Development of Practical Semi-active Suspension Control System

Hideaki Takahashi, Feifei Zhang, Kiyoshi Mishima and Masanori Ito

Divisions of the graduate of Electronic and Mechanical Engineering Tokyo University of Mercantile Marine
Tel : +81-3-5245-7422 2-1-6 Etchujima Koto-ku, Tokyo 135-8533, Japan
E-mail: hide@ipc.tosho-u.ac.jp, zhang@ipc.tosho-u.ac.jp, mishima@ipc.tosho-u.ac.jp, itom@ipc.tosho-u.ac.jp

Abstract: The focus of this research is to realize the function which is equivalent to the active suspension system, with controlling semi-active suspension through the attenuation of power variable damper in lower cost and smaller energy. Actually some semi-active suspension systems have been adopted, but they are not sufficient in performance. The authors intended to develop more effective and practical system and applied the optimal control technique. The results of experiments with practical suspension system showed a degree of improvement of comfortableness.

Keywords: Semi-active suspension, continuous, type control, practical actuator based experiment

1. INTRODUCTION

The active suspension and semi-active suspension have being studied for the vibration control of vehicle. As for the former, it is well known that it has ability of high performance, but it results increasing of energy consumption and weight of system, and has the risk of resonance. On the other hand, as for the latter, performance is not higher but problem is lesser than the former.

Therefore the latter is thought to be more practical. Al -though the mechanism is so complex that control has been accomplished with just looking data table. That is the present condition. So more effective control method is desired.

In this study, we tried a continuous type feedback control based on damping characteristic, and carried out experiments with practical suspension syst-em to confirm the performance.

This new control method shows a smooth contr-olling characteristics, and the vibrations over wider frequency can be decreased as well. Farther, it has better performance comparing with conventional data look-up system.

2. COMPOSITION OF A SYSTEM

The composition of the experimental system is sh -own in Fig. 1.and 2, which is consisted of a moti-on base, a iron plate, suspension equipments (one (1) damper, and three(3) springs), suspension driv-ing unit, sensor and a computer.

The motion base giving vibration can generate Six(6) Degree of Freedom motions to the platform, so the suspension system can be tested under any kinds of vibration mode.

Generally, the suspension of a car is consisted of four(4) dampers and springs, and this equipment is thought as 1/4 of scales of a real vehicle, that is one(1) damper and a iron plate of 300kg weight. Three springs are chosen in consideration of supp-ort and peculiar pitch of the equipment.
Two kinds of sensors, accelerometer and distance sensors are installed such that absolute position and acceleration of the plate are measurable. As shown in the figure, these signals are feedbacked to a co-mputer, and the computer sends a control signal to the driver of damper to control damping power .

Fig. 1 Experimental Equipments

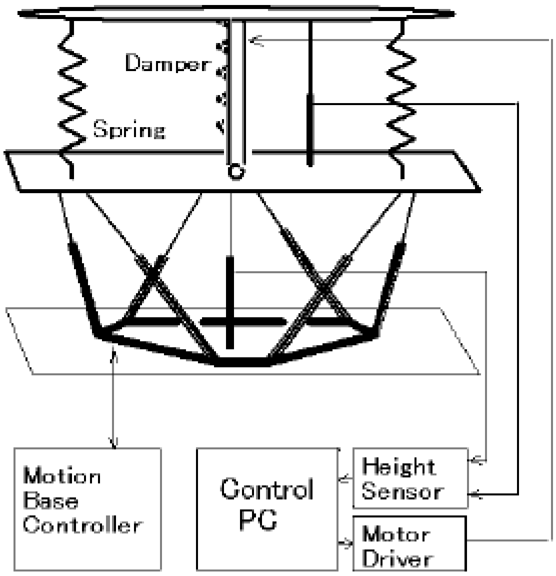

Fig. 2 Composition of experiment

3. CONTROL SYSTEM DESIGN

3.1 Semi-active suspension

In this study, we tried to use the practical system which is made by KAYABA Co. Ltd and applied on RODEO by ISUZU Co. Ltd.

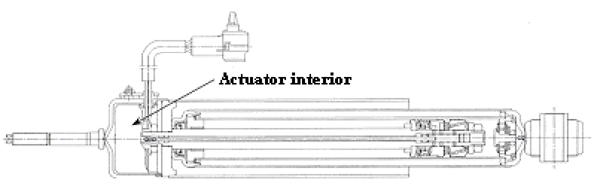

Fig. 3 Semi-active Damper

The power of the damper is based on the viscosity of the oil which opposes movement of a piston. With this damper, power is changed by adjusting the space of the circulating line of the oil which is suppressed by movement of a piston, and a stepping motor is servers as a regulator of the space. Therefore, a computer signal controls the rotation angle of the motor and damping power.

Now, as for the relation between the rotation angle of motor and the force of the damper, Figure 4-1 and Figure 4-2 are attenuation power characteristic results obtained by experiment. In Figure 4-1 vertical axis shows the power and horizontal axis shows angle. In Figure 4-2, horizontal axis is moving speed.

