**MOTIVATION**

Unmanned aerial systems (UASs) perform critical tasks such as observation and reconnaissance where use of manned aircraft is cost prohibitive or dangerous. While aircraft guidance and remote sensing technology have rapidly developed, propulsion systems for small scale UAs have not dramatically changed, typically relying on internal combustion engine (ICE) technology. ICE propulsion systems are noisy and produce significant vibrational loads on the airframe and payload while presenting mechanical wear issues. Electrical propulsion systems using battery power are quiet and impart minimal vibrational loads to the aircraft, but are limited to flight times typically less than one hour. Fuel cell powered propulsion systems using hydrogen are a compelling alternative that combine the quiet, reliable attributes of electrical propulsion with flight times that approach that of gasoline powered UAs.

**GOAL**

UAS manufacturers are currently developing fuel cell powered variants of their gas powered aircraft. Fueling options include compressed gas and cryogenic liquid hydrogen. A liquid hydrogen storage system was determined to provide higher energy density (MJ/m³), specific energy (MJ/kg) and gravimetric capacity (M/Wt%) than a high pressure (300 or 700 bar) gas system. Our goal is to design, build, and validate a liquid hydrogen storage system that integrates the heat exchanger into the tank wall to minimize mass and volume while reducing heat flux into the tank. This research presents the computational fluid dynamics and thermal modeling of a 3D printed Liquid Hydrogen Tank with Vapor Cooled Exchanger.

**TANK DESIGN**

- Cooling in vapor channels enhanced by para-orthohydrogen conversion
- 3D printed shells allow for complex heat exchanger flow geometry
- Copper evaporation on shells creates hydrogen permeation barrier
- Integrated temperature sensors and heater provide mass flow control
- Insulation material minimized by relying on vapor cooling
- Cryogel (aero gel derivative) provides barrier for remainder of thermal barrier
- Insulating cavities filled with Cryogel are evacuated

**FLUIDS & THERMAL MODEL**

A 3D axisymmetric thermal-fluids model was developed in COMSOL Multiphysics to evaluate the optimal configuration of counter-flow gas passages and insulation cavities. Heat flux into the tank was varied by changing the thickness of vapor and insulation cavities until the required mass flow rate was achieved. The outer vapor duct was situated towards the outer shell to ensure the hydrogen would reach ambient temperature before leaving the tank for the fuel cell, eliminating the need for a separate heat exchanger.

**RESULTS**

- Steady state heat flux across inner and outer wall of a) inner duct and b) outer duct. Sharp spikes in plot (a) are due to modeling artifacts at the edge junctions. High heat flux across outer wall in the outer duct (b) due to separation of 200K gas and 293K duct. Flow gas passages and insulation cavities.

**PREDICTED PERFORMANCE**

- Par-orthohydrogen conversion in vapor duct provides 5 W additional cooling power
- Vapor jacket results in 44 W cooling power
- 5.2 W heat load into liquid
- Results assume 0.01 torr pressure in insulation layers

**VAPOR COOLED LIQUID HYDROGEN TANK SPECIFICATIONS**

- Energy density 320MJ/m³
- Specific energy 60MJ/kg
- Gravimetric capacity 4.8Wt%

**ACKNOWLEDGEMENTS**

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