SPACE PROPULSION SYMPOSIUM (C4)
Poster Session (P)

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EFFECT OF SURFACE CONTAMINATION ON IGNITION TRANSIENT IN SOLID BOOSTERS

Abstract

Ignition transient of solid rocket motor is a very short duration phenomenon controlled by complex heat, mass and momentum transfer processes of propellant combustion. Longer ignition transient which results in large ignition delay is not favourable in solid motors and can cause mission failure. Moreover, in the case of paired motors, large ignition delay of one of the motors may result in huge thrust imbalance beyond the control envelope. Hence, accurate prediction of ignition transient is very important for the successful mission of a launch vehicle. Many factors such as 1) low nozzle closure burst pressure 2) low burning rate of the propellant and 3) presence of contaminants like grease, frost, or chemical deposits on the propellant surface affect the ignition delay. In the present study, we look into the possibility of large ignition delay in solid motors due to contamination of the propellant surface by silicon grease which is used as a lubricant on the mandrel surface for the easy removal of mandrel. The result is compared with the large ignition delay observed in one of the test of a large booster motor and the cause of the delay is attributed to the possible surface contamination by silicon grease.

The ignition transient is computed using the mathematical model working based on the coupled solutions of heat diffusion and mass balance equations. In the model, two dimensional transient heat conduction equation in cartesian is discretized using Galerkin's weighted residual finite element formulation and the simultaneous equations are solved iteratively using frontal solution technique. Runge-Kutta fourth order time stepping scheme is used for solving the mass balance equation. Heat flux experienced by the propellant grain surface is computed from the empirical correlations available in literature. As the propellant being an insulating material, fine mesh (quadrilateral elements) is employed at the propellant surface exposed to hot combustion products for capturing the temperature gradients. A gas temperature of 2500 K (based on the composition of ignite propellant) is assumed for the combustion products from the igniter. Stability analysis of the numerical scheme is performed for different mesh densities and time steps. Rate of combustion gas generation and flame spreading speed is estimated based on motor propellant critical ignition temperature criteria. The study indicated that a thin grease layer on the surface may produce an ignition delay as that observed in the tested motor.