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VISUALIZATION OF HYBRID COMBUSTION BETWEEN PARAFFIN AND GASEOUS OXYGEN

Abstract

Historically, the adoption of hybrid rocket systems as a viable form of propulsion for both in-space and launch applications was inhibited by performance issues stemming from the use of low regression rate polymeric fuels, such as hydroxyl terminated polybutadiene (HTPB). In 1997, Karabeyoglu, Altman and Cantwell recorded a class of high regression rate fuels [1], including paraffin wax, which overcome many of the problems that have plagued classical hybrid motors. It was proposed that the high regression rate of these fuels is due to the formation of unsteady roll waves along the surface of the fuel grain under the shear forces of the oxidizer flow, resulting in droplet entrainment into the gas stream. Combustion visualization experiments conducted at atmospheric pressure have confirmed behavior consistent with this mechanism for chamber pressures below the subcritical pressure of paraffin.

This paper presents recent results in the form of video and pressure data from the Stanford hybrid combustion facility for the combustion of paraffin wax with oxygen at elevated pressures. The first section of the paper describes the hybrid combustion facility and the methodology adopted for testing. The second section of the paper focuses on results for the combustion of paraffin wax with oxygen across a range of chamber pressures. These results are contrasted against those for the combustion of classical fuels, such as HTPB, with oxygen. The third section of the paper is dedicated to the analysis of the unsteady video and pressure data. Various imaging techniques are employed to quantitatively and qualitatively improve the understanding of the combustion mechanism responsible for high regression rate hybrid fuels. Cross correlation particle image velocimetry is used to analyze droplet speeds. Frequency analysis techniques are adopted to characterize flow instabilities. Visual analysis of the flame profile is presented as a means of estimating boundary layer development within the combustion chamber. The paper concludes by summarizing the effects of changing mass flux and combustion chamber pressure on the entrainment mechanism.

[1] Karabeyoglu, M.A., Cantwell, B.J., and Altman, D., Development and Testing of Paraffin-Based Hybrid Rocket fuels, 37th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, No. AIAA 2001-4503, Salt Lake City, Utah, 2001.