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SOLID FUEL ANALYSIS IN HYBRID ROCKET ENGINE USING IMAGE PROCESSING

Abstract

Hybrid Rocket Motors (HRMs) combine solid and liquid propulsion advantages, enhancing safety and design flexibility. However, HRMs face challenges in internal ballistics and combustion dynamics, underscoring the need for accurate oxidizer feed and fuel interaction management. This study delves into HRM optimization through advanced image processing of combustion phenomena within a slab burner setup, focusing on the flame and fuel regression rate analysis.

We aim to deepen the understanding of HRM combustion dynamics, quantitatively analyzing flame luminosity and fuel regression, using high-speed video analysis to reveal flame behavior and fuel consumption patterns. This investigation intends to refine HRM performance and stability, correlating flame luminosity with performance metrics and validating results against recent studies (Moutette et al., 2022; Rutters et al., 2021; Repossi, 2022; Surina et al., 2022).

Image Processing: Utilizing Python, we leveraged OpenCV for image analysis. This included converting RGB images to grayscale, applying thresholding for image segmentation, and detecting contours to analyze flame characteristics and fuel regression rates.

Intensity Scale Extraction: We quantified flame intensity using OpenCV, adjusting threshold values manually for each video to ensure precise segmentation, considering variations in lighting and contrast.

Regression Rate Calculation: The fuel regression rate was calculated from the detected flame contours, with particular attention to high-pressure tests where flame spread complicates contour identification.

Challenges and Future Directions: High-pressure conditions posed significant challenges, necessitating manual adjustments for accurate flame segmentation. Future research could explore automated threshold adjustment methods to enhance analysis efficiency and accuracy.

Results: Analyzing the MOUETTE flat burner tests from April to May 2022 provided insights into paraffin regression rates under various oxidant mass flow rates and combustion chamber pressures. These tests, part of broader HRM dynamics research, utilized high-speed imaging to document flame intensity and fuel regression, contributing valuable data to the field.

Contribution: This concise exploration into HRM combustion dynamics aims to bolster motor efficiency and safety, offering empirical and theoretical insights to advance the aerospace field. By addressing current knowledge gaps and presenting a methodological framework for flame behavior and fuel consumption analysis, the study underscores the critical relationship between combustion processes and HRM performance.