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A NEW MODELING METHOD BASED ON MODAL VARIABLES FOR POGO ANALYSIS OF LIQUID ROCKETS

Abstract

Among all the Pogo modeling and analysis methods, Rubin provides a systematic method for advanced Pogo analysis of complex liquid rockets by introducing the finite element description of the propulsion system, which has been widely used. However, in order to improve the accuracy of the low-order modes of the propulsion system, the pipeline needs to be finely divided, resulting in the increasingly high dimensions of the propulsion system (while the high-order modes are not accurate). At the same time, the equations of the propulsion system and the structural system in in almost all Pogo models uses physical variables and modal variables, respectively. The combination of modal variables and physical variables may lead to great difference in the size of system coefficients and affect the numerical stability. Therefore, a new Pogo modeling and analysis method based on the unified description of modal variables is proposed. Considering the asymmetry of stiffness matrix caused by the pump dynamics and the probable singularity of system matrix, the decoupling form of propulsion system equations in modal coordinates is derived based on the theory of eigen-transformation. Then, the state space equation of propulsion system based on modal variables is derived by mode truncation. Furtherly, by coupling with the structural system described by modal variables, the Pogo state space model is established with the unified description of modal variables. In the proposed Pogo model, the dynamics of the propulsion system is described by modal variables instead of traditional physical variables, which is consistent with the fact that dynamics of structural system is usually described by structural modal variables. So the Pogo model with united descriptions of modal variables can intuitively reveal the coupling relationships between the propulsion system mode and the structural mode. Moreover, the proposed Pogo model has the advantages of non-singular and low dimensions, which can be directly applied to Pogo stability analysis and time domain simulation. Finally, numerical results of the Pogo analysis and simulation of a certain launch vehicle demonstrate the correctness and effectiveness of the proposed method.