Analysis and Optimization of Adjustable Magnetic Fluid Damper in DC Magnetic Field

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ID:#668
MT25-Wed-Af-Po3.08-20

Background

The spacecraft in orbit will cause a lot of low frequency vibrations, and the vibration will cause extra vibration acceleration, which are not only easy to create some fatigue damage of spacecraft structures, but also affect the stability and orientation accuracy of spacecraft. At present, the smart materials and structures, such as piezoelectric material and composite materials are mainly used to control the vibration. However, the smart materials are prone to damage and the damage is difficult to predict. That increased the difficulty of modeling.

Contents

- In order to solve the vibration problems in the aerospace field and increase the reliability, a magnetic fluid damper with adjustable damping is proposed.
- The dynamic theoretical model of the damper is established. The magnetic field distribution and damping characteristics of the shock absorber are discussed.

Conclusion

- In view of the vibration reduction problem in aerospace field, a magnetic fluid damper with adjustable damping is proposed in this paper, and the performance of the absorber is analyzed.
- The theoretical results show that In the DC magnetic field, the magnetic fluid can be approximated in a uniform magnetic field, and the magnetic force of the magnetic fluid is approximately 0. The magnetic field is mainly used to regulate the dynamic viscosity of the magnetic fluid.
- The numerical results show that the magnetic field distribution of damper is approximated uniform between the vessel and the inertia mass, and the amplitude of the beam and inertia mass can be detected. In a certain radius *r*, the flow of a magnetic fluid approaches a sinusoidal flow. That is good agreement with the theoretical results.

Structure

Cylindrical Damper

Adjustable magnetic fluid damper is composed of an induction coil, a non-magnetic vessel, two non-magnetic springs, and a cylindrical inertia mass.

When the magnetic fluid damper begins to work, the inertia mass reciprocates in the vessel, which dissipates the vibration energy.

The different input currents in the coil can be changed to adjust the damping parameters of the damper.

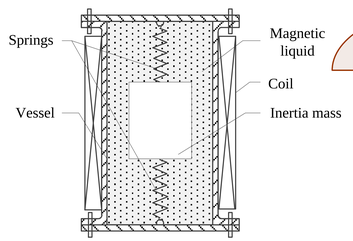
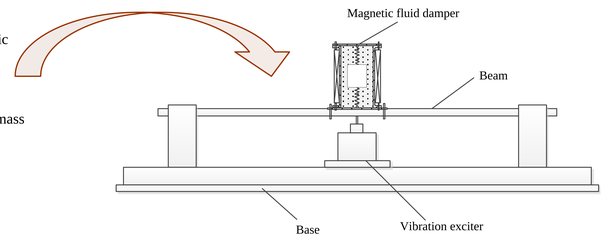


Fig.1 Sketch of the adjustable magnetic fluid damper

Experimental Apparatus



The freely supported beam vibration system is established. The magnetic fluid damper is fixed to the middle of the beam. The contact vibration exciter applies simple harmonic vibration to the beam. The displacement sensor measures the vibration displacement response and the frequency spectrum can be calculates.

Theoretical analysis

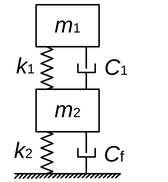


Fig.2 Equivalent two order system

The damping system can be equivalent to the second-order vibration system.

$$\begin{bmatrix} m_2 & 0 \\ 0 & m_1 \end{bmatrix}\begin{bmatrix} \ddot{x}_2 \\ \ddot{x}_1 \end{bmatrix}+\begin{bmatrix} C_f+c_1 & -c_1 \\ -c_1 & c_1 \end{bmatrix}\begin{bmatrix} \dot{x}_2 \\ \dot{x}_1 \end{bmatrix}+\begin{bmatrix} k_2+k_1 & -k_1 \\ -k_1 & k_1 \end{bmatrix}\begin{bmatrix} x_2 \\ x_1 \end{bmatrix}=\begin{bmatrix} F_0\sin\omega t \\ 0 \end{bmatrix}$$

The resilience of the damper is the elasticity of two springs

$$F_k=(k_1+k_2)\Delta x_m$$

The damping force is the sum of the viscosity force and the frictional force

$$F_c=f_\eta+F_f=\eta_H\nabla^2\boldsymbol{v}_1+S_L\cdot\tau=C_f\cdot\dot{x}_1$$

The motion equation of the magnetic fluid is as follows:

$$\rho_f\frac{\mathrm{d}\boldsymbol{v}}{\mathrm{d}t}=\boldsymbol{f}_\eta+\boldsymbol{f}_m+\boldsymbol{f}_p$$

fp, fη, and fm are the pressure gradient, the viscous force and magnetic force respectively

$$\boldsymbol{f}_\eta=\eta_H\nabla^2\boldsymbol{v}_z,\quad \boldsymbol{f}_m=\mu_0 M\nabla H=0,\quad \boldsymbol{f}_p=-\left(\frac{\partial p}{\partial r}\boldsymbol{e}_r+\frac{\partial p}{\partial\theta}\boldsymbol{e}_\theta+\frac{\partial p}{\partial z}\boldsymbol{e}_z\right)$$

