MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Space Structures - Dynamics and Microdynamics (3)

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STUDY ON FLUID-STRUCTURE INTERACTION IN LIQUID ROCKET FEED SYSTEM

Abstract

In the flight of the large-scale launch vehicle using liquid rocket engines, the longtitudinal vibrations have always been observed. The phenomenon of closed-loop instability vibrations, generated by the interaction of the vehicle structure and the liquid propulsion system, is known as pogo. With respect to the pogo study, the solution to the fluid-structure interaction (FSI) in the liquid rocket feed system is proposed as one of the key points for the design and analysis of the launch vehicle. In present study, the liquid propellent feed lines were defined as a planar model with Poisson coupling and junction coupling, which could vibrate in the axial and lateral directions. Based on the FSI mechanisms along with the Timoshenko beam theory, the motion differential equations were set up for the feed lines, and then solved using the finite volume method (FVM). As a part of the work to design and develop the next generation launch vehicle, numerical FSI analysis on three different specific feed line models between the propellant tank and the pump were thus conducted. The first model was just a straight liquid oxidizer feed line for contrast. The second model was the feed lines consist of three straight pipes connected by two elbow pipes without middle restrictions. And the last one was the feed lines with full restrictions. The pressure curve of the first model appears many hackles oscillation compared with the solution to traditional water hammer model. These hackles demonstrate the effect of the stress wave. For the second model, the axial and lateral vibrations affect each other due to the junction coupling and, thereafter, the curve becomes very complex. As the interaction of axial and lateral vibration is reduced in the third model, the corresponding curve is close to that of the first one. The reasonable results with respect to the frequencies and modes indicate that the FSI affects the dynamic analysis remarkably, and thus show the necessity of the proposed FSI model. This study would give a reference to the liquid rocket feed system design, as well as facilitate the further study on pogo suppression for large-scale launch vehicles.