World Academy of Science, Engineering and Technology
International Journal of Mechanical and Industrial Engineering
Vol:19, No:08, 2025

An investigation of the High-frequency Isolation Performance of Quasi-Zero-Stiffness Vibration Isolators

Authors : Chen Zhang, Yongpeng Gu, Xiaotian Li

Abstract : Quasi-zero-stiffness (QZS) vibration isolation technology has garnered significant attention in both academia and industry, which enables ultra-low-frequency vibration isolation. In modern industries, such as shipbuilding and aerospace, rotating machinery generates vibrations over a wide frequency range, thus imposing more stringent requirements on vibration isolation technologies. These technologies must not only achieve ultra-low starting isolation frequencies but also provide effective isolation across mid- to high-frequency ranges. However, existing research on QZS vibration isolators primarily focuses on frequency ranges below 50 Hz. Moreover, studies have shown that in the mid-to high-frequency ranges, QZS isolators tend to generate resonance peaks that adversely affect their isolation performance. This limitation significantly restricts the practical applicability of QZS isolation technology. To address this issue, the present study investigates the high-frequency isolation performance of two typical QZS isolators: the mechanism type three-spring QZS isolator mechanism and the structure and bowl-shaped QZS isolator structure. First, the parameter conditions required to achieve quasi-zero stiffness characteristics for two isolators are derived based on static mechanical analysis. The theoretical transmissibility characteristics are then calculated using the harmonic balance method. Three-dimensional finite element models of two QZS isolators are developed using ABAQUS simulation software, and transmissibility curves are computed for the 0-500 Hz frequency range. The results indicate that the three-spring QZS mechanism exhibits multiple higher-order resonance peaks in the mid-to high-frequency ranges due to the higher-order models of the springs. Springs with fewer coils and larger diameters can shift the higher-order modals to higher frequencies but cannot entirely eliminate their occurrence. In contrast, the bowl-shaped QZS isolator, through shape optimization using a spline-based representation, effectively mitigates the generation of higher-order resonance modes, resulting in superior isolation performance in the mid-to high-frequency ranges. This study provides essential theoretical insights for optimizing the vibration isolation performance of QZS technologies in complex, wide-frequency vibration environments, offering significant practical value for their application.

Keywords : quasi-zero-stiffness, wide-frequency vibration, vibration isolator, transmissibility
Conference Title : ICNVE 2025 : International Conference on Noise and Vibration Engineering
Conference Location : Amsterdam, Netherlands
Conference Dates : August 07-08, 2025