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Study on adaptive hydraulic device for vertical vibration

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ABSTRACT

In this study, hydraulic vibration controller was proposed and tentatively manufactured. Adaptive control method was tried in this experiment for vibration reduction. Proposed vibration absorber is composed of bellows, actuator and accumulator. The device is filled with oil. For input vibration, the actuator is controlled so as to make bellows inside pressure zero. Thus vibration transmission is aimed to reduce. In time, adaptive control method which is able to track non-stationary vibration phenomena is applied.

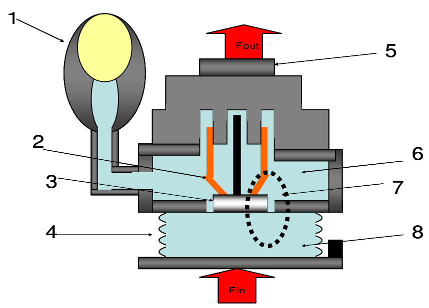
KEY WORDS

Vibration, Adaptive control, Active mount,
Adaptive Hydraulic Device

INTRODUCTION

As far as construction machinery are concerned, there is problem of the vibration transmitted to the operator room at actual work. Each company is developing mount. To date, a mount as a passive control method has been used for low frequency. That is, vibration reduction is achieved by passive action of rubber without using energy from outside. The effect of the vibration reduction depends on the characteristic of the conventional mount and its layout. For supporting operator room weight and static rigidity of the mount requires large space. As a result, issue of space occurs.

This study proposed a hydraulic theory of the vibration reduction, and by using adaptive control, the authors aimed to reduce the transmitted vibration in the operator room. Here, the vibration reduction from 20 to 50 [Hz] of low frequency is main target of this study. This paper shows the effectiveness of the theory by using the simulation, the structure of the control method and the device that can achieve the theory.



1	Accumulator
2	Voice coil motor
3	Moving mass
4	Bellows spring
5	Load cell
6	Upper chamber
7	Clearance
8	Lower chamber

Fig1 **Structure of Active Mount**

Active Mount Structure

Recently vibration reduce technique uses the cancel each other by actively generating the power of the input vibration and the opposite phase. But this shows heavy weight (operator room) support is difficult especially for construction machinery, because large static rigidity is necessary and as a result high control power is inevitably required. This study develops a new hydraulic active mount, which is filled inside with oil for the operator room. Fig1 shows new theory model device. This device is composed of bellows, actuator and accumulator. The device is filled with oil. The operator room weight can be supported by the oil pressure. In a word, this configuration of this mount has the advantage of being able to support the weight without any external power sources.

Theory of Vibration Reduction

This chapter explains the theory of the vibration of the active mount. When the excitation force acts on the under part of the mount, the actuator moves in the upper direction by the control signal. Consequently the volume inside the bellows does not change so much and the dynamic pressure becomes small. Therefore the transmitted force becomes low.

When the actuator is controlled so as volume flow continuity equation AbXb=AvXv holds, it is assumed to reduce vibration. Here, let us simulate the vibration reduction effect when the following equation (1) is applied in this system, Fig2 shows simulation model.

$$X_v = \frac{A_b}{A_v} X_b \qquad (1)$$

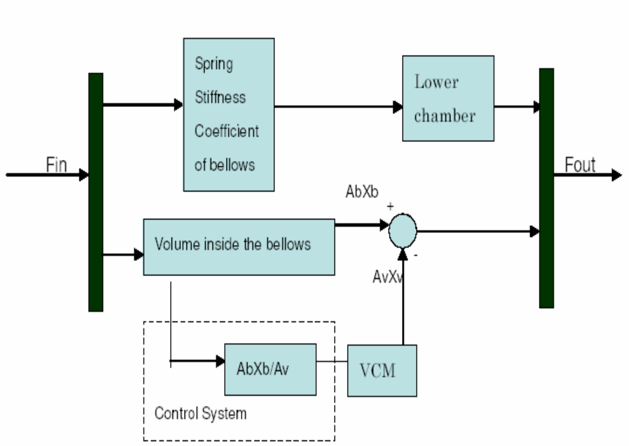


Fig2 Simulation Model Of Theory

Simulation Result

Figure 3,4,5 shows the comparison of the input force, under pressure and the transmitted force as the error signal when the control is active. In this figure it was found that when the pressure P1 is nearly 0[Pa], the transmitted force is also approximately 0[N]. That is, the assumption explained above is demonstrated. However, as this control scheme is open loop, the adjustment of the amplitude will be difficult when system fluctuates frequently. Actually, engine vibration is not stationary. It fluctuates considerably due to surrounding condition. Therefore more flexible control scheme will be needed.

