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NUMERICAL SIMULATION OF IGNITION TRANSIENT IN SOLID ROCKET MOTORS

Abstract

The ignition transient of a solid motor is a short period operation during which a rapid pressure build-up occurs in the motor until the equilibrium operating pressure is reached. Large pressure transients produce high strains on the propellant, leads to stress concentration and crack in the grain. The overall ignition transient is composed of three components processes: 1) initial ignition event, 2) flame spreading and 3) final chamber filling. Development of reliable numerical tools for accurate prediction of ignition transient can contribute to limit the number of expensive experiments, development times and costs. Convection is found to be the dominant heat transfer mode in the heat transfer mechanism in the gas phase. However, radiation is also found to have a significant role. The flame spreading rate is calculated by successive heating-to-ignition along the propellant surface. Chamber filling process is calculated considering mass balance.

In the present study, an efficient conductive heat transfer code coupled to mass balance equation is developed in order to predict ignition transient in solid rocket motors with different grain configuration and propellant type. To estimate the temperature distribution in the propellant, a time-dependent, axi-symmetric, non-linear, implicit finite element heat transfer code is developed for heat diffusion equation with moving surfaces. Heat transfer from combustion products of igniter and propellant to the propellant grain surface is taken into account. Weighted residual Galerkin finite element formulation is used for converting heat diffusion equation into finite elemental equations. The resulting non-linear elemental equations are solved iteratively using frontal solution technique. Validation of code is done with a separate non-moving surface problem of graphite throat insert in a rocket nozzle. The propellant grain burn back profile is computed for every millisecond assuming that the propellant element burns if the temperature is above a threshold temperature. The resulting new burn back profile is used for generating a new non-uniform finite element mesh in the unburned propellant. Convective and radiative heat transfer co-efficients are computed along the propellant grain based on the empirical equations available in literature. The first order ordinary partial differential equation for mass balance is solved using Runge-Kutta fourth order time stepping scheme. The present numerical model has been validated using the measured data of various ISRO motors. Good agreement of the calculated pressure transients with the measured data indicated that the code is capable to simulate ignition transient of the solid rocket motors of different configurations.