Bipropellant Rocket Engine

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Objective

This project was done for CPSS to investigate the effects of film cooling on a small liquid bipropellant rocket engine. CPSS completed a similar project without film cooling.

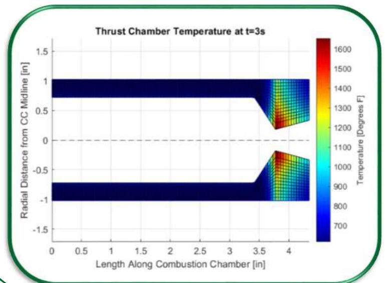
The main objectives are:
- Ethanol Nitrous Bipropellant
- **25 lbf** of Thrust
- Film Cooling
- **3 second** burn time

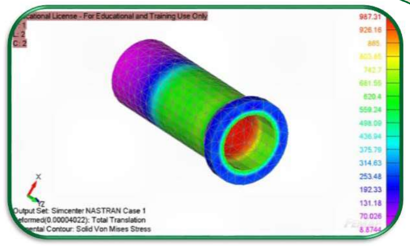
Analysis

Heat map of combustion chamber based on Bartz heat transfer relation (below)

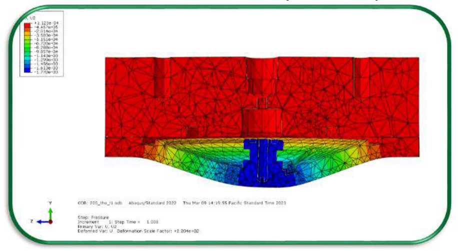
$$\sigma = \frac{1}{\left[\frac{1}{2}\frac{T_{wg}}{(T_c)_{ns}}\left(1+\frac{\gamma-1}{2}M^2\right)+\frac{1}{2}\right]^{0.68}\left[1+\frac{\gamma-1}{2}M^2\right]^{0.12}}$$

$$h_g = \left[\frac{0.026}{D_t^{0.2}}\left(\frac{\mu^{0.2}C_p}{Pr^{0.6}}\right)\left(\frac{((p_c)_{ns}g)}{c^*}\right)\left(\frac{D_t}{R}\right)^{0.1}\right]\left(\frac{A_t}{A}\right)^{0.9}\sigma$$





Finite element analysis of combustion chamber for strength (above) and of injector for deflection (below)



Testing

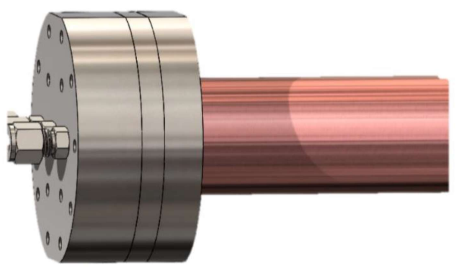
Hydrostatic
Tests sealing by pumping water

High Pressure Water Flow Test
Injector performance

Cold Flow Test
Full System Test

Final Product

Final CAD Model

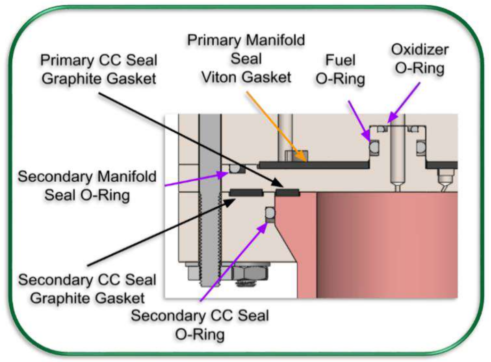


Conclusions

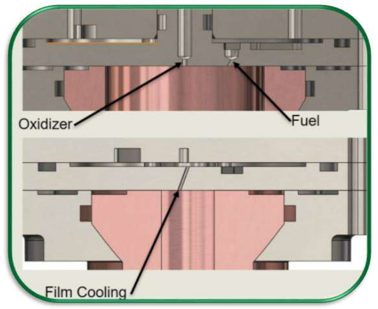
- Design for manufacturability needs to be balanced with ideal design
- Recommend more layers of sealing between film cooling and fuel passages to improve efficiency
- Successful cold flow test confirms likelihood of hot fire success

Design

Sealing:
- Viton rubber O-rings, Viton gasket, and graphite gasket
- Redundant sealing between fuel and oxidizer



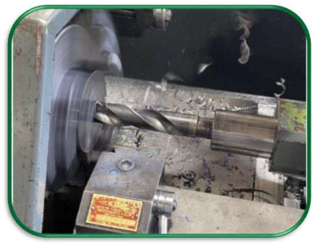
Injector Orifices:
- **Fuel** 0.027 in diameter holes allow liquid fuel to atomize and mix with the oxidizer
- **Film Cooling** angled holes on edge of injector swirl for excess fuel to create insulating film for chamber wall



Manufacturing

L1 Injector Plate:
- Machined via Haas VF 4 CNC Mill
- Angled holes drilled on manual mill

Retaining Ring:
- Machined via Aero Hangar manual lathe & mill



L2 Injector Plate:
- Machined via Haas Super Mini Mill 2

Combustion Chamber:
- Machined via Aero Hangar manual lathe