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OPTICAL ANALYSIS OF LIQUID FILM INSTABILITIES IN PARAFFIN-BASED HYBRID ROCKET FUELS

Abstract

The interest in hybrid rocket propulsion has been renewed in recent years due to the discovery of liquefying fuels (e.g. paraffin), which show higher regression rates with respect to the classical polymeric ones. This is caused by a different combustion mechanism typical of fuels which are able to form a low viscosity and surface tension liquid layer over their burning surface. During the combustion, the high velocity gas flow in the fuel port induce instabilities in the melt layer (Kelvin-Helmholtz instability), which cause entrainment of liquid droplets from the fuel surface into the oxidizer gas flow. Although many studies have been done in recent years on this topic, investigations still need to be performed in order to better understand the combustion mechanism responsible for the droplets entrainment. Therefore, optical investigations on the combustion behavior of paraffin-based hybrid rocket fuels in combination with gaseous oxygen (GOX) have been conducted in the framework of this research. Combustion tests were performed in a 2D single-slab burner with windows on two sides at atmospheric conditions. High speed videos were recorded and analyzed in detail by using an automated video evaluation routine. Two different decomposition techniques (Proper Orthogonal Decomposition and Independent Component Analysis) were applied to the scalar field of the flame luminosity and the most excited frequencies and wavelengths of the wave-like structures characterizing the liquid melt layer were computed. The fuel slab composition and configuration and the oxidizer mass flow have been varied in order to study the influence of these parameters on the liquid layer instability process. The main focus of the research is to understand the relation between the unstable waves which enable the droplets entrainment process and the regression rate. The results show that the combustion is dominated by periodic, wave-like structures for all the analyzed fuels. The frequencies and the wavelengths characterizing the liquid melt layer depend on the fuel viscosity and geometry and on the oxidizer mass flow. Moreover, a dependency of the regression rate on the most excited frequencies and longitudinal wavelengths was found. This is important to better understand the relation between the increased regression rate and the onset and development of the entrainment process, which is connected to the amplification of longitudinal unstable waves caused by the high velocity gas flow over the fuel surface.