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SPACE PROPULSION SYMPOSIUM (C4)
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STUDENT DESIGN/BUILD/TEST OF A THROTTLEABLE LOX-LCH4 THRUST CHAMBER

Abstract

In partnership with NASA Johnson Space Center (JSC), a throttleable liquid oxygen/liquid methane thrust chamber was designed, built, and tested by a group of Purdue University students for use in a planetary lander. JSC provided a list of project requirements and participated in design reviews and discussions. The engine was designed to throttle over a range of 4,200 lbf down to 1,300 lbf. A fixed geometry pintle was chosen as the injector. Testing of a development engine was performed to collect temperature and performance data for use in the design refinement of a flight-weight engine. The basic top level design requirements for the project provided by JSC are given below.

- Propellants shall be liquid oxygen and liquid methane
- Thrust chamber shall be throttleable from 4,200 lbf down to 1,300 lbf
- Required injector upstream pressure shall be no more than 315 psi
- Deliverable thrust chamber weight shall be less than 80 lb
- Mission averaged specific impulse for a hovering mission shall be at least 215s

There were several design challenges associated with the given requirements. The low pressure requirement directly opposes performance for a throttling thrust chamber. To ensure that there are no low frequency feed coupled instabilities, it was necessary to maintain a certain amount of pressure drop across the injector. Additionally, to avoid flow separation in the nozzle, it was necessary to have a relatively low area ratio which led to a decrease in potential performance.

The overall design requirements above were broken down into more specific requirements. This complete set of requirements was used as an aid in making design decisions. For example, the requirement that the thrust chamber shall consist of a robust design led to the eventual decision to not attempt to create a movable pintle. It was decided that there was not enough information on temperatures inside the chamber to design a flight weight engine. It was therefore necessary to design a development heat sink cooled thrust chamber in order to gather the required temperature data.

Temperature and pressure data from the development hardware tests are provided and the flight weight engine design is discussed. The project was entirely student based. Students performed all of the work necessary including all thrust chamber design work, thermal analysis, structural analysis, facility design, facility buildup, component testing, thrust chamber testing, and data analysis. Various professors and engineers in industry provided valuable advice and insight during design reviews.