Boundary conditions:

$$v_z=\dot{x}_m,\quad \text{for } r=R_1;\quad v_z=0,\quad \text{for } r=R_2$$

Combined with the boundary conditions, the flow velocity can be solved by

$$v=\frac{F}{4\eta_H}\cdot r^2+C_1\ln r+C_2$$

$$C_1=\frac{\dot{x}_m}{\ln R_1-\ln R_2}-\frac{F}{4\eta_H}\cdot\frac{R_1^2-R_2^2}{\ln R_1-\ln R_2}$$

$$C_2=-\frac{\ln R_2}{\ln R_1-\ln R_2}\dot{x}_m+\frac{F}{4\eta_H}\cdot\frac{R_1^2\ln R_2-R_2^2\ln R_1}{\ln R_1-\ln R_2}$$

$$F=\rho_f\ddot{x}_1+\frac{\partial p}{\partial z}$$

Results

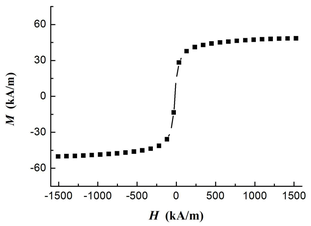


Fig.3 Magnetization curve of the kerosene - based magnetic fluid

In the DC magnetic field perpendicular to the vortex vector of the magnetic fluid, the viscosity will increase with the magnetic flux density, which is the magneto-viscous characteristic of the magnetic fluid. The fitting curve is

$$\eta_H=6.6312-0.0406B+0.0002B^2$$

The damping liquid is kerosene - based magnetic fluid. The density of the magnetic fluid is 1.76 kg/m^3. The saturation magnetization is 1500 kA/m.

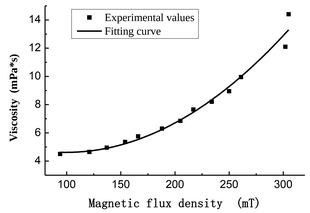


Fig.4 The curve of Magneto-viscous characteristic

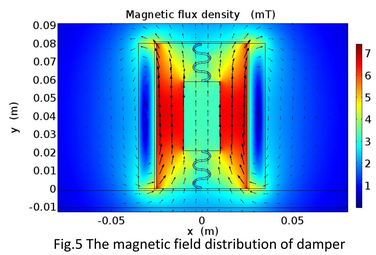


Fig.5 The magnetic field distribution of damper

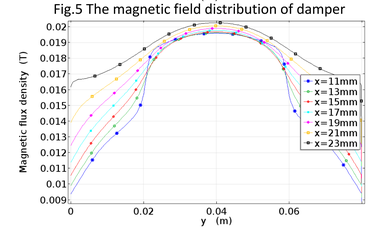


Fig.6Magnetic flux density of magnetic fluid in the direction of *x* axis

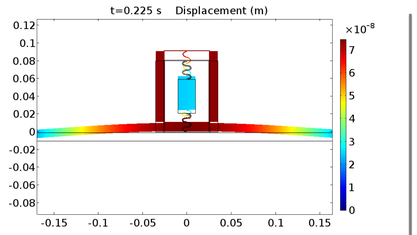


Fig.7 Displacement of beam and damper

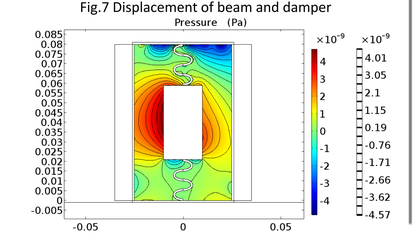


Fig.8 Fluid pressure f_p

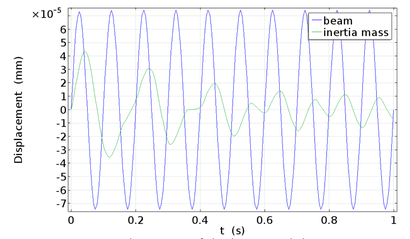


Fig.9 Displacement of the beam and the inertia mass

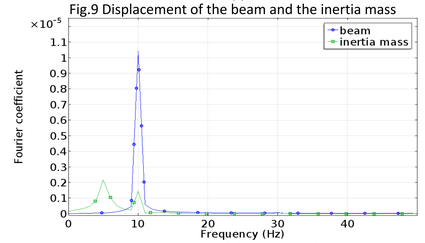


Fig.10 Frequency spectrum of the beam and the inertia mass

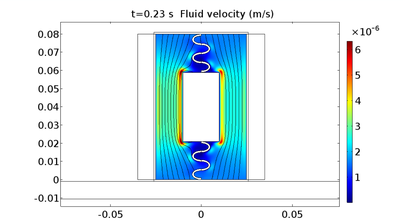


Fig.11 Velocity distribution of magnetic fluid

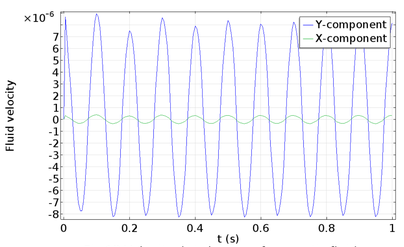


Fig.12 Velocity distribution of magnetic fluid

Presented at the Applied Superconductivity Conference , 2012 Oct. 7 – 12, Portland, Oregon; Session: Nb-based Wires and Tapes II; Program I.D. number: 2MPQ-10