SOLID FUEL REGRESSION IN HYBRID ROCKETS

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Hybrid rocket combustion has important effects on the rocket performance. One of the primary parameters in the analysis of the performance of the hybrid rocket engine is the regression rate of the solid fuel. In the previous studies, experimental and analytical investigations have been conducted in order to find correlations to predict correctly the regression rate. Numerical computations are becoming more important in the estimation of the characteristic parameters of such a complex combustion which embraces many different phenomena. Many studies in the past few years have theoretically claimed, or experimentally shown, a possible dependence between the regression rate itself and the chamber total pressure; however, agreement is needed about the targeted trend. The cause of the behavior is generally traced back to the presence of oxygen below the flame zone and of heterogeneous reactions occurring at the surface.

The experimental program performed for the present work at the Space Propulsion Laboratory of the Politecnico di Milano shows, within the explored operating conditions and the associated uncertainty bands, a neutral trend for the solid fuel regression rate with increasing pressure. The formulation tested was HTPB in Gaseous Oxygen (GOX) at pressures ranging from 4 to 16 bar.

Two analytical models that account in general for neutral or pressure dependent behavior of a given experimental data set have been then developed, together with the corresponding numerical simulations. The first model assumed similarity in the steady-state boundary layer for oxygen flow over the solid fuel surface. It uses a turbulent diffusivity and a turbulent viscosity. Gas-phase and solid-phase behaviors are coupled with each other and with the surface pyrolysis rate. The experimental results are used as an input to the developed model, in order to fit a semi-empirical law for the regression rate that could also interpret a possible pressure dependency.

The second analytical study uses a multi-dimensional, unsteady reacting flow computation using a two-equation model of turbulence. The surface pyrolysis arte and the multi-dimensional, unsteady solid-phase heat transfer are coupled with the gas-phase. This model also predicts the regression rate of the HTPB/GOX formulation and its sensitivities to some operating parameters, such as combustion chamber pressure, oxygen inlet temperature and mass flow rate. Furthermore, the analysis of the other variables is used to explain the experimentally observed regression rate behavior. Particular emphasis is given to the effect of the oxygen between the flame and the surface which is considered responsible for the pyrolysis process enhancement.