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FLOW-INDUCED VIBRATIONS OF LIQUID ROCKET ENGINE BELLOWS SUBJECTED TO INTERNAL HIGH PRESSURE AND VELOCITY

Abstract

Bellows are important compensation components of liquid rocket engine.The flow-induced vibrations in flexible bellows can cause the fatigue damage of structure.During the development of the Saturn V second stage engine,the problem of bellows fatigue failures caused by flow-induced vibrations had taken place.Currently,continuous development of high performance LOX/kerosene rocket engine takes more high demand for the bellows.Under the limits of structure size and weight,the bellows must satisfy the environment of high pressure,high flow rate and flow velocity.Thus,the research of flow-induced vibrations characteristics of high pressure bellows is important for improving the product structural reliability. In the first place,a finite element dynamic model has been developed for computing the natural frequencies of bellows.The results of modal analysis are compared with EJMA standard and Jakubauskas' method,and the agreement is found to be very well.Subsequently,the fluid-structure interaction simulation is adopted to deal with flow-induced structural vibrations in bellows.The pressure fluctuation on the bellows internal surface is obtained by large-eddy simulation(LES)of internal flow,and the vibration of the structural portion is simulated using Newmark integral method.The influencing rules of structure parameters,such as convolute tip width and convolute pitch etc,are analyzed by fluid-structure interaction simulation. Moreover,the bellow is placed immediately downstream of an elbow to determine the effect of nonuniform flow.By the test data from reference the fluid-structure interaction model is also validated,and the effect of upstream elbow of the bellows on critical velocities is analyzed. The results indicate that,the coupled of vortex shedding frequency in bellows and the structure mode results in the flow-structure coupled vibration.The upstream elbow of the bellows can cause a shift in the critical velocities and a higher convolute stress level.The numerical simulation in this paper is the feasibility method for flow-induced vibrations of bellows subjected to internal high pressure and velocity,and it can be taken a reference for product design.