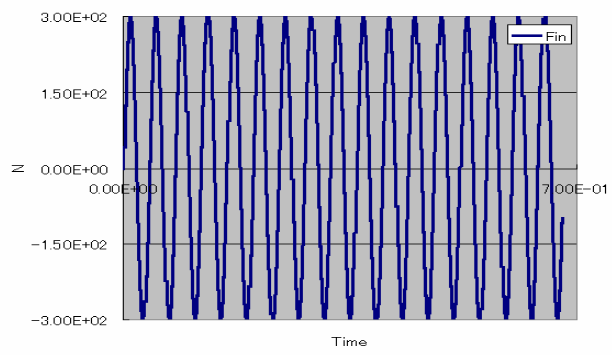


Fig3 Input Force

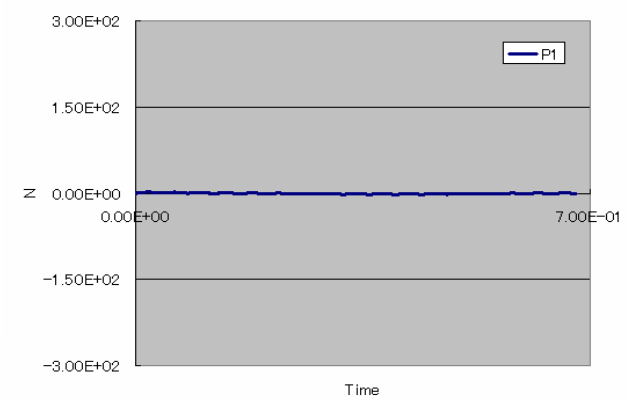


Fig4 lower chamber Pressure

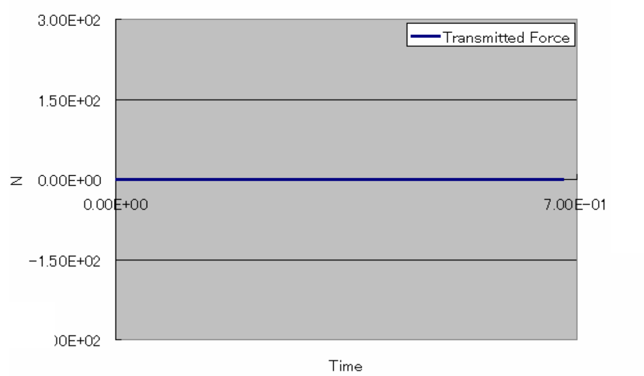


Fig5 Transmitted Force

System Consideration

In a classical control method, time variant system is frequently treated. But computing power is not sufficient, time variant statistical system is difficult to treat effectively. But, now adaptive control scheme using, LMS(Least Mean Square) algorithm, becomes easy to apply for this kind of system.

1.Adaptive Control

Adaptive control is a type of control which adapts control system to follow the plant (control object) characteristics change. Algorithm to realize this process is called adaptive algorithm. Unknown system and adaptive filter response to input reference are added. This added signal is treated as error signal. Control is done to make this error signal minimum by refreshing adaptive filter characteristics.

2 .Adaptive FIR filter

By making the filter coefficient as time variable, adaptive filter is possible to realize which changes its characteristics. This block diagram is shown in Fig６. Unknown system and adaptive FIR filter are allocated in parallel, and by LMS algorithm, error signal e_k is followed to minimum.

3 LMS (Least Mean Square) algorithm

As a refreshing method of coefficient of adaptive FIR, there exist many kinds of algorithm, such as RLS (Recursive Mean Square) algorithm. In this study, LMS algorithm was chosen as simplified steep descent algorithm.

$$h_{k+1} = h_k - 2\mu e_k x_k$$

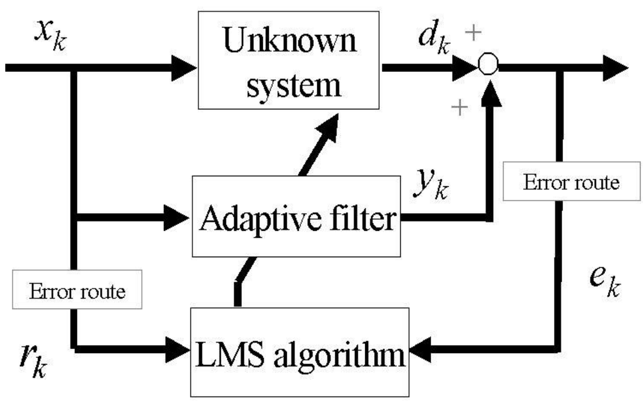


Fig6. Adaptive Control

LMS algorithm

In the previous chapter, absorber model and adaptive filter control scheme were described. Now, let us explain system configuration. Active control system, shown in Fig.6 was applied here. Signal from upper vibration is treated as reference signal. Both output response of unknown system, that is, dynamic system and signal from adaptive filter are coupled together. The latter adaptive signal is inputted to VCM. By changing filter coefficient continuously, transmitted force to the ground is aimed to make minimum.

1 LMS Simulation

The filter is repeatedly renewed by comparing input signal with transmitted force, thus it to minimum. VCM position is controlled by this algorithm and the effect is proven. The effect of the adaptive control is understood from the simulation by using the active mount model. The LMS algorithm is evaluated by using the active mount model. Fig７ shows the model.

