Vibration control for steel frame based on magnetorheological fluid absorber

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The similar model is made to three-layer building structure, the 4-DOF vibration system is built up; the parameter of MRF absorber is optimized and designed, the mass ,damping coefficient and rigidity are obtained according to the characteristic of structure; a set of testing system of semi-active vibration control is designed to study the effect of MRF damper , considering the natural frequency and strength of external magnetic field, the amplitude of structure can be decreased obviously after using MRF absorber and the vibrating process is stabilized, validating the effect on shock absorber of MRF absorber.

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It is a focus recently on shock absorption to control the vibration of building structure by MRF absorber, the working principium is to get the different magnetic field by adjusting the excited current in loop of MRF absorber, and changing the flowing characteristic of MR fluid in the damping channels, the process are continuous and reversible, thus the damping force of the MR absorber can be controlled. Presently, a majority of scholars fix their attention on the application in automotive suspension system with the MRF absorber [1,2], and a little in building structure. In 1997, Dyke had studied a 3- tier frame using MRF absorber to control the response of earth shock [3]; in 2000, Ou jin-ping [4] had studied the vibration of a tier frame by MRF absorber; which show that the method of shock absorption using the MRF absorber on building structure is superior to the conventional. But as to large-scale building, when the accurate design and analysis are no need and the direct test is difficult, the study method of similar theory is feasible.

The paper takes the 3-tier building structure as the research object, and similar model is made, the parameter of the MRF absorber is obtained by optimizing design. A set of testing system based on semi-active vibration control is designed, and the damping effect of MRF absorber is studied. The study can provide the theoretic and experimental method for the vibration control of building structure by MRF absorber.

1. Vibration model of structure

As to a 3-tier building structure, considering the dimension of building and vibration characteristics, the 3-tier building structure related to the model which is made by the steel frame is simplified on proportion 5:1, as Fig. 1.The frame of model is welded by 40x40x5 equal angle steel and four anchors are welded in the bottom by t10 steel plate, and the interlayer are welded by t20 steel plate. The height of the first and second floor is 600mm, the third is 800mm and the total is 2000mm, sectional area is 800 × 600mm^2. According to experiment, the MRF absorber is set on top floor and the 4-DOF vibration system is built up, the equivalent mechanics model is as Fig. 2.

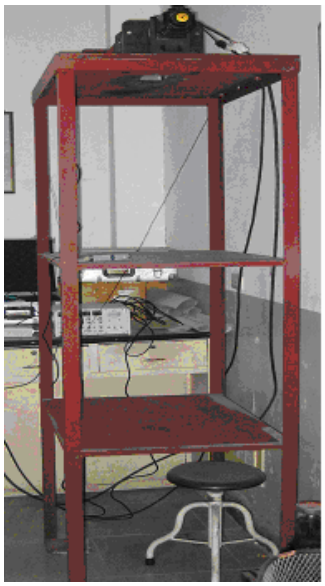

Fig. 1. The similar model of structure.

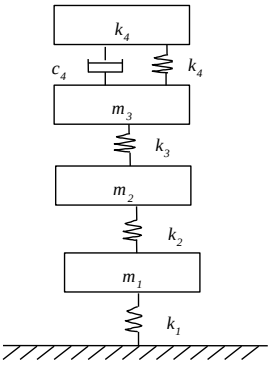

Fig. 2. The equivalent mechanics model.

Where m_1, m_2, and m_3 are equivalent mass of each layer respectively, k_1, k_2 and k_3 are equivalent stiffness coefficient of each layer stents respectively, and m_1 =65.1336kg, m_2 =65.1336kg, m_3 =118.2116kg, $k_1 = k_2 = k_3$ =2696113.6N/m.

2. Design of vibration control system

According to the above, MRF absorber is designed and manufactured, and the working mode is shear. The damping coefficient can be adjusted by the control of the speed of the piston of MRF absorber [5], as Fig. 3.The test of the damping effect is designed accordingly, as Fig. 4.

