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High Performance Passive Damper with Ingenious Hydraulic Valve System

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I. Introduction

Various types of semi-active damping devices have been recently developed in the civil engineering field for controlling the structures. Semi-active oil damper HiDAX can change the damping coefficient between maximum and minimum using solenoid valve, and has excellent performance beyond the conventional passive dampers.

Though the semi-active device consumes only small amount of external energy, the device must have failsafe functions to cope with an external energy failure, regardless of how small it might be.

The new valve system autonomously controls the flow control valve opening between two hydraulic chambers utilizing the pressure balance between them without an external power source. This impressive function can create a passive hydraulic damper with high performance equivalent to that of above semi-active damper.

II. Hydraulic Mechanism

The new valve system is required to realize the same valve action as the conventional HiDAX system without any external energy.

The new valve's basic hydraulic circuit diagram is shown in Fig.1. It mainly consists of logic type flow control valve (1) which directly controls the damping force between two hydraulic chambers, also a kind of logic type pilot valve (2) which controls the back pressure of the flow control valve and buffer (3) which activate the pilot valve with accumulated hydraulic power. Other components such as buffer relief valves (4), main relief valve (5), accumulator (6), and check valves are also installed at this system. Variable orifice (7) is used just for the test to close the main valve compulsorily.

The flow control valve between the two hydraulic chambers is closed while the piston continues moving to one end, and opened only when the piston changes its direction at the end. This mechanism enables the system to produce two different levels of damping coefficient.

III. Hydraulic Characteristics Simulation

Hydraulic simulation was carried out based on the mechanical model shown in Fig.2 using general mathematical analization software MATLAB/Simulink. The main purpose of this simulation is to make sure if the new valve system has the possibility to be realized through further development process. The simulation was executed through numerically integrating the relating equation between the hydraulic pressure and the flow rate.

Fig.3 shows the pressure time history results, and this

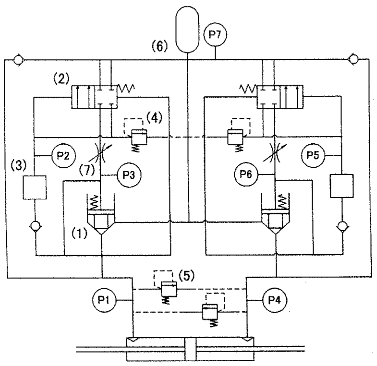

Fig. 1 Hydraulic Circuit

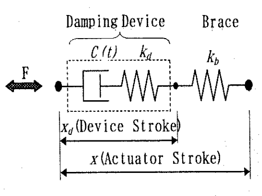

Fig. 2 Installed Damping Device's Mechanical Model

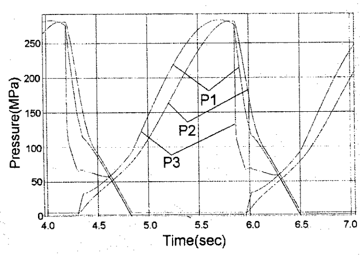

Fig. 3 Pressure Time History (Simulation)

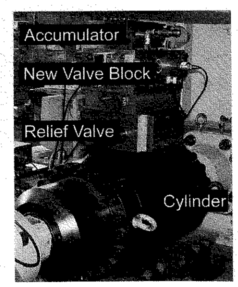

Fig. 4 Overall View of Full-scale Damper

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indicates that the valve moves correctly and is worth realizing through further development process.

IV. Full Scale Prototype Device

Fig.4 shows an overall view of the full-scale damper equipped with the new valve system. The device is about 1.4m long, 1,000kg weight, and has 2MN maximum force capacity. Its hydraulic circuit is basically the same as the one in Fig.1.

V. Dynamic Loading Test

1. Experimental Method

The loading setup was to be equivalent to the model in fig.2 assuming k_b as the loading frame stiffness. A dynamic actuator is operated through controlling its stroke referring to the displacement between the stories in actual building.

2. Test Results under Sinusoidal Loading

The device's force-displacement relationships obtained under sinusoidal loading of 0.3Hz, 0.5Hz and 1Hz are shown in Fig.5.

It is recognized that the characteristic rectangular loop associated with the control law was accurately realized here. Though a little delay is observed at 1.0Hz, valve operation was adequately realized as expected especially at 0.3Hz and 0.5Hz that represent a fundamental frequency of high-rise buildings. Fig.6 shows the time histories of the pressure in the new valve system under 0.5Hz, ±2.0mm loading. The main pressure P1 drops smoothly in a short time (about 0.1sec).

3. Test Results under Seismic Response Wave Loading

Dynamic loading test is conducted using a seismic response displacement time history at the 1st floor of a 30-story bending-share vibration analytical model for El Centro. The 1st natural frequency of this model is 0.3Hz. Fig.7 (left) shows the force-displacement relationship, and it indicates that valve is stably operated based on the pressure balance even under such a complex loading.

4. System Evaluation

In order to evaluate the system feasibility, simple analytical model was developed for structural response analyses use. This macro-model simply changes its damping coefficient corresponding to the direction of the generated force. Fig.7 (right) shows the force-displacement relationship under the same loading condition as the above seismic response test. This simulation results agree well with the test results, and it is confirmed that the device's dynamic behavior can be accurately simulated with simple analytical parameters.

As the several tests under seismic response wave loading exhibited exactly the same results every time, the new valve system can be said to have great stability. At the same time, this system showed excellent durability through 53,000 cycles of sinusoidal continuous loading test.

VI. Conclusions

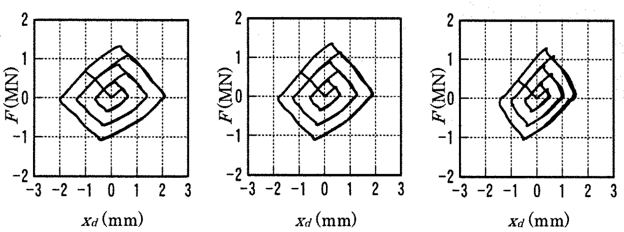
The new valve system can create a passive hydraulic damper with high performance equivalent to that of semi-active damper which can absorb much more structural vibration energy than a conventional passive damper.

The hydraulic simulation results indicated that the valve moves correctly and is worth realizing through further development process.

Through dynamic loading test, this system showed enough performance to be applied to the actual buildings.

The macro-model simulation results agree well with the tests results, and it can be used for system evaluation.

We will continue to search after another application suitable for this ingenious valve system.



0.3Hz　0.5Hz　1.0Hz

Fig. 5 Force-displacement Relationship (Sinusoidal Loading)

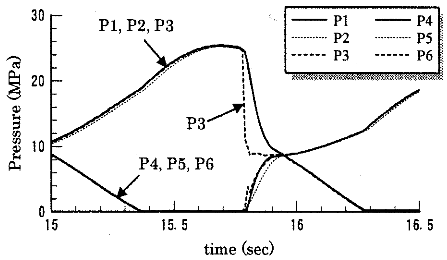
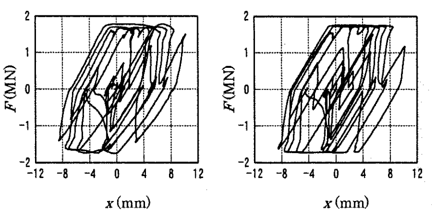


Fig. 6 Pressure Time History (0.5Hz, ±2.0mm Loading)



Test　Simulation

Fig. 7 Force-displacement Relationship (Seismic Response Wave Loading)