Accepted Manuscript

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PII: S0022-460X(18)30576-5

DOI: 10.1016/j.jsv.2018.08.023

Reference: YJSVI 14314

To appear in: *Journal of Sound and Vibration*

Received Date: 17 April 2018

Revised Date: 9 August 2018

Accepted Date: 31 August 2018

Please cite this article as: D. Du, E. He, D. Huang, G. Wang, Intense vibration mechanism analysis and vibration control technology for the combustion chamber of a liquid rocket engine, *Journal of Sound and Vibration* (2018), doi: 10.1016/j.jsv.2018.08.023.

Intense Vibration Mechanism Analysis and Vibration Control Technology for the Combustion Chamber of a Liquid Rocket Engine

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ABSTRACT

High-amplitude vibration in the combustion chambers of large-thrust liquid rocket engines (LREs) has been the main concern of aerospace structural engineers in China for many years. Excessive vibration poses a serious threat to the structural safety of engine and the reliability of system operation. In this study, the structural vibration and gas pulsation data of an LRE during an intense-vibration test condition were analysed in detail. The coupling characteristics between the sound pressure and the vibration signal of a combustion chamber were determined. A 3D dynamic model of the combustion chamber structure was then established with the modelling method of the corrugated composite sandwich plate. The accuracy of the model was verified by the results obtained from operational modal analyses of an engine hot test. Moreover, a novel vibro–acoustic coupling analysis method was proposed, and a vibro–acoustic coupling model for the combustor was established. By examining the acoustic and structural dynamic characteristics and acoustic–solid coupling relationship of the combustor, we were able to show the mechanism of intense vibration under the coupled resonance of acoustics and vibration. Finally, an engineering solution for suppressing the intense vibration of combustion chamber structures was proposed. We found that the intense vibration of the combustion chamber was caused by the 'rough combustion' or 'oscillatory combustion' in the combustor. The first-order longitudinal acoustic mode coupled with the three-node diameter structure mode, and thus formed a coupled resonance and generated a high dynamic gain because of the chamber pressure pulsation. The most effective and economical means of intense vibration suppression in combustion chamber structures is to decouple the acoustic–vibration coupling mode through structural improvements. In this way, the anti-resonance margin of the improved structure became larger than 7.5%. With the improved design, the vibration acceleration of the combustion chamber was reduced by two-thirds, and the effectiveness of the improvement measures was verified.

***Keywords*:**

Vibro–acoustic coupling; Intense vibration; Combustion chamber; Liquid rocket engine

1. Introduction

Combustors in LREs are important devices that convert the chemical energy of propellant into gas heat energy.

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