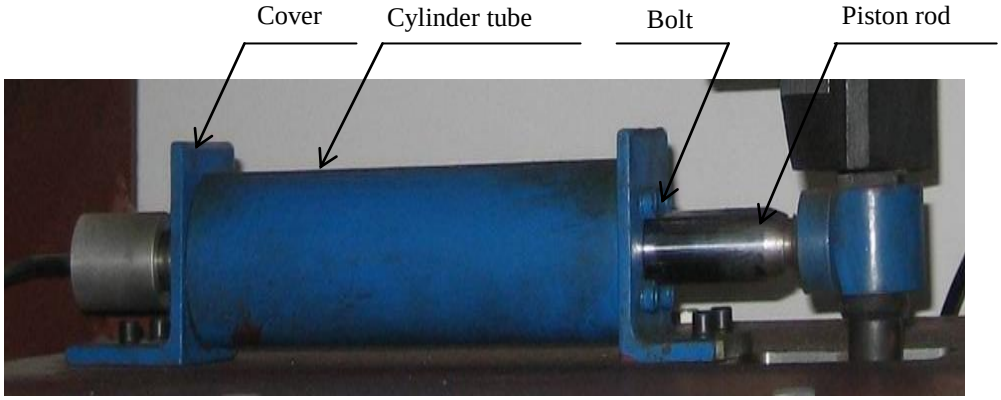

Fig. 3. The moving system.

By controlling the rotation of servomotor, the slide on screw and the piston of absorber are driven to move to and fro. the frequency and amplitude of MRF absorber are controlled by the rotating direction of servomotor, the moving velocity and the displacement of the slider; the outside vibrating amplitude is tested by the sensors, by controlling the moving velocity of piston and the magnetic field, the magnitude of damping force is regulated to approach the outside exciting force, they are contrary in the working direction, however, in order to improve the effect of absorber, the frequency of MRF absorber is made to approach that of the exciting force.

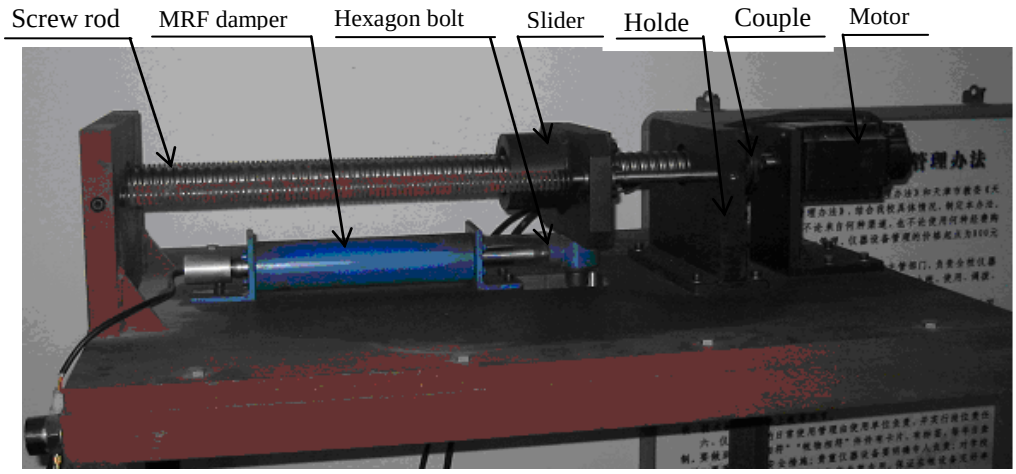

Fig. 4. Test of the damping effect of MRF absorber.

The parameter of main components is as follows: Piezoelectric acceleration sensor: testing the state of system, the sensitivity is 4.22pc/N. Controller, receive control signal and process, and provide the correlative damping force.

After shaking the structure, detecting the response signal by sensor, filtering and amplifying it by charge amplifier, and then store in data acquisition card, and this is the outside vibrating signal. According to inputting control signal, driving the electromotor, by controlling the rotating velocity and the displacement of piston to modify the frequency and amplitude of vibration control force, at the same time, the vibrating state of structure is put into the controller of MRF absorber by sensor; by the feedback input of vibration acceleration, the controller proceeds to regulate the signal automatically, which can control the rheological character of MRF absorber, then damping force is exported to control vibration character of the structure.

3. Experiment design and results

In order to test the damping effect on vibration of MRF absorber, the experiment is divided into two parts.

