TASK HISTORY	TASK TITLE Hybrid Hot Fire	TASK NUMBER ISS-TH-H001	PROJECT IREC Hybrid
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DATE May 13, 2018	MILESTONE 1st Summer Hot Fire	REVIEWER'S INITIALS CL	

Purpose

Test a variety of fuel grains at 1200 psi to find what casting procedure or original inner diameter produces the most effective hybrid engine fire.

Background

This was the first hot fire of the summer including many new members to the hybrid propulsion project to carry on the work done by previous ISS members and implement it into the 2018-19 IREC competition. The team followed checklists and procedures documented by the 2017-18 HRE team to the best of their ability. The team also utilized code for the control box passed on by the Hybrid members. Unfortunately, there was no updated version of the load cell code available to read thrust data during the test fire.

Results

Two fuel grains were tested. The first being a fuel grain casted at 120°C with an ID of 1.75" and fired at 1200 psi. This test fire was a success with only a little sputtering towards the end of the burn. Before the first fire, the NOS tank weighted 14.27lbs and after 13.24lbs. The second fuel grain was also casted at 120°C with and ID of 1.5" and fired at 1200 psi. This test fire was less successful, but ignition sparks were still seen in the nozzle of the engine. The team cut off the pressure system supply 2 seconds early once they recognized that full ignition was not achieved, resulting in the engine burning for a total of 6 seconds instead of 8 seconds like the first fire. A large cloud of gas was formed as a result of this test fire. After the second test the NOS tank weighed 12.59lbs. Both of these burns were filmed and can be viewed in the IREC google drive under *Media* > *May 13th Hot Fire* > *Videos*. Despite the minor setbacks encountered by not having the correct code, forgetting a few items, and having only a few experience hybrid members; the team had a successful hot fire and left with a slew of new information about ISS's current hybrid engine and the future of this project.

Table 1: Fuel Grain Characteristics

	1st Fuel Grain	2nd Fuel Grain
Inner Diameter (in)	1.75	1.5
Casting Temperature (°C)	120	120
Diametric Regression Rate (in/sec)	0.087	0.083
Firing Pressure (psi)	1200	1200
NOS used (lbs)	1.03	0.65

Data Analysis

Variable control has been a chokepoint on previous hot fires, and an effort has been made for this hot fire to better identify and limit variables. The both test fires were in optimal setup using a full/nearly full NOS tank, large grain inner diameters, and robust ignitor setups (Oreo precombuster with Aerotech igniter). Despite this, there was significant variation between the two tests, with the first fire displaying expected burn performance until the fuel burn area exceeded the supplied oxidizer. The second displayed symptoms of insufficient oxidizer upon ignition with significant smoke production.

Upon review of the tests, two variables were present, the planned fuel grain diameters and the unplanned NOS/He settling time. The second test utilized a smaller inner diameter which the team theorized would require less oxidizer due to the lower fuel grain burn area. The first test fire had a NOS/He (Helium) settling time of approximately 1 minute due to a false-alarm shut-down call made following He valve cycling. The second test was ran in the planned time configuration with a ~20 second delay between He valve closure and ignition. The settling time of He in NOS is unknown by the team, so it may be possible that the increased delay allowed the He present in the lines and tank to separate to a greater extent, allowing more NOS to reach the injector during the firing.

Future tests should carefully track the NOS/He settling times, and further testing should be done to examine the impact this has on burn quality.

Lessons Learned

- While assembling the test stand and mounting it to the beams at the test site, the team encountered some difficulties with the previous procedures and remembering the order as to which different elements needed to be attached, so all steps taken were documented once test stand was accurately assembled.
    1. Attach load cell pressure sensor and the plate it is mounted on to the test stand

    (Note: Load cell may need to be attached to only one screw and swivel)

    2. Remove the 8 screws attaching the orange plate to the test stand to make the U-bolt connections more accessible
    3. Fasten engine to orange plate with the U-bolts
    4. Reattach the orange plate to the test stand
- While assembling the hoses for the pressure system, the team realized it would have been much more efficient if all the hoses had been threaded/partially assembled prior to the hot fire
- A few miscellaneous items were mentioned or caused issues during the hot fire and need to be at least considered to be ordered for the summer team;
    - Gasket for NOS tank (****important****)
    - Ratchet Strap (connecting NOS tank to test beams on site)
    - Vice grips (I'm just jealous of Noe)
    - Walkie talkies for test site (or cans attached to string??)
- If using plugs on the engine instead of thermocouples, then attached them before coming to test site to save time
- While working with the code and control box electronics, some important notes were made by the team;
    - Order to turn on switches is Power, Ignitor, Valve, Fire

  - The Fire switch acts as a commit switch and needs to be in the off position when the code is started and can be turned on during the countdown phase
  - When the screen reads *Starting Rocket Controller* the Arduino is hooked up correctly
  - The settings for the Arduino code must be *115200 Baud, No Line Ending*
- The existing code for the control box provided by the past HRE team was slightly altered during our testing to do the following:
  1. Type *start* to begin code
  2. 20 second delay
  3. Open Valve B and begin 30 second countdown
  4. Fire switch must be flipped to on position
  5. Valve B closes at 20 seconds
  6. Valve A opens at 2 seconds
  7. Ignition begins at 0 seconds
  8. Valve A closes after being open for 10 seconds (8 seconds after 0)
  9. End Test
- The test facility was very dirty, the team proposed selecting a weekend to at least power wash or sweep the facility to make it a little nicer for hot fires
- There were several issues with the pressure system fittings and the potential for leaks within the pressure system due to these inconsistent fittings.
  - The primary issue with the current system is the mismatching of fitting types, with NPT, JIC, and O-ring face seal fittings being threaded against each other. If continued, this will result in damaged fittings, system leaks, and possible safety hazards.
  - The team would like to revamp the pressure system whether that be through new fittings or altering the design to create a more efficient system
  - The revamped system would ideally be built to be capable of operating at/above the maximum pressure foreseeable in the hybrid test program.
  - Redo the schematic provided by the 2018-19 HRE team as the one provided is a hand sketched schematic and hard to read in a few places
- Always unplug box before anyone touches the test stand
- Create a better Hot Fire packing checklist in test procedures documents so that nothing is left behind and so that its nots just a vague list (get into specifics like wrench sizes etc.)
- Update the procedures in the new ISS-P- format, have a printed copy on hand throughout the packing/firing/safing process, checking and verifying the doc along the way.
- Stick with the commercial Ignitors
- Don't fill tank before next hot fire, but after drain the entire tank to get weight
- Plan for Hot Fire May 27th (control the port diameter at 1.75" for this test @ 120 degrees Celsius)

Impact Statement

This hot fire reignited some momentum into this project that was much needed. The frustrations of this day were caused mainly by factors that were out of our control, but some that were in our control. The biggest factor that will reduce our further stress and frustration is documentation and organization of files. As the summer begins the team should focus on documentation of procedures, code, safety, etc. before making any major design/test changes to improve future hot fires.