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RESEACH OF THE OXIDIZER-RICH PREBURNER-PIPE SYSTEM DYNAMIC CHARACTERISTICS

Abstract

Oxidizer-rich preburner-pipe coupled system is an important local system of the staged combustion LOX/kerosene rocket engine. The high pressure, large LOX flow rate, the mixture ratio far from the stoichiometric ratio,low gas temperature and long gas residence time make the coupled system very sensitive for disturbances, even produce spontaneous instability. In this paper, the linearized models for every component in the preburner-pipe system suiting acoustics analysis were established, including the liquid pipe model, open swirl injector dynamics model, combustion model of smooth burnout curve and one dimensional distributed parameter gas flow model. The validity of the open liquid swirl injector model is confirmed by the test data from reference. The distributed characteristic of the combustion process is described by established the reasonable relation curve of the burned propellant and the residence time. By the test data from reference, the gas flow model is also validated that, it not only describes the entropy wave during the low frequency range, but also indicates the longitudinal acoustic oscillation of the gas segment, so it can be used during quite wide frequency range. At last, the frequency characteristics of preburner under the fluctuation of propellant pipe inlet pressure and the entire system stability at certain boundry conditions are studied by transfer matrix method, and the influencing rules of some factors on the frequency characteristics and stability of the system are also ananlyzed. The results indicate that, distinct entropy wave exists in the preburner during low frequency range, and larger slope of combustion temperature with mixture rate causes more apparent influence of entropy wave. Kerosene pipe inlet pressure disturbance produces higher entropy wave amplitude than LOX. With increasing disturbance frequency, the response amplitude of the system is quite high near the acoustic resonance frequency of liquid pipes or the preburner. The system may easily encounter coupled instability, when the resonance frequencies of liquid pipe and preburner are close to each other. And the mechanism of the coupled instability is identified that the injector position should be the flow rate antinode of the standing wave in the liquid pipe. Extending the burnout curve reducing the amplitude of the frequency response illustrates, distributing combustion along the preburner axis will increase the stability of the system. Increasing the injection pressure drop or installing local resistance at right position of the pipe, will produce more oscillation energy dissipation and improve the coupled stability of the system.