Exp1. Without the MRF absorber, excite the structure by vibrator, detecting the response signal by sensor, the filtered and amplified signal is put into acquisition card and computer, and then the computer saves the relation between exciting forces and responding acceleration and time.

Exp2. Based on Exp1, export the obtained signal to acquisition card and computer, and regulate the rotating velocity and direction of servomotor according to PID control, drive the screw and make the slide moving, produce inertia force to reduce the outer force of the experiment mode. At the same time, modify the magnetic field and the damping force in MRF absorber by controller in the light of optimum shock absorb.

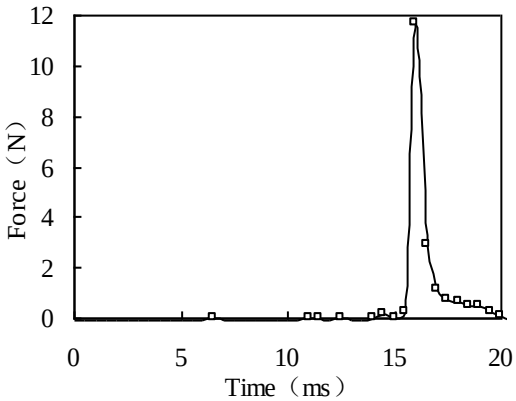

Fig. 5. Relationship between exciting force and time.

The results are as Fig. 5 and Fig. 6. According to the difference in acting time and amplitude of outside excited force, the data are regulated linearly. With the proportion to regulate the response amplitude, as the force change only a little after being regulated linearly, they can be treated as the same approximately.

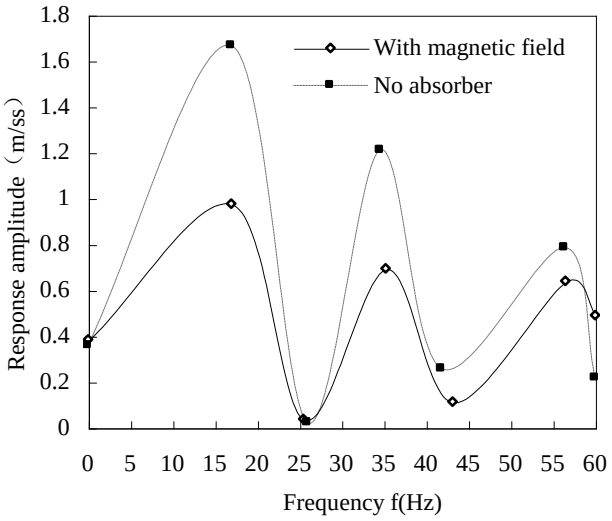

Fig. 6. Effect of MRF absorber.

4. Conclusions

Analyzing the vibration circumstantialities that the structure is fixed with the MRF absorber or not, according to Fig. 6, when the magnetic field in MRF absorber is on, the response vibrating amplitude of the structure reduce clearly and the wholly process is more stable, which shows that the effect on shaking absorb of MRF absorber is obvious and validates that it is available to put MRF absorber into the vibration absorb on building structure. As the 2nd proper frequency of the vibration system is nearly two times of 1st and the 3rd is nearly three times of 1st, the three proper vibration response can be restrained by one MRF absorber; during the low frequency, for the influence of the low rigid and the servomotor startup frequently and outside noise, the absorbing effect of MRF absorber descends. External magnetic field has great influence on vibration control force of MRF absorber; at the same time, which shows that it is feasible to control the amplitude of the vibration control force by changing external magnetic field, and the vibration control of structure can come true more simply.

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References

[1] Wang Enrong, Ma Xiaoqing, Journal of Southeast University, **19**(3), 264 (2003).
[2] Ying Zuguang, Ni Yi-qing, Acta Mechanica Solida Sinica, **17**(3), 223 (2004).
[3] Dyke, Spencer Jr., J. D. Carlson, Proc. the 3rd Int. Conf. On Motion and Vibr. Control, (3), 291 (1996).
[4] Ou Jinping, Guan XiChun, Earthquake Engineering and Engineering Vibr. **12**, 1 (2001).
[5] Li Lianjin, Ge Wei-min, Transactions of Tianjin University, **10**(1), 9 (2004).

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