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RESEARCH ON DYNAMIC CHARACTERISTICS AND CONTROL SCHEME OF KEROSENE-BASED SCRAMJET SYSTEM

Abstract

The scramjet engine has been researched about sixty years, but some problems, such as severe operating conditions and high nonlinearity, are still unsolved. Currently, few studies have been devoted to dynamic characteristics and control scheme of scramjet system. This paper mainly investigated the dynamic characteristics and control scheme on the kerosene-based scramjet system, which is a competitive scheme with high combustion performance and long-duration thermal protection. Supercritical/cracking kerosene with high pressure and high temperature is formed through motor-pump pressurization and heat exchanging in cooling channels. Then, supercritical/cracking kerosene from cooling channel exits is injected into the combustor, and reacts with compressed air to produce heat release and thrust. The key parts of such system are motor pump pressurization and kerosene-based regeneration cooling. Firstly, the system scheme design and parametric study for the scramjet system were conducted. For motor (gear) pump, the linear relationship between volume flow rate and rotating speed under steady state was obtained according to the experimental data. 2D/1D numerical simulation method was employed to model the unsteady reacting flow within the cooling channel and combustor. The total reaction with 10-species proportional product distributions was coded by C++ language for cracking, while multi-step chemical reaction for combustion. There exists remarkably coupling effects to heat exchanging between regenerative cooling and combustion. In order to understand the characteristics of kerosene cracking, heat transfer and fuel injection distribution, the DOE (Design of Experiment) method was used to obtain sampling points, and the parametric sensitivity was analyzed on the basis of trained sampling database. Then, different control-oriented models, such as static RBF model and transfer function, were established to model the scramjet engine performance and the dynamic characteristics of fuel supply system, respectively. The step response characteristics, frequency response characteristics, and responding time scale of main components were presented. The research results show that the dynamic characteristics of kerosene-based regenerative cooling are the predominate dynamic characteristics of the overall system. And, the general simulation model of kerosene-based scramjet system was built by AMESim and Simulink software. At last, the study for scramjet control scheme was carried out by means of numerical simulation method. Based on the thorough understanding of scramjet system, the relevant thrust control scheme, including stabilized and transition state circles, was carefully designed. And the designed control scheme can well meet thrust control need of the overall system.