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QUANTITATIVE VISUALIZATION STUDIES OF SELF-PRESSURIZING PROPELLANT TANK DYNAMICS

Abstract

Hybrid rockets are commonly configured using nitrous oxide as a self-pressurizing oxidizer, forcing the liquid from the tank and into the combustion chamber using its own high vapor pressure. This set-up eliminates the need for a pressurization system or turbopump, but generates other problems. The fluid mechanics and thermodynamics of this emptying tank are complex and without an accurate model for them the prediction of the oxidizer flowrate and hence motor performance is impossible.

To date several models have been developed for this system but recent studies have demonstrated by comparison with experiment that the models differ greatly in their predictions and none are accurate enough for design purposes. The likely cause for the disparity between experimental and model results is a fundamental lack of knowledge about the system and the kinds of heat and mass transfer mechanisms that are present.

A small scale experimental system was previously developed that incorporated a transparent pressure vessel to enable visualization of the internal tank flowfield. An earlier work reported some results with this system, describing the mechanisms in a qualitative manner. Significant amounts of boiling and condensation were observed and transient bubble phenomena appeared to be responsible for some characteristics of the pressure history.

Recently an improved system has been constructed. By using a pressure vessel manufactured from cast acrylic as opposed to the previous extruded polycarbonate, the optical clarity has been greatly increased. Along with a new camera that has been procured which allows for improved optical and digital resolution, these two features combine to facilitate quantitative measurement of bubble features and other flow quantities.

Pressure and temperature measurements have also been improved. Additional pressure transducers record pressure in the ullage, at the base of the tank, and in the exit lines. Temperature sensors in these locations allow the complete determination of the thermodynamic state. Fast response time thermocouples have been used to capture transient temperature changes.

A system of flat plate orifices are used to control the flow rate over a wider range than the previously used needle valves. This enables the evaluation of limiting cases with either slow or fast flow rates, equating to times required to drain the tank from 1 second to 500 seconds.