Executive Summary

This month I had two flight test and one static test. All three test were an attempt to get a higher thrust. In the flight tests, I increased the throat diameter of the graphite phenolic nozzle to 6.7 mm. The first flight test blew the nozzle and failed to clear the rail guide. The second flight test cleared the rail guide and then blew out the nozzle. I surmised that hot gases were leaking around the o-ring seal melting the PLA thus weakening the bond between the PLA adapter and CPVC coupling.

In the static test, I increased the flow rate to ~ 23 ml/sec but keep all other parameters the same. Once again, the nozzle blew out immediately on ignition. Test results show a pressure spike of ~ 140 psig in the mixing chamber and a peak thrust of ~ 33 N. I plan to introduce a variable orifice (ref: edzieba reply #28) at the end of the fuel grain to reduce the initial flow rate thus allowing the mixing chamber time to stabilize.

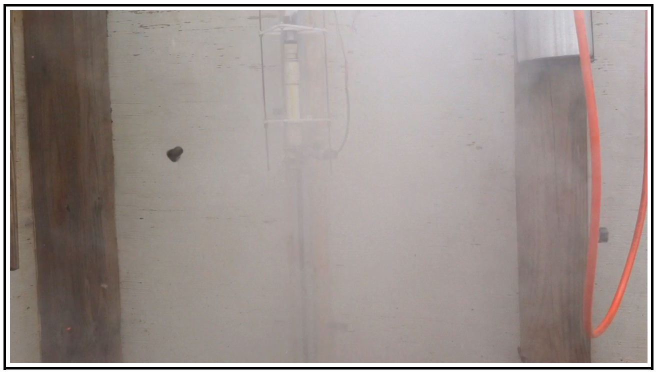
Technical Stuff

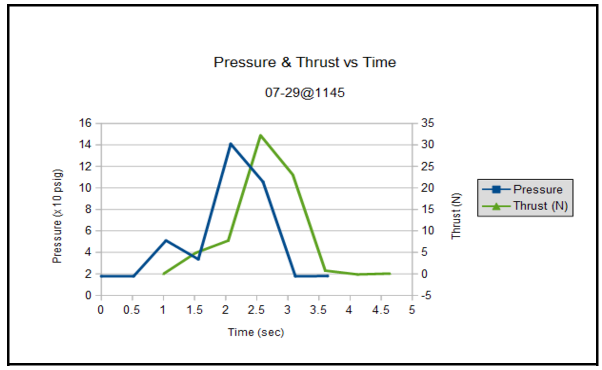
This month I had two flight test and one static test. As mentioned in the Jun 2022 end of month report, the Mk I Viper left the rail guide at ~ 2.0 m/sec, not enough velocity for aerodynamic control. I looked at two approaches to increase thrust and get a higher velocity. First, I drilled out the graphite phenolic nozzle from 5.0 mm to 6.7 mm throat diameter and ran two flight test. For the second approach, I drilled out the throat to 6.0 mm diameter and, to increase the flow rate, changed my injector from a 1.0 mm orifice to a 1.5 mm orifice.

The first two flight test with the new throat diameter did not go well! In the first test, the Mk I Viper made it to the top of the rail guide, blew out the nozzle, lost thrust, broke through the stop, came off the rail guide, and crashed onto the concrete pad. In the second test, the Mk I Viper left the rail guide at ~ 1.5 m/sec, began to pitch up, blew out the nozzle, flipped over once, and crash landed next to the test stand (Flt Test).

The question is, what was causing the blowout of my graphite phenolic nozzle? All of the other parameters (with the exception of one minor parameter as noted below) were the same as before. The physical analysis revealed a significant erosion of the PLA adapter I used to install the nozzle to the 1" CPVC coupling. It appeared to erode from the bottom up. From this analysis, I surmised that I have reached a structural limit to drilling out the throat diameter of the graphite phenolic nozzle, drilling out to 6.7 mm was a little to much. Hot exhaust was leaking around the nozzle throat bypassing the o-ring seal and melting the PLA. As such, for the next test, I went back to a 6.0 mm throat diameter and increased the flow rate.

For the past year, I've been using a 1/4" stainless steel mist nozzle with a 1.0 mm orifice for all test. With the 1.0 mm orifice, I get an initial HTPE flow rate of ~ 14.8 ml/sec when pressurized to 140 psig. The same mist nozzle design with a 1.5 mm orifice gives me an ~ 23.0 ml/sec flow rate at 140 psig. Keeping all other parameters the same and using previous test results as a guide, I estimated a thrust of ~ 28.5 N. The test results are shown in the graph below ([Static Test]).





The graph shows a peak pressure followed by a peak thrust. The pressure was ~ 140 psig (154.7 psia) which was over the design limit (100 psia) of the CPVC and PLA adapter bond. I'm not sure this is good or bad. The oxidizer tank pressure was 140 psig. This means there was either no pressure drop across the 12 V DC solenoid valve, the check valve, and the mist nozzle injector (unlikely) or the pressure sensor needs to be re-calibrated (more likely). Either way, there was an over pressure in the mixing chamber which blew out the nozzle (notice the black object flying around in the photo to the left). I'm convinced that the over pressure is due to the increase in HTPE flow rate (23 vs 14.8 ml/sec). The larger diameter orifice (1.5 vs 1.0 mm) has a lower pressure drop across the injector resulting in a larger initial pressure in the mixing chamber. The combustion process is to fast for the mixing chamber to recover and the nozzle gets blown out. Fear not, I believe I have a solution.

As shown in the graph, the peak thrust was about 33 N. Based on previous experience with this propellant combination, I estimated a thrust of ~ 29 N. I believe the thrust is there. I just have to tame it, enter the variable orifice (ref: edzieba reply #28).

Earlier I mentioned one minor parameter was different between the first and second flight test. I had been getting less than a second for the ignition time on the test. On the second flight test, I left out a 1" diameter stainless steel washer that I used to retain the fuel core. This washer has a 14 mm inner diameter. On this test, the ignition time was ~ 1.8 seconds. I began to think that this washer was slowing the flow in the fuel grain for ignition to occur in 1.0 second. As such, I'll replace the stainless steel washer with a 1" O.D. PLA washer with the same thickness but with a 10 mm inner diameter. The idea here is to slow the initial flow rate to reduce both the ignition time and the initial chamber pressure. Once ignition occurs, the PLA inner diameter will erode allowing the maximum flow rate and thrust. Ten millimeter I.O. may not be small enough, but it is a start.

I will launch the Mk I Viper again next month. This time it will fly straight and true, be under thrust for five seconds, and set a new record for Fisher Space Systems, LLC!

Ref: edzieba reply #28 on 11/05/21, forum.nasaspaceflight.com/index.php?topic=53964.msg2306836#msg2306836