

An Approach to Combustion Instability Analysis from High-Speed OH-PLIF Images using Dynamic Mode Decomposition

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초록 Abstract

DMD can fully characterize and quantify dynamically relevant coherent structures in a complex flow field by projecting it onto a simplified dynamical system with significantly fewer degrees of freedom. Coherent structures are extracted from three different data sets (one numerical and two experimental) and appropriately attributed to dominant flame dynamics without a priori knowledge of the reactive flow field. Numerically-constructed images and laminar flame OH-PLIF images served to validate DMD analysis and its application on combustion phenomenon, respectively. Based on these validations, DMD analysis of acoustically-forced swirl-stabilized turbulent flames was carried out using high-speed OH-PLIF images. Acoustic forcing at different frequencies and amplitudes were induced using a speaker. Dominant spatial structures and their energy contents in the recirculation zone or shear layer were accurately resolved with DMD. In addition to the global frequency response spectrum, DMD can provide detailed descriptions of spectrally pure coherent features that can be systematically correlated to underlying physics that drives combustion instability and provide a consistent interpretation. The findings presented in this study enable a step forward for experimental community in flame oscillation and combustion instability analysis. The key insight regarding complex interactions between acoustics, fluid mechanics and combustion will ultimately serve a critical role in developing detailed combustion instability models.