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IMPROVING ALUMINA-CAP CHARACTERISATION IN ALUMINIZED SOLID-ROCKET MOTORS WITH COMPUTER VISION

Abstract

In solid-rocket motors, micrometric aluminium particles are usually included in the propellant formulation to improve the motor performances. Nowadays, the design of the motor mostly relies on numerical simulations requiring representative models and accurate propellant parameterization. These simulations help in predicting the motor pressure oscillations, possibly harmful to the payload. Among the other sources, the thermo-acoustic instabilities (ITHAC) can manifest when pressure and heat release oscillations synchronize near the burning surface, within the acoustic boundary layer [1]. These phenomena are driven by the aluminium-droplet combustion which can distribute up to centimetres away from the burning surface, in function of the droplets size and velocity distribution. Such instabilities are difficult to predict due to the complexity of the phenomena, not-completely mature aluminium-combustion models and to limited experimental data. In recent years, the development of imaging techniques (i.e. high-speed shadowgraphy, laser interferometry) and the application of deep learning-based algorithms (i.e. UNET, Mask-RCNN, YoloV8, etc.) enabled the estimation of the aluminium-droplet size and velocity distributions with unprecedent precision [2]. Building on these advancements, this study tackles another important factor that has not been fully characterized: the effect of the alumina lobe. Aluminium agglomerates are partially covered by an oxide cap that modifies the droplet's structure and impacts the heat-release rate. The application of computer vision techniques to observe the alumina lobe is challenged by the aluminium-droplet rotation, resulting in partial or complete occlusions, by the quality of the experimental images, affecting the precision on the alumina lobe shape and size determination, and by the alumina-aluminium class imbalance, challenging the training of a deep learning model. This paper introduces possible solutions to such computer vision challenges, effectively extracting the characteristics of the oxide lobe from the experimental data thus opening a way towards correcting the models for the heat release.

[1] A. Genot, S. Gallier and T. Schuller, Thermo-acoustic instabilities driven by fuel droplet lifetime oscillations, Proceedings of the Combustion Institute, 37 (4), pp. 5359–5366 (2019).

[2] M. Airiau, R. W. Devillers, A. Chan Hon Tong and G. Le Besnerais, Evolution of aluminium droplets in solid propellant combustion by image analysis using deep learning, Dans EUCASS-CEAS 2023, Lausanne, Switzerland, EUCASS AISBL (2023).