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Studies on Pre-ignition Chamber Dynamics of Solid Rockets with Different Port Geometries

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Abstract : In this paper numerical studies have been carried out to examine the starting transient flow features of high-performance solid propellant rocket motors with different port geometries but with same propellant loading density. Numerical computations have been carried out using a 3D SST k-ω turbulence model. This code solves standard k-omega turbulence equations with shear flow corrections using a coupled second order implicit unsteady formulation. In the numerical study, a fully implicit finite volume scheme of the compressible, Reynolds-Averaged, Navier-Stokes equations are employed. We have observed from the numerical results that in solid rocket motors with highly loaded propellants having divergent port geometry the hot igniter gases can create pre-ignition thrust oscillations due to flow unsteadiness and recirculation. Under these conditions the convective flux to the surface of the propellant will be enhanced, which will create reattachment point far downstream of the transition region and it will create a situation for secondary ignition and formation of multiple-flame fronts. As a result the effective time required for the complete burning surface area to be ignited comes down drastically giving rise to a high pressurization rate (dp/dt) in the second phase of starting transient. This in effect could lead to starting thrust oscillations and eventually a hard start of the solid rocket motor. We have also observed that the igniter temperature fluctuations will be diminished rapidly and will reach the steady state value faster in the case of solid propellant rocket motors with convergent port than the divergent port irrespective of the igniter total pressure. We have concluded that the thrust oscillations and unexpected thrust spike often observed in solid rockets with non-uniform ports are presumably contributed due to the joint effects of the geometry dependent driving forces, transient burning and the chamber gas dynamics forces. We also concluded that the prudent selection of the port geometry, without altering the propellant loading density, for damping the total temperature fluctuations within the motor is a meaningful objective for the suppression and control of instability and/or pressure/thrust oscillations often observed in solid propellant rocket motors with non-uniform port geometry.

Keywords : ignition transient, solid rockets, starting transient, thrust transient

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