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THERMO STRUCTURAL ANALYSIS OF SOLID ROCKET SCARFED NOZZLE WITH COMPOSITE ABLATIVE LINERS FOR CREW ESCAPE SOLID MOTOR

Abstract

Crew Escape systems (CES) is one of the most critical sub-systems in a human rated launch vehicle. CES has four different types of solid Motors. One is the High altitude Escape Motor (HEM). This Motor has the scarfed Nozzle region at the divergent aft end side which is different from conventional Nozzle to accommodate the Nozzle inside the envelope of the crew module shroud. The composite ablative phenolic liners are bonded to the Nozzle metallic hardware by means of adhesive. The structural integrity of this scarfed Nozzle region due to temperature and pressure play an important role for the success of the Motor. The Nozzle hardware of this Motor comprises of three subassemblies connected together by flanged joint. Composite ablative liners are primarily designed to satisfy the thermal and internal ballistics constraints requirements. Though, metallic nozzle hardware are designed to bear the complete internal pressure loads, liners share a substantial part during operation due to its stiffness which is comparable with that of the metallic backup. In addition, the high thermal gradient also results in stresses near the inner surface of the liner. These stresses cannot be estimated by closed form solutions considering the complexity in geometry, direction dependent material property and arbitrary temperature distribution arising during operation. The temperature of the liner at its inner surface is the highest due to its direct contact with hot gases. The temperature within the liner decreases across thickness. It is required to be ensured that the temperature at the liner-hardware interface does not exceed the safe operating temperature. Thermo structural analysis of composite ablative liners is essential to estimate the complete stress state in liners and to arrive at the minimum available structural margins. The temperature and scarfed geometry make the analysis all the more complicated. Challenges in modeling liners with the 3-D contact surface elements are highlighted. Varying pressure load along the inner surface of the liners is simulated in an exclusive load step and additionally temperature data estimated from transient thermal analysis is applied in another load step. Temperature dependent thermal and structural properties are used for the analysis. The temperature distribution across the liner thickness and stresses in the liner and metallic Nozzle are reported at different cross sections and their criticality is analysed. This paper highlights the integrated 3-D Finite Element modeling and analysis of composite ablative liners of Solid Rocket scarfed Nozzle.