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VALIDATION AGAINST EXPERIMENTAL DATA OF NUMERICAL PREDICTION OF CHARACTERISTICS OF COMBUSTION INSTABILITY IN HYBRID ROCKET MOTORS

Abstract

Combustion instability is one of the disadvantages in hybrid motors that need to be addressed before hybrid motors can play a significant role in major space applications. A computational model has been developed for the purpose of simulation of hybrid intrinsic combustion instability widely reported in axial-injection type hybrid rocket motors.

The numerical modeling consists of a quasi-1-dimensional Eulerian flow solver, a chemical reaction model using CEA, an analytical model for heat feedback from flame (due to the absence of the simulation of a real boundary layer in an Eulerian flow) and a 1-D thermal conduction model inside the solid fuel. The local regression rate is obtained at each time step by solving the energy balance equation at the regressing surface.

A steady state solution is first reached and then a boundary layer delay in the heat feedback from the flame to the regressing surface is modelled into the system during the unsteady time-dependent simulation. From our previous study, it was observed that under the presence of this boundary layer delay, the system becomes unstable and the pressure oscillations grow from an oscillating linear region into a nonlinear limit cycle region. A finite positive DC shift is also observed. A possible explanation for the unstable behavior is provided through a hypothesis which considers the effect of negative damping causing self-excited oscillations. The explicit time delay for the movement of the unburnt fuel from the regressing surface to the flame region is further modelled. Upon modelling this, an increase in the amplitude of oscillations and DC shift is observed.

This paper particularly highlights the validation of the numerical results obtained with the above mentioned methodology against existing experimental data in literature. In particular, the validation is carried out for the prediction of frequencies of different modes (using FFT of pressure oscillation data), the amplitude of oscillations in the limit cycle region and the magnitude of DC shift. Finally, based on the results, conclusions are drawn on the accuracy of the numerical predictions. Limitations of the current modelling and subsequent upgrades for the model would also be noted.