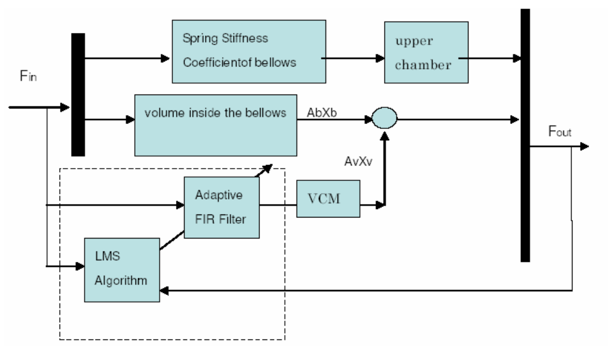


Fig7. LMS Simulation Model

2 LMS Simulation Result

Figure 8 shows the simulation result. Graph above is input vibration Fin. Graph below is Fout force transmitted to the highest part at active mount (LMS algorithm) control. When Fin=±20[N] was input to the regulating system, vibrations almost 0 were transmitted to the highest part. That is to say, it was able to say that the vibration attenuation in active mount became possible by using the adaptive behavior control (LMS algorithm).

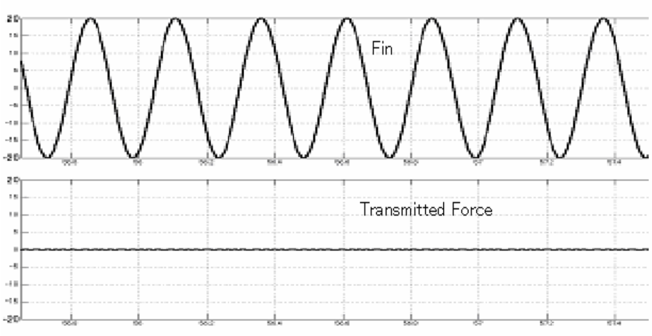


Fig8.　LMS Simulation Result

Basic Examination

Fig9 shows the experimental result. The vibration damping of 40[dB] was obtained in whole area of the frequency from 20 to 50 [Hz] in control OFF and ON. The vibration of +5 was amplified by control OFF. It is thought that this is because the reaction force acts, actuator always keeps neutral point. As for control ON, it was confirmed that the vibration reduction of 30[dB] is obtained, and the vibration attenuation of this wet type active mount becomes effective as shown in the result of the simulation.

Conclusion

This research, we developed a new active mount of wet type using actuator. In this device, static load is sustained by hydraulic pressure of upper and lower chamber. As the result, power consumption is low compared with conventional device.
First, static test jig was constructed, and fundamental vibration examination was conducted. We confirmed the effectiveness of the developed device.

Detailed results are shown in the following.

1: By simulation, volume flow continuity relationship between upper chamber and voice coil motor was studied. From this result, we developed adaptive control scheme for vibration reduction to the operator room.

2: By basic examination, vibration attenuation of 50 to 60[dB] was obtained in the whole area from 20 to 50[Hz].

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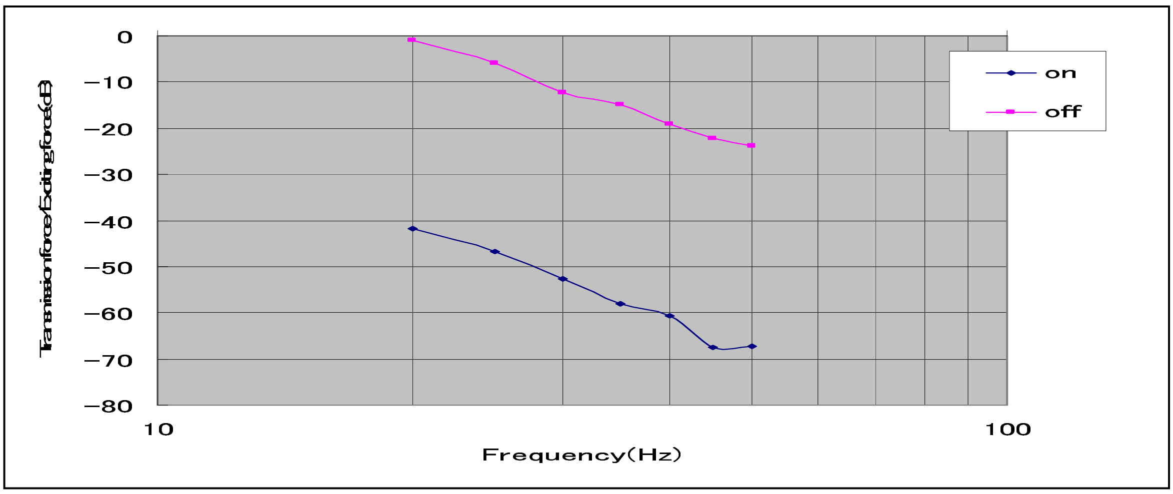

Fig9.　Basic Examination Result