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OXIDIZER-RICH PREBURNER-FEED SYSTEM MEDIUM FREQUENCY COUPLED STABILITY INVESTIGATION

Abstract

Oxidizer-rich preburner-feed 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. During the engine hot test, the first longitudinal pressure oscillation even spontaneously produced in the preburner. In this paper, in order to study the system coupled stability, the linear transfer matrix models for every component satisfying acoustics analysis are established, including liquid pipe model, open swirl injector dynamic model, flow regulator model, smooth burnout curve combustion model and one dimensional distributed parameter gas flow model, et al. The applied frequency ranges of these models include the first longitudinal acoustic frequency of preburner or feed pipe system. Based on these models, the amplitude frequency characteristics of preburner under the fluctuation of propellant flow rate are calculated, as well as the injection admittances of liquid oxygen and kerosene feed system. The coupled stability of preburner-feed system under different conditions are researched by using Nyquist stability method, and the influences of liquid oxygen injection pressure drop and the engine thrust level on the coupled stability are analyzed. The computation results agree with the engine test phenomenas. During the medium frequency range, preburner pressure has high response amplitude both for kerosene and LOX flow rate disturbance, and the response amplitude by kerosene flow rate disturbance is slightly higher than LOX disturbance. But on other hand, due to large volume of LOX main manifold, oxygen injection admittance has high amplitude during wide frequency, and is much larger than the kerosene injection admittance during the range of 600Hz-800Hz, which indicates that the oxygen feed system is easier to be disturbed under the preburner pressure fluctuation, and has larger flow rate feedback to the preburner. The physical mechanism of medium frequency coupled instability for preburner and feed system is LOX feed system outlet flow rate oscillation coupled with the longitudinal acoustic oscillation in preburner. Extending the burnout curve reducing the amplitude of the frequency response illustrates that distributing combustion along the preburner axis will increase the coupled stability of the system. Increasing the injection pressure drop, improving the injector inertia or decreasing the compliance of oxygen main manifold, will all reduce the LOX flow rate feedback and improve the coupled stability of the system.