Abstract

Cryogenic rocket engines using Liquid Oxygen (LOX) and Liquid hydrogen (LH_2) propellant combination are used in the satellite launch vehicles, in view of their higher performance. Based on the propellant feed systems, the engines are grouped into pressure-fed engines and pump-fed engines. While most of the advanced countries have operational cryogenic engines, the Indian Space Research Organisation (ISRO) is developing cryogenic rocket engines for the Geo-synchronous satellite launch vehicle (GSLV).

Two experimental pressure-fed cryogenic engines have been designed, and successfully hot tested using LOX and LH_2. A full scale pump-fed engine working on staged combustion cycle (SCC) is in advanced stage of development. Another pump-fed engine working on Gas Generator cycle is in the preliminary stage of development for meeting the future higher payload launch capabilities. The engine parameters such as thrust and mixture ratio should be regulated for the safe and efficient operation of the engine with minimum propellant outage. This dissertation details the design and development of thrust and mixture ratio regulation systems of these cryogenic engines. A large number of ISRO Scientists / Engineers are working on the development and testing of various sub-systems of the cryogenic engines. Only the contribution of the author of the dissertation in the development and testing of various regulation systems is highlighted.

For the pressure-fed cryogenic engines, a propellant flow and mixture ratio regulation system using cavitaitng venturies as the flow control element has been developed and used for the hot tests. Detailed studies have been carried out for the development of venturies. Performance equations for the engines have been generated and the engine performance has been estimated by analytical studies during the design phase. Cold flow tests have been conducted using LOX and LH_2, and the performance parameters obtained analytically were verified by experimental results and suitable modifications were incorporated before the hot tests. The regulation system, controlled the propellant flow within the prescribed

limits and ensured the successful hot firing of the engines. Hot test results and estimated performance parameters were found to be in good agreement.

The thrust and mixture ratio regulation systems of pump-fed SCC engine are designed in closed loop mode with two independent electro-mechanically actuated flow control valves. The necessary control algorithms were developed. A mathematical model of the integrated engine system has been developed and the response of different engine sub-systems while operating the regulation system have been studied. Qualification tests and test methodology for the system validation and acceptance have been developed.

In the case of GG cycle engine, different thrust and mixture ratio regulation schemes were studied and an open loop thrust and a closed loop mixture ratio regulation systems have been developed. A flow control system was developed and employed for testing a sub scale Gas Generator.

The studies presented in this thesis have been useful for the development of cryogenic engines at ISRO.

Key words : Cryogenic rocket engines, Thrust regulation, mixture ratio regulation, Engine cycles, Algorithms for engine regulation, mathematical model, Engine hot tests.