Executive Summary

This month I used some similarity scaling parameters to increase the thrust of the HTPE/PLA hybrid rocket engine. Recall, the objective is to increase launch velocity and thus aerodynamic control of the Mk I Viper rocket glider. The three scaling parameters I looked at were initial gas flux, initial surface area flux, and length to diameter ratio. I designed and printed a higher flux fuel grain and inserted a variable PLA flow restrictor at the end of the fuel core. My average thrust went from ~19 N to ~23 N and overall performance was on par with previous test.

Technical Stuff

This month I looked at the scaling parameters as outlined in paper on similarity (ref: Gany) for hybrid rocket motors. The three scaling parameters I looked at were initial gas flux (IGF), initial surface area flux (ISF), and length to diameter (L/D) ratio. The initial volume flow rate for the 1/2" mist nozzle with an orifice of 1.0 mm is ~14.8 ml/sec at 140 psig. The PLA/$KMnO_4$ fuel core cross sectional area for the star geometry is 1.4 cm^2. With an HTP to ethanol ratio of 25, the mass flow rate of HTPE is 20.1 gm/sec giving an IGF of 14.4 gm/cm^2/sec. I'll refer to this core as the low flux (LF) core.

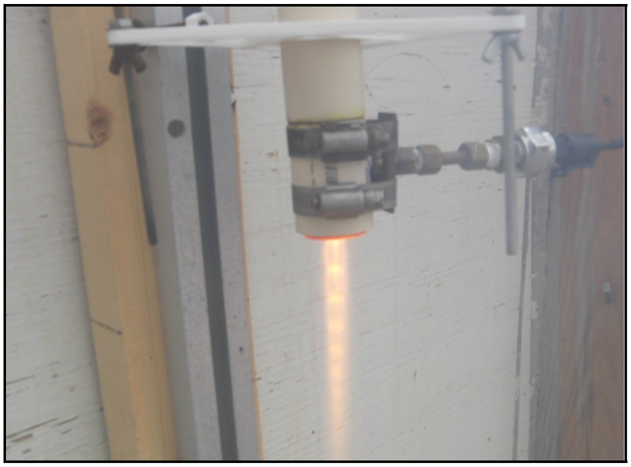
With the same type of mist nozzle but with an orifice of 1.5 mm, the initial volume flow rate is ~23.0 ml/sec at 130 psig. The cross sectional area is ~1.82 cm^2. With an HTP to ethanol ratio of 25, the mass flow rate of HTPE is 31.2 gm/sec and the IGF is 17.1 gm/cm^2/sec. I'll refer to this core as the high flux (HF) core. The objective here is to get the HF core IGF as close as possible to the LF core IGF.

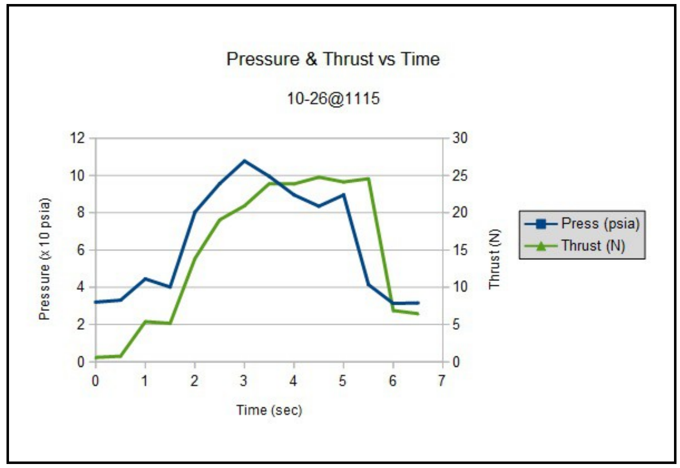
The second scaling parameter I looked at is the initial surface area flux (ISF). For the LF core, the length of the core is 12.5 cm, the internal surface area is ~100.0 cm^2, and the ISF is 0.20 gm/cm^2/sec. For the HF core, the length of the core is 15.0 cm, the surface area is ~165.4 cm^2, and the ISF is 0.18 gm/cm^2/sec. Again, the objective here is to get the HF core ISF as close as possible to the LF core ISF.

The last scaling parameter is the L/D ratio. However, the star chamber geometry doesn't have a true diameter. As such, I used an equivalent diameter. I used the cross sectional area for each core, divided by pi, and took the square root. This gave me an equivalent diameter of ~1.34 cm for the LF core and ~1.52 cm for the HF core. As such, the L/D for the LF and HF cores is 9.3 and 9.9 respectively. Again, for similarity scaling, the objective here is to get the HF core L/D as close as possible to the LF core L/D.

Well that was fun but how did it work? In the first test with the HF core, ignition occurred in ~1.8 sec and burn time was ~2.3 sec. Thrust peaked at 28.5 N and averaged out at 22.2 N. I didn't get any pressure data due to an SD card failure on the data logger. But, I can surmise that the peak pressure matched that of the peak thrust. To tame the pressure and thrust, I inserted a PLA flow restrictor (ref: edzieba) with an inner diameter of 4 mm at the end of the fuel core and ran the same test with the flow restrictor. The results are shown in the video and graph below.

Ignition occurred in ~1.1 sec and burn time was ~3.9 sec. Peak pressure was at 108 psia with an average pressure of ~92.3 psia. Peak thrust was at 25 N and averaged out at ~23 N. I'd like to emphasize two key results of this test. First, notice in the graph the relatively slow climb at the beginning of the burn in pressure and thrust. This is probably due to the flow restrictor (more testing to confirm). Also, notice that the thrust peaks to 25 N at the end of the burn. C-star efficiency was ~102% and the coefficient of thrust was 0.91. It looks like some improvement in thrust coefficient is necessary but overall, I'm happy with the results. Keep in mind, this is for a class I rocket. The total propellant mass was ~85 gm. So, I can add a little more HTPE and still keep it under 100 gm.





References

1) Gany, A, "Similarity and Scaling Effects in Hybrid Rocket Motors", *Fundamentals of Hybrid Rocket Combustion and Propulsion*, AIAA, Progress in Astronautics and Aeronautics, Martin J. Chiaverini & Kenneth K. Kuo, Editors, Vol 218, 2007

2)edzieba, Reply #28, NASASpaceflight.com Forums>>General Discussion>>Advanced Concepts>> HTP/PLA/$KMnO_4$ Hybrid Rocket Engine, 11/05/2021