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Triaxial Fuzzy Control of a Compact Magnetorheological Vibration Absorber for Precision Platforms

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Precision platforms subject to three-axis, broadband (1-500 Hz), low amplitude random vibrations that critically affect their dynamic performance can be effectively addressed by a magnetically controllable variable-damping magnetorheological (MR) triaxial vibration absorber. However, achieving vibration suppression control for such a triaxial nonlinear MR system remains a challenge. To address this issue, this paper proposes a model-free rule-based triaxial fuzzy controller. Firstly, a triaxial dynamic model of the system is established, which integrates a conical rubber element and a magnetic fluid damping channel to achieve three-axis independent controllable variable damping within a single structure. Then, theoretical analysis of the swept-frequency characteristics of the MR triaxial vibration isolation system is conducted, and its controllable damping performance is analyzed. Experimental results demonstrate the damping increases by 31.5% (Z-axis, 3 A) and 22.8% (X/Y-axis, 3 A). Secondly, a model-free triaxial fuzzy controller with dual-velocity feedback (relative velocity and absolute velocity) is designed. The fuzzy rules are established based on the swept-frequency characteristics obtained under various current conditions. Finally, experimental validation under broadband random excitation demonstrates that the proposed fuzzy control strategy achieves superior overall vibration isolation efficiencies of 68.8% (Z-axis) and 64.4% (X/Y-axis), while significantly reducing power consumption by 33.2% (Z-axis) and 51.3% (X/Y-axis) compared to ON-OFF.

Type:

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