MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Interactive Presentations (IP)

Author: Mr. khadar voli
Indian Space Research Organization (ISRO), India

Mr. J Jayaprakash
ISRO, India
Dr. Jeenu Raghavan
Indian Space Research Organization (ISRO), India
Mr. Prasanth Chandrashekharan
Vikram Sarabhai Space Centre, Trivandrum, India, India
Mr. KIRAN PINUMALLA
Vikram Sarabhai Space Centre, Thiruvananthapuram-695 022, INDIA, India

NUMERICAL ANALYSIS OF THE TRANSIENT RESPONSE OF SPACE CAPSULE THERMAL PROTECTION SYSTEM FOR RE-ENTRY AERODYNAMIC HEATING

Abstract

Re-entry vehicle configurations are being investigated for various conceptual design options for manned missions in space arena for providing indigenous access to space station, for interplanetary missions, to carry out micro-gravity experiments and servicing and refueling of satellites in space. One of the major design aspects of manned re-entry vehicle is the selection and design of Thermal Protection Systems (TPS). TPS is used to withstand severe thermal environment and maintain a reusable launch vehicle structural temperature within acceptable limits during re-entry. Most of the metallic materials used in aerospace applications cannot withstand high temperatures. Hence identification of materials that withstand high temperatures is one of the critical issues in the design of manned modules. Re-entry vehicles follow different trajectories depending on the parameters such as the g-levels and the heat flux levels that the capsule can withstand and aerodynamic efficiency of the vehicle. Re-entry vehicles encounter different speed regimes from hypersonic to subsonic speeds. The aerodynamic heating rates varies for different speed regimes and hence heat flux values are taken from the literature for thermal analysis. In the present study, a thermal response analysis of high temperature insulation material due to aerodynamic heating is studied for a space capsule module using a finite element numerical model. Governing partial differential equations are formulated with reference to a fixed coordinate system for the in-depth phase changing ablatives. Weighted residual Galerkin finite element formulation is used for obtaining simultaneous equations which are solved iteratively using frontal solver. The numerical computation uses a non-linear charring ablation heat transfer code on an axi-symmetric body of space capsule. Developed code is validated with the results obtained from the standard software before attempting actual problem. Grid resolution and convergence requirements studied for accurate computation temperature distribution in the TPS material. Numerical experiments show that the code is numerically stable and solves a much wider range of problems. Results are presented at various time levels for different surface heat fluxes. The solver includes an arbitrary number of material layers, contact resistances between materials, temperature dependent material properties in the form of polynomial functions, general boundary-conditions and any type of material including the advanced access-to-space TPS materials like carbon-carbon or silica tiles. This code can be used for performing TPS sizing at every surface point on a vehicle based on constraints which include material temperature limits, maximum back wall temperature, and cumulative exterior heat flux.