SPACE PROPULSION SYMPOSIUM (C4)
Propulsion System (2) (2)

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INVESTIGATION OF IGNITION TRANSIENT PROCESS INSIDE A LONGITUDINAL SOLID PROPELLANT CRACK

Abstract

Cracks may exit in solid propellant grains as a result of manufacturing defects, aging or mechanical damage. The propagation of cracks may significantly increase burning surface area, thus initiating combustion chamber over-pressure which is the main characteristic of a transition from deflagration to detonation (DDT). Therefore, such gas permeable solid propellant grains were observed more likely to undergo a DDT process. To study the gas dynamic and heat transfer phenomena within a single isolated crack, a 3-D geometric model with a longitudinal semi-elliptic crack was constructed. Concerning the influence of propagation of jet from the igniter in a solid rocket motor on excess pressure and flame spreading phenomena in cracks, flow regions around the opening of the crack were also included in the above geometric model. CFD simulations were performed using ANSYS CFX for modeling the conjugate heat transfer in the combustion channel and the crack cavity. With high speed hot gases flowing into crack cavity, strain fields can be considerably complex and flow separation may exit. An Omega-Based Reynolds Stress Model was applied in this paper instead of two-equation turbulence models. In order to avoid the step function change in burning rate, a simple two-temperature criterion is used to achieve full ignition within a finite time interval. As the erosive-burning and dynamic-burning effects are concurrent in the crack combustion environment, the burning rate calculation was proceeded with an approximation method. Results showed that ignition shock wave can spread into the crack and cause complex flow structure within the crack cavity. Besides that extremely high excess pressure and pressurization rate were observed at the points along the crack front, the convective heating phenomena was highly non-uniform while the shock wave swept over the crack faces. Moreover, as the reflection of the shock wave, vortices occurred which produced violent excess pressure fluctuation within the crack cavity in the initial stage. Thus, it is possible that the crack propagate before the flame front reaches them. After the moving shock wave in the combustion channel passed by, there was a decrease in the intensity of excess pressure fluctuation over time while the propellant surface temperature increased continuously. An ignited region located at the crack front near to the channel surface in downstream direction was generated long before the out flame front reached the crack entrance. And pressure there was always relatively high for igniter jet impingement.