Experimental Study on Dynamic Characteristics of Open-type Swirl Injector

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Abstract

Liquid rocket engines are operated with combustors where the high pressure combustion processes are done. This fact led the liquid rocket engine to have a great demand for combustion stability. Due to the great demand, extensive research has been done on combustion instability since 1940s. Despite the large amounts of human and financial resources invested on the research, the combustion instability is still an unsolved problem since it is a very complicated phenomenon which involves many physical phenomena. With these efforts for revealing the cause, efforts for suppressing the symptom of combustion instability has been made also. As the result, the baffle, which is the additional structures installed in the combustion chamber to suppress the combustion instability was developed in the United States and has been used widely in their engines. But these additional structures mean additional mass which is a critical disadvantage for a liquid rocket engine. Also it can spoil the combustion efficiency. But in Russia where the swirl type injectors are used, they tried to suppress the combustion instability by modifying the injectors. By this method, they were able to take out the instability without adding any structures. The study for this method is called injector dynamics. Combustion instabilities in a liquid rocket engine are generated by coupling between the heat release oscillations and the acoustic pressure oscillations in the combustor. This instability from the combustor can affect the injector and the feed line which are in front of the combustor. These transfers worsen the instability of liquid rocket engine. A dynamically properly designed injector can be used to prevent the transfer and suppress the combustion instability. For this reason, studying the dynamic characteristics of the injectors is essential to liquid rocket engine design. An open-type swirl injector was designed in order to investigate the dynamic characteristics of an open-type swirl injector through experimental study. A hydro-mechanical pulsator was installed in front of the manifold of the open-type swirl injector which produces pressure oscillations in the feed line. Pressure in the manifold, liquid film thickness in the orifice and the pressure in the orifice were measured simultaneously in order to understand the dynamic characteristics of the open-type swirl injector. The liquid film thickness was measured by electrical conductivity between two electrodes installed in the orifice as the method proposed by Lefebvre. A direct pressure measuring method was used to calculate the axial velocity of the propellant in the orifice and the mass flow rate through the orifice. These measured and calculated values were analyzed to observe the amplitude and phase differences between the input value in the manifold and the output values in the orifice. As a result, a phase-amplitude diagram was obtained which exhibits the injector's responses to certain pressure fluctuation inputs. The mass flow rate was calculated by the direct pressure measuring method and measured directly through the actual injection to ensure the method's accuracy. Furthermore, the difference between the open-type injector's dynamic characteristics and that of the closed-type swirl injector can be suggested for the selection of injector type during the designing process of liquid rocket engine.

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