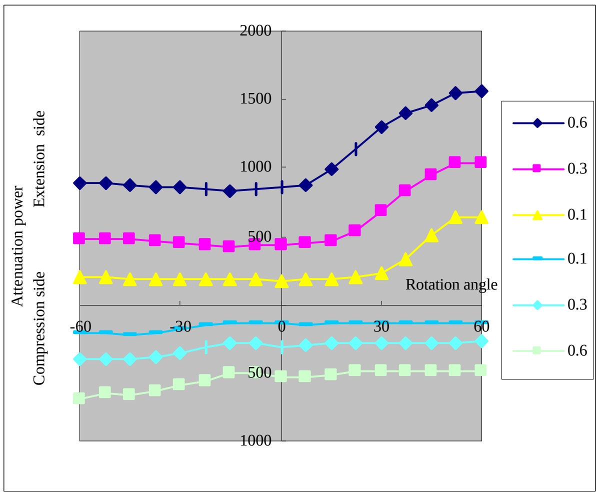

Fig. 4-1 Force characteristic of damper

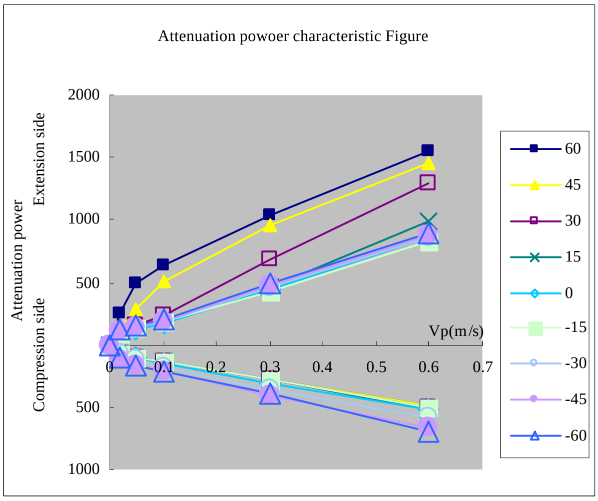

Fig. 4 -2 Attenuation power characteristic

It is shown that the characteristic of damping force is nonlinear and corresponding to moving speed too.

, The specification of the motor is shown in the following table .

Specification	
Rating Voltage	DC12V
Operation voltage range	DC8～14V
Operation temperature range	-30～100℃
Preservation temperature range	-40～120℃
Consumption current	2. 6A Following/
	(12V, 20°C)
Winding resistance	5±0. 3Ω (20°C)
Drive frequency	200PPS
Step angle	7. 5deg
Output torque	59mN·m Above
Maintenance torque	10mN·m Above
Maintenance torque	1MΩ Above (DC 500V)

Table 1 Specification of a suspension

3.2 Control System Design

In order to design a control rule, the flow of the signals of the system is expressed with a block diagram.

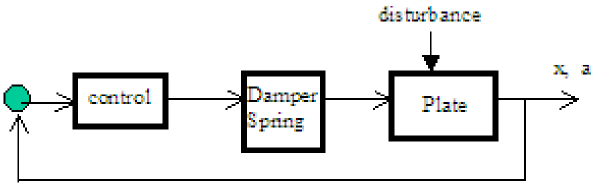

Fig.5 Bock Diagram of Control System

where x indicates distance of the Plate from equilibrium position.

As for the characteristic of a damper, it is usually described as $f_d = C\dot{x}$, where C indicates damping coefficient and $\dot{x}$ the moving speed. However we notice the characteristic curve shown in Figure 4 cannot be reduced to his formula completely. Here, we tried to constitute a control rule based on experiment data. For this, at first, a control rule (for example, PID control) decides the output force of damper. Then, a rotation angle of motor is calculated where a speed at that time is taken into consideration, too. Concretely, The measured force-angle relationships (see Figure 5) are expressed in the polynomials $f_{i(v)}(q)$, where $i(v)$ means the index corresponding to speeds, and an interpolation technique is applied to speeds such that all the control signals can be determined depending on continuous calculation:

$$f = Function(x)$$

$$q = Interpolation(f_{i(v)}(q))$$

$$V = Function(q)$$

In consideration of practical application, only an acceleration signal can be used to make control signals. Then, after the control with position feedback could be done well, it succeeded also in the feedback control of only acceleration signal by shifting a difference in phase between acceleration signal and position signal.

4. CONTROL RESULTS

In this section, both simulation and experimental results are shown to confirm the performance of control system.

4.1 Simulation result

In order to carry out computer simulation, the m athematical model of the system is written as:

$$M\ddot{x} = -K(x - x_d) - f_d = 0$$

$$f_d = C(\dot{x} - \dot{x}_d)$$

where, x and x_d are distances of Plate and Mot -ion base surface, respectively, from equilibrium pos -ition. According to the experimental equipments, M =250kg is the value of which is about 9000N/m.

The damping force f_d is supposed as the prod-uct of oil viscosity coefficient C and moving speed, and the force is controlled with changing the coef-ficient C.

