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EJECTOR DEVELOPING OF VACUUM IGNITION TEST SYSTEM FOR UPPER-STAGE LH2-LOX ROCKET ENGINES

Abstract

To verify the ignition reliability of the upper-stage rocket engines at the corresponding height, it is necessary to meet the vacuum ambient pressure requirement at the ignition timing of the liquid rocket engine. Such a test is called vacuum ignition test. A corresponding system is configured to meet the vacuum pressure requirement, such as placing the engine in a vacuum chamber and pumping the vacuum chamber with a vacuum pump. To develop a high-attitude LH2-LOX rocket engine and carry out corresponding high-altitude tests, a vacuum chamber and a multi-stage ejector pumping system will be built. The engine emits a large amount of cold hydrogen from the nozzle a few seconds before ignition to pre-cool the equipment downstream of the injector panel. The estimated cold hydrogen temperature is between 90K and 300K. Because of the large amount of hydrogen, it is very difficult to pump vacuum chamber to the ignition ambient pressure of the engine. Fortunately, when the pressure downstream of the nozzle gets lower that a certain pressure P, the throat of the nozzle will no longer affect the pressure of the combustion chamber. That is, as long as the pressure in the vacuum chamber keeps lower than P, the ignition environment in the engine's combustion chamber is consistent with its real working environment. The key point of the test system then translates into how to pump and hold a vacuum chamber that discharges a large amount of cold hydrogen below P. A two-stage ejector for pumping will be built. Steam is supplied by multiple liquid oxygen alcohol gas generators. However, due to the small molecular weight of hydrogen, the heat exchange between cold hydrogen and steam is very significant. The ejector design experience parameter error will be relatively large. In this paper, two different types of ejectors are designed using theoretical methods. The single-phase CFD method and scaled ejector tests are carried out to validate the design. The effect of hydrogen temperature on ejector efficiency, the relationship between positions of the nozzle and ejector efficiency, the difference between hydrogen and air as gas been ejected, how to choose experience parameter for design and the difference between CFD and tests are researched in this paper. A multi-phase model is finally added to simulate the condensation of steam to improve the CFD model's accuracy.