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NUMERICAL SIMULATION AND EXPERIMENTAL STUDY ON THE ATOMIZATION CHARACTERISTICS OF IMPINGING LIQUID JETS COUPLED WITH FORCED PERTURBATION

Abstract

Combustion instability is a critical technical problem common when developing liquid rocket engines. It is significantly characterized by periodic pressure oscillations in combustion chamber. Oscillating back-pressure causes periodic variation of pressure drop, thereby periodically varying injection velocity modulated by Klystron effect. To investigate injection and atomization characteristics coupled with forced perturbation, combustion instability could be further understood.

In this study, the effects of forced perturbation on atomization characteristics of impinging liquid jets were investigated numerically and experimentally. For the experiment, hydro-mechanical pulsator was used to generate pressure fluctuations of a certain frequency and amplitude in the feed line. The frequency varied from 447Hz to 3568Hz, and the amplitude from 0 to 50% of the average pressure. The corresponding Strouhal number ranged from 0.014 to 0.110, covering the stable and unstable states of the engine using impinging jet injector based on Hewitt correlation. High speed camera was used to capture the dynamic atomization process, and Phase Doppler Particle Analyzer (PDPA) was employed to measure droplet diameter and velocity distribution. For the numerical simulation, velocity inlet boundary condition with perturbation of a certain frequency and amplitude was set using a tree-based adaptive algorithm that incorporates a time-dependent incompressible two-phase Navier-Stokes solver to simulate atomization process. First, the numerical scheme was validated by comparing droplet diameter distribution with experimental data. Numerical results were found well consistent with experimental data with the maximum refinement Level-9. For the time-varying atomization parameters, e.g. Sauter mean diameter of an interrogation window downstream the impingement point, FFT analysis was conducted, as well as the correlation analysis with inlet velocity. According to the results, when the amplitude of pressure fluctuation is lower than a critical value, the atomization filed will not reflect obvious response. The atomization field will vary obviously only when the amplitude of perturbation is higher than the critical value. There exists significant difference between natural atomization filed and atomization field with forced perturbation. Atomization parameters do not manifest periodicity in natural atomization field while these parameters with forced perturbation exhibits good periodicity. According to the correlation analysis, the higher the amplitude of pressure drop fluctuation is, the larger the correlation coefficient will

be. The phase relation between inlet velocity and periodic atomization field is determined by perturbation frequency. The study can help to reveal the mechanism of combustion instability and achieve the active control of combustion instability in liquid rocket engines.