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DESIGN AND DEVELOPMENTAL CHALLENGES OF SLOW BURNING SOLID BOOSTER FOR SUB-ORBITAL HYPER SONIC RE-ENTRY EXPERIMENT

Abstract

Newly developed slow burning solid booster is chosen for the first stage of Reusable Launch Vehicle-Technology Demonstration flight programme of ISRO. The real challenge for the grain design was to achieve an action time of 90 s and deliverable thrust of 300 kN to limit the dynamic pressure up to 35kPa in transonic regime within the diameter constraint of 1 m of the motor along with prescribed thrust-time profile. The qualified slowest burn rate propellant available had a burning rate of 5mm/s, which would give a motor action time of 50 s only. Among the large number of burning rate retardant, oxamide was finally selected based on its effectiveness in bringing down the burning rate to 3.15mm/s and maintaining the mechanical properties. The oxamide decomposes in the same temperature regime, liberating ammonia and retarding the decomposing process of Ammonium Perchlorate, enabling to reduce the forward reaction for liberating oxygen in the reversible chemical reactions and finally helps for lowering the burning rate of propellant. Nearly 3 percentage of oxamide is required to bring down the burning rate to the required level. As a result, specific impulse reduced by 3s compared to its parent uncatalysed propellant. In addition, the propellant exhibited slightly higher ignition delay. Newly designed igniter with larger action time was used to increase overlap to wipe out the doubt of initial hang firing. Total solid loading (Ammonium Perchlorate +Aluminum + Oxamide) of the finalized formulation was 85 percentages. A detailed study was carried out for the length to diameter and port area to throat area ratio to modulate the pressure thrust during transient phases. Several grain and configurations were worked out to avoid erosive burning and acceptable mass flux ratio of less than 60. Mechanical properties, interface properties, instability at low pressures and ballistic properties were evaluated and established after large number of testing in lab scale and motor level. Motor was inducted in to flight after two successful static tests. Mid-web anomaly and throat erosion studied from two full scale static tests and perturbed for flight. The close match of ballistic parameters gave the confidence for further processing of the flight motor. The achieved ballistic performance of the motor in flight was close to the pre-flight prediction, and within the mission limits. The challenges faced in the design, development, qualification, realization of the motor and performance of the flight motor is presented in detail.