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DEVELOPMENT OF A THRUST CONTROL SYSTEM FOR ROCKET ENGINES

Abstract

In the aerospace industry, a thrust control system on rocket engines is fundamental to the engine operation process in its flight envelope to accomplish all mission requirements. The thrust modulation has been studied through years of research in many countries. However, in general, flow control systems have complexity, regional availability and costs issues, making it inaccessible for smaller companies, agencies or laboratories. A lack of flow control solutions for aerospace applications on the Brazilian market for research laboratories and universities was the main motivation of the current research. In this work a thrust control system, with propellant mass flow rate control, was designed, built and tested in three years project at the Chemical Propulsion Laboratory (CPL) of the University of Brasília. A reliable, low-cost flow control system consists mainly of CoTS components and allows a wide range of flow regulation. It consists of the control valves, hydraulic lines, servo motors, pressure and temperature sensors, feedback electronic system, DAQ and control systems, and homemade software. A set of the design requirements for the current development projects have been defined in terms of the flow characteristics, response time, materials compatibility, electric and electronic compatibility, minimal size, mass and volume, reliability, ambient conditions, etc. The system characteristics have been proven in a big number of experiments working with gaseous (air, oxygen) and bi-phase (nitrous oxide) self-pressurized propellants, and water as a model liquid. The whole system was tested on a series of cold flow and firing tests, as well as control, impermeability of the case, response time, integrity, and repeatability. It was found that control of the purely gaseous and liquid flows is relatively simple and well-predictable by analytical models when compared with bi-phase flows. As an example of the thrust control system application, the study of the nitrous oxide control is shown in current work as one of the most complex (from the computational point of view) fluids used in hybrid rocket motor applications. The valve flow and discharge coefficients have been found experimentally for various valve opening levels and flow conditions. As a result, empirical relations between the flow characteristics and the control signal were found experimentally, allowing us to build an efficient real-time thrust control algorithm implemented in control software. The thrust control system has been widely used in the testing of hybrid rocket motors and ramjets developed at CPL, achieving TRL = 5 for aerospace applications.