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TWO DIMENSIONAL AXISYMMETRIC NAVIER-STOKES ANALYSIS OF HYBRID ROCKET INTRINSIC INSTABILITY

Abstract

Combustion instability is one of the inherent disadvantages in hybrid motors which need to be addressed before hybrid motors can play a significant role in major space applications. The presence of this phenomenon in the low-frequency spectrum (Hybrid Intrinsic Instability – HII) has been reported in several motor tests. The reason has been attributed to the presence of boundary layer time lag in the hybrid turbulent boundary layer - fuel from the burning surface takes finite time to reach the flame region and subsequently there is a delay in the transfer of heat to the burning surface. Our previous work attempts to investigate this phenomenon through a computational approach. The numerical model consisted of a Quasi 1-D gas dynamics model for solving a Euler flowfield, a chemical model using CEA, an analytical heat transfer model (since implicit heat transfer cannot be simulated in a Eulerian flowfield) and a 1-D solid fuel thermal conduction model. Unsteady simulations were carried out. No instabilities were found when the delay experienced by wall heat flux to the changes in the regression rate is not modelled explicitly. But, upon consideration of the delay, at first an oscillating periodic increase in the regression rate and chamber pressure is observed (linear regime) – which then transitions into a non-linear limit cycle. Using the FFT of pressure oscillations, peak in the low-frequency spectrum – corresponding to HII could be clearly seen along with other peaks corresponding to other natural modes of the system. But, this theory suggests that such an intrinsic phenomenon should exist in 'all' hybrid motors. In reality, not all the motors tested were susceptible to HII. Also in some, the instabilities died out some time after the onset. So the factors which 'kick start' the instability and also quench it are not yet clearly understood. These factors clearly depend on the complex turbulent fluid flow interaction involving turbulent eddy generation, dissipation and heat transfer, occurring inside the combustion chamber. Therefore, in our current paper, we develop a CFD model which models the 2D-axisymmetric flowfield by solving Navier Stokes equations unsteadily. This eliminates the need for a distinct convective turbulent heat transfer model as before, because the heat transfer is implicitly simulated through the flowfield. Other subsystems remain as before. The numerical model is then tested for instability using the same methodology described above. A parametric analysis is also carried out and regions of stability plotted.