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THERMO STRUCTURAL ANALYSIS AND TEST RESULTS OF SOLID ROCKET MOTOR SUBMERGED NOZZLE THROAT WITH 4-D CARBON-CARBON (C-C) AND GRAPHITE MATERIAL

Abstract

The Nozzle of the 7 ton propellant loaded upper stage Solid rocket Motor has convergent subassembly which interfaces with submerged flex Nozzle and divergent sub assembly. The component under discussion is the throat material which is bonded to metallic convergent hardware with back up material of silica phenolic (SP) and carbon phenolic (CP) ablatives. The thermal, chemical, and mechanical environments produced by solid propellants introduce many materials problems in the development of rocket nozzles. The interaction of environmental conditions together with the usual requirement that dimensional stability in the nozzle throat be maintained makes the selection of suitable nozzle materials extremely difficult. Graphite material is being used as nozzle throat for the past three decades in the above upper stage motor. It is very difficult to get good quality and consistent characteristics of graphite material now a days. Also erosion or cracking due to thermal stresses is the main problem with graphite. Hence indigenously developed 4D Carbon-carbon (C-C) material was replaced with graphite for the Nozzle throat. Because Carbon-carbon are promising materials for use in space applications, due to their excellent thermal and mechanical properties. Carbon-carbon (C-C) is the material which is having lower density, lower coefficient of thermal expansion, good dimensional stability, higher erosion and thermal shock resistance, low out gassing and insignificant change in mechanical properties at elevated temperatures which make C-C as ideal candidate for various space applications especially the throat of Nozzle in the Solid Motor. The bonding integrity between the throat, SP,CP ablative materials and the required gap between the sub system like between the throat and divergent and throat and Nose insert liner is very important with respect to process and functional point of view. If the gap is less between the system then throat material will slide with other and causes failure of the throat. More gap will allow the leak path to the metallic hardware. Hence in order the assess the above, detailed integrated 2-D thermo structural analyses were carried out with 4D C-C and graphite material using in house tested thermo physical properties of the above. Full scale level static test with both the throat material was carried out and post test inspection showed that the good comparison with the prediction. This paper covers the details of the finite element approach, thermo structural analyses and comparison of its results with post test inspection.