Applying Laplace transformation, the above eqati-on can be represented by

$$x(s) = \frac{K}{M}\frac{1}{s^2}(x_d(s) - x(s)) + \frac{1}{M}\frac{1}{s}C(\dot{x}_d(s) - \dot{x}(s))$$

The simulation was carried out on Matlab Simul-ink, the blok diagram of which is as follows, wher-e block "disturbance" makes x_d

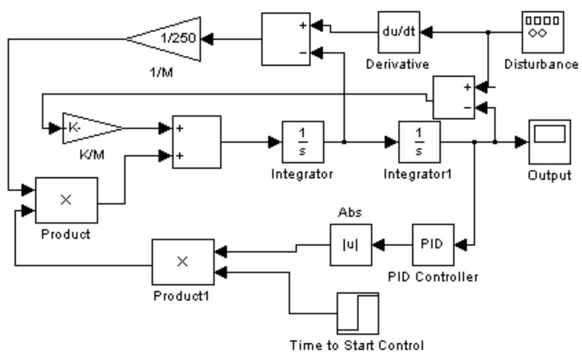

Fig. 6 Simulation Block Diagram

The following Figure is a simulation result where control was addes at five minutes later from the experiment start. It shows that the vibration can be reduced about 40%.

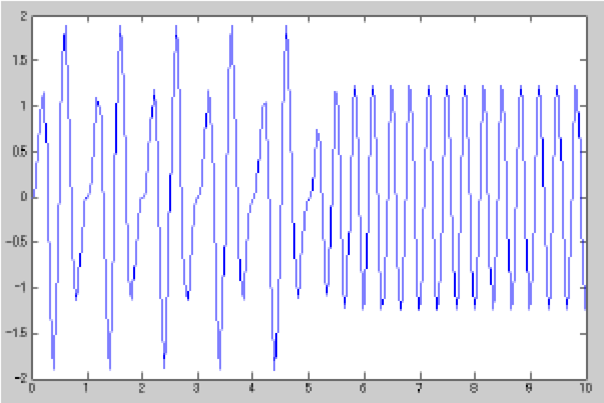

Fig. 7 Control Result by Simulation

4.2 Experimental Results

Control experiment was carried out based on the investigation of simulations. Figure8-1 shows one of the experimental result, the vertical axis is position x and horizontal axis is time. The vibration frequency is 1Hz , and control was started at 2.5 minutes from the experiment start. It is obvious that the amplitude decreased greatly.

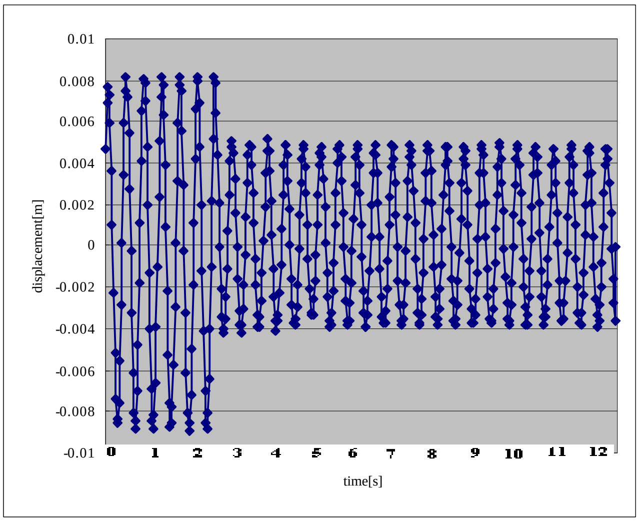

Fig. 8-1 Experimental Result

Another experimental result is shown in Figure8-2, which also sounds good effece of control.

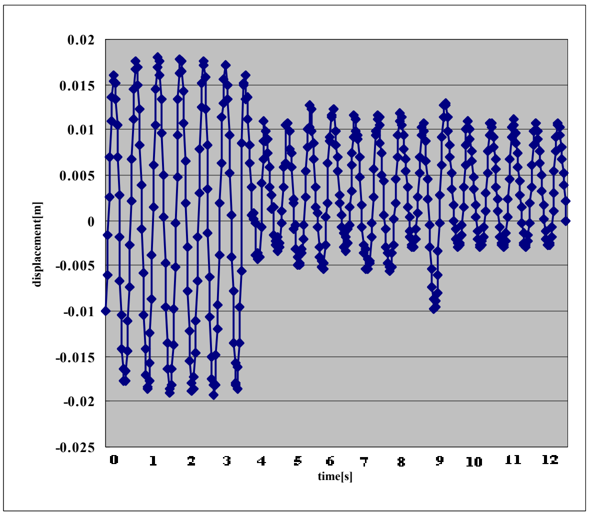

Fig. 8-2 Experimental Result

5. CONCULUSION

In this study, we tried a continuous type feedback control based change of damping characteristic, and carried out experiments with practical semi-active suspension system for automobile to confirm the performance.

This new control method shows a smooth controlling characteristics, and the vibrations over wider frequency can be decreased as well. Farther, it has better performance comparing with conventional data look-up system.

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