Injector Configuration and Development of a Methodology to Scale Between Cold-Flow and Hot-Fire Evaluations

Ilian Rojas¹, Malissa Lightfoot ²,Nils Sedano³, Kriss Vanderhyde⁴
1: STEM Teacher and Researcher, University of Houston-Downtown, 2: Aerospace Systems Directorate, AFRL, Edwards Air Force Base

Introduction

In this study, cold flow and hot fire testing were performed on a gas-centered swirl coaxial injector (GCSC). The purpose of these scaling methodologies is to establish a connection between the two sets of data that were examined. It is important to have a better understanding of the complex behavior that this type of injector exhibits. The goal is to be able to manipulate the information that we extracted from the data and to be able to model it through simulations in order to optimize the sprays patterns.

Background

Propellant injectors’ main functions are to atomize the fuel into very fine droplets and mix the fuel to produce efficient and stable combustion. The injector in a liquid rocket engine is a very crucial part because it will determine the overall combustion efficiency and thrust performance.

Experimental Setup

Cold flow testing uses water to simulate the liquid fuel and gaseous nitrogen to simulate central gaseous oxygen (GOX). Testing was performed in the flow lab located in Area 1-14. The diagnostic instruments utilized to performed this study were a back-light and high speed camera. These instruments were used to capture images that allowed the evaluation of the spray patterns of an individual injector. The spray consisted of different cone widths that included widest, narrow, and solid spray patterns. The cold flow conditions were designed to simulate hot fire conditions with respect to the conditions of the injector. The image shows an outline of the outside boundary of the width of the cone.

Hot fire evaluations were conducted in EC-1 at the AFRL/Edwards Research Site. In the figure below, you can see the copper, heat-sink combustion chamber that were used for testing. The uni-element combustor has simple components and is comprised of the injector head, the ignition port, water-cooled nozzle, the combustion chamber and the nozzle. Testing was conducted at chamber pressures ranging from 200-1100 pound per square inch gauge (psig) and a typical steady state firing time would be a minimum of 1 seconds for each test. After completion of the multiple baseline tests, we were able to demonstrate initial stages of the combustion performance and chamber/injector configurations.

Analysis Of Results

The test results from both analysis show a pressure oscillation of low level chugging and luminance oscillation behavior of low level pulse. The relationship between hot fire and cold flow qualitative results demonstrate chugging conditions and pulsing behavior in both analysis. In this case study the injector features were not stable within both graphs.

Conclusion

A GCSC injector was examined using two different methods. The spray images were evaluate using image processing techniques. The results of this particular case study detected pressure oscillations within hot firing test and luminescence oscillation within the cold flow results. These results will allow us to better understand the behavior of shielded GCSC injectors and develop a design methodology to improve injector design.

Future Work

In continuation with this work the AFRL plans to develop a design methodology for all characteristics of a shielded gas-centered swirl coaxial (GCSC) injector configuration that would improve combustion stability, performance, and environmental control that consist of temperature and pressure. We want to modify injector design of cup links, fuel temperature study, make direct comparisons between experimental and computational result, successfully test GCSC injector at a demonstrator scale, and continue to refining injector design methodology.

References

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Figure 1. A Schematic of a GCSC injector

The gas-centered swirl coaxial injector uses hydrocarbon fuels. The liquid propellant is injected along the straight-run post while the swirling liquid is introduced along the wall forming an annular sheet.

Figure 2. A typical image from inside the injector cup with the boundary determined from the automated process overlaid (yellow). The edges of the injector are shown by blue lines.

Figure 3. Picture of Area 1-14 Water/Nitrogen Injection Spray Test (WNIST) rig

Figure 4. Picture of EC-1 Uni-element combustor firing test rig

Figure 5. GCSC injector with larger droplet size

Figure 6. GCSC injector narrower spray cone

Figure 7. Fuel rich engine plumes

Figure 8. Stoichiometric engine plume

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