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HEAT AND MASS TRANSFER ANALYSIS FOR PARAFFIN / NITROUS OXIDE BURNING RATE IN HYBRID PROPULSION

Abstract

This research presents a theoretical study consisting of a physical-mathematical model for the combustion of liquefying fuels in hybrid combustion chambers, accounting for blowing effect on the heat transfer. A particular attention is given to a paraffin / nitrous oxide hybrid system. The use of a paraffin fuel in hybrid propulsion has been considered because of its much higher regression rate enabling significantly higher thrust compared to that of common polymeric fuels. The model was developed to predict the overall regression rate (melting rate) of the fuel and the different mechanisms involved, including evaporation, entrainment of droplets of molten material, and mass loss due to melt flow on the burning fuel surface. Prediction of the thickness and velocity of the liquid (melt) layer formed at the surface during combustion was done as well. The process of the paraffin-based (liquefying) hybrid fuel combustion occurs in a three-phase environment: solid, liquid, and gas. The contributions of the three mass loss mechanisms mentioned above to the overall mass loss rate (melting rate) are determined on the basis of heat and mass transfer balances in the gas-liquid and the liquid-solid interfaces, accounting also for the blowing effect resulting from the fuel surface gasification. Applying the model for an oxidizer mass flux of 45 kg/(s m2) it was found that 21% of the molten liquid is vaporized, 30% enters the gas flow by the entrainment mechanism, and 49% reaches the end of the combustion chamber as a flowing liquid layer. When increasing the oxidizer mass flux in the port, the effect of entrainment increases while that of the flowing liquid layer along the surface shows a relatively lower contribution. Yet, the latter is predicted to have a significant contribution to the overall mass loss. In practical applications it may cause reduced combustion efficiency and should be taken into account in the motor design, e.g., by reinforcing the paraffin fuel with different additives. The model predictions have been compared to a series of experimental results revealing good agreement.