A NEW MR FLUID-ELASTOMER (MRF-E) VIBRATION ISOLATOR

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Abstract

In this study, the performance of a new design concept utilizing a magnetorheological (MR) fluid composite material is examined through encapsulating a MR fluid into an elastomer. A prototype of MR fluid-elastomer vibration isolator is built and its dynamic behavior is studied in oscillatory compressions for a wide range of frequencies under various input electric currents. The experimental results show that both the stiffness and the damping capability of the MR fluid-elastomer vibration isolator is a function of the displacement amplitude and magnetic field strength, and only weakly dependent upon the frequency of excitation; unlike the squeeze film mode counterparts [1]. This demonstrates that the new vibration isolator, whose mechanical properties can be controlled by an applied magnetic field, has potential in applications where tuning vibration characteristics are desired.

Introduction

A previous work focused on the characterization of a new MR fluid-elastomer (MRF-E) that encapsulated MR fluid inside a polymer shell [2]. In that study, it has been shown that the MRF-E has the capacity to vary its damping and dynamic stiffness through an applied magnetic field. In the present study a MRF-E is integrated into a semi-active device for mechanical vibration control. The design configuration presented offers vibration control and energy dissipation through the controllable characteristics of the MR fluid contained within the elastomer casing, and the passive flexible nature of the elastomer material. In order to evaluate the performance of the MRF-E, a prototype MR fluid-elastomer vibration isolator is designed and tested.

A three-dimensional finite element analysis (FEA) program is used to optimize the electromagnetic design that can generate strong electromagnetic field strength inside the MRF-E when fully activated. The dynamic behavior of the MR elastomer vibration isolator is examined using anInstron Model 8821S servo hydraulic actuator.

MR Fluid-Elastomer Vibration Isolator

The schematic design of the MRF-E vibration isolator is shown in Figure 1. The device consists of several elements. Each element is fully optimized in order to obtain the most efficient electromagnetic design. The geometry of the core material placed above and below the MRF-E had the most direct effect on the embedded MR fluid. The individual diameters and lengths of each part are adjusted (by halving or doubling) such that the model of encased MR fluid becomes saturated with magnetic flux. The optimization of each part is complete when no significant change (less than 10 percent) in the magnetic flux occurs when the dimensions of said part are altered further. The optimized electromagnetic design is realized using a three-dimensional finite element program. Figure 2 shows the photograph of three MRF-E prototypes which are used in the vibration isolation device.

Results and Discussion

Figure 3a shows the typical force response results of harmonic compressive deformation at constant frequency and amplitude, and for different applied currents to the MRF-E vibration isolator. It can be seen that in the off-state (0.0 Amp input), the force response curve of the MRF-E is in-phase with the sinusoidal input trace, and that the MRF-E behaves similar to a viscoelastic material [2]. However, as the magnetic field is activated and the strength is increased, the response force increases to a peak value of 470N at an input current of 3.0amps compared to the peak value of 282N for the passive case without magnetic field, while the force response deviates from the in-phase sinusoidal response.

These changes indicate that the MR fluid-elastomer vibration isolator, through changing magnetic field strengths, has the ability to alter the dynamic behavior of the MRF-E from linear viscoelastic to nonlinear viscoelastic, while also increasing its damping and stiffness capabilities. Figure 3b shows the typical experimental results of the hysteresis loop for the same constant frequency and amplitude as in Figure 3a. The areas of the loops enlarge with increasing current. Since the area inside each of the loops represents the energy dissipated-per-cycle, the energy dissipated-per-cycle by the MRF-E vibration isolator increases with increasing current.

Figure 4a shows the maximum energy dissipated-per-cycle for an amplitude of 0.2mm for every frequency tested (0.1Hz-10Hz). It can be seen that the energy dissipated-per-cycle increases with increasing amplitude and current. The closely clustered “dots” located at different measured amplitudes identify the energy dissipated-per-cycle at each tested frequency.

Conclusions

From the results of the experimental investigation on the dynamic behavior of the MRF-E vibration isolator under different compressive oscillatory cycles, it can be concluded that the MRF-E has the capacity to vary its damping and dynamic stiffness through an applied magnetic field. The damping and stiffness capability of the MRF-E vibration isolator is a function of the displacement amplitude and magnetic field strength, and only weakly dependent on the frequency of excitation.

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References