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CHARACTERIZATION OF REGRESSION RATE AND COMBUSTION PROCESS IN A HIGH-PRESSURE 2D HYBRID ROCKET ENGINE WITH OPTICAL ACCESS

Abstract

Hybrid rocket engines (HRE) are a promising alternative to solid and liquid rocket engines as they are intrinsically safer and easier to manufacture. They are simpler in launch preparation and the thrust is controllable. One remaining problem of classic HREs is the low energy release rate of various fuels, which limits the engine efficiency and application flexibility. There are either high energetic fuels with low regression rates (e.g. hydroxyl-terminated polybutadiene (HTPB)) or low energetic fuels with higher regression rates (e.g. paraffin). To successfully employ HREs in various applications like boosters or upper stages, this problem has to be overcome.

As HTPB has many advantages over paraffin, the laboratory combustion chamber ARIEL was designed and commissioned by the German Aerospace Center (DLR) in Braunschweig to determine the regression rates of various HTPB-based fuel mixtures. The chamber has a rectangular cross-section and utilizes a two-dimensional slab fuel geometry. Four windows provide an insight into the combustion process and enable its characterization with contactless measurement techniques. The experiment allows studying the combustion process at high pressures of up to 25 bars, at high, pure oxidizer mass flows of up to 250 g/s and realistic combustion temperatures. While reaction kinetics is different under such realistic conditions, a large number of previously published studies were conducted with low chamber pressures, low oxidizer mass flows and/or diluted oxidizers. They didn't provide a representative impression of the process inside a realistic HRE.

Fuel mixtures based on HTPB were tested with 87.5 wt% hydrogen peroxide (HTP) as oxidizer. A HTP catalyst chamber was used to deliver a mixture of overheated steam and oxygen at about 650°C to the combustion chamber. This gas mixture mass flow enables self-ignition without an additional igniter system. To enhance the regression rates of HTPB-based fuel mixtures, research has been done in using fuel mixtures containing additional polymer particles. Fuel slabs made of pure HTPB were used as reference mixture. The regression rates during the experiments are measured with two ultrasonic probes. In addition the surface heights of the fuel slabs were measured before and after the experiments to obtain time-averaged spatially-resolved regression rates. A high speed camera, a two-color pyrometer and IR-measurements were also used.

The first results show a regression rate of about 0.6 mm/s for HTPB for chamber pressures of 25 bars depending on the oxidizer mass flow rate. Within this paper the regression rates and the properties of the combustion are characterized and extensively evaluated.