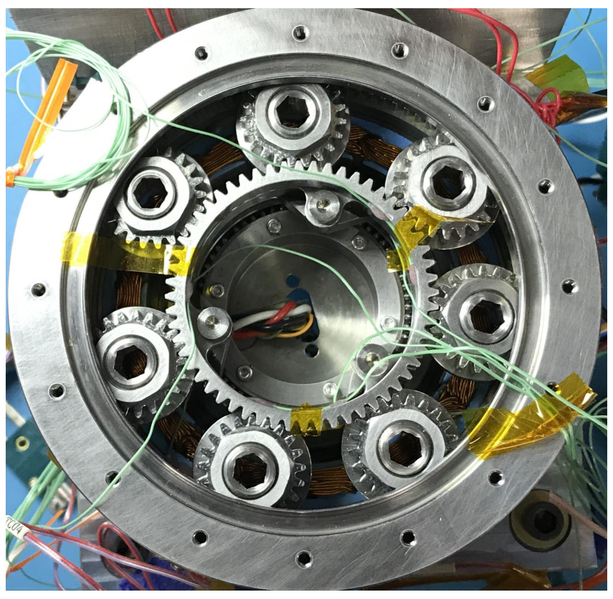


Support prototyping

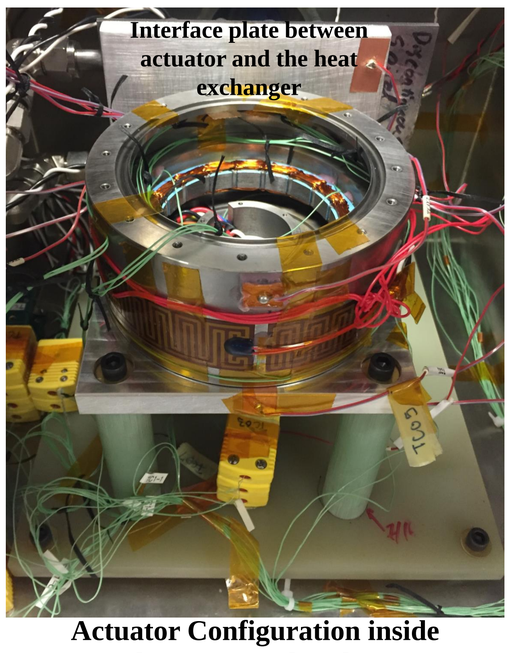
- Seal fluid (air, coolant, etc.) inside
- Transparent window
- Minimum viable gears

Thermal

- Fabricated actuator prototype thermally tested in a vacuum chamber and thermally characterized (actuator bearing, and gear conductance characterized).
- A Thermal Desktop model of the actuator prototype was built and validated against test data within ±4ºC.



Actuator Baseline Design – Fabricated Prototype



Actuator Configuration inside the vacuum chamber

FY19 Results - Continued:

Manufacturing Technology:

Ring test coupons fabricated using Hiperco and following 3D Printing techniques: DED, L-PBF, and UAM.

DED Hiperco Ring

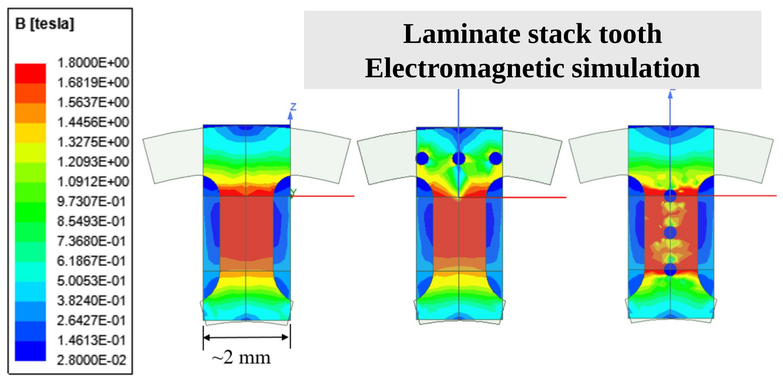
L-PBF Coupons

UAM Hiperco Coupon

- Creative material selection and geometry configurations used to compensate for traditional epoxy dielectric and minimize the core loss.
- Microscopy techniques used to investigate the test coupons dielectric.

Electromagnetics:

- Electro-magnetic properties of 3D printed test coupons characterized.
- Electromagnetic simulation of WATER actuator and next fiscal year laminate stack completed to better understand the impact of taking material out of laminate stack on the magnetic field of the laminate stack.



FY 20 Plan

- Down-select 3D printing method based on electro-magnetic characterization test results.
- Finalize two phase thermal management design.
- 3D print laminate stack with thermal management.
- Replace the current laminate stack in the current prototype with 3D printed laminate stack.
- Characterization, testing and thermal vacuum test of finalized full actuator prototype.

Acknowledgment: **Samad Firdosy** for DED test coupons printing and electromagnetic characterization; **Peter Dillon** and **Michael Johnson** for motor concept design; **Thomas Peev** for actuator/heat exchanger interface design; **Emma Nelson** for actuator thermal desktop model and model validation, **Katherine Dang** and **Nikola Georgiev** for laminate stack electromagnetic simulation, **Andre pate** and **Rafael Martinez** for L-PBF test coupon printing.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

PI/Task Mgr. Contact Information:
Elham.Maghsoudi@jpl.nasa.gov
Phone: 818-354-7444

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