上智大学大学院理工学研究科物理学専攻

14. Mechanical Damper Using Piezoelectric Ceramics

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INTRODUCTION

It is important to prevent vibration noise in precision mechanical instruments or elements.

In this study, a new type of damper was fabricated using piezoelectric materials. In principle, mechanical energy generated by vibration noise is transformed into electrical energy through the piezoelectric effect, then dissipated as heat energy through an external resistance.

PRINCIPLE

Piezoelectric ceramics exhibit charge generation when an external force is applied. Accordingly, mechanical vibration induces alternating voltage. Then, when an external resistance is connected to the piezoceramics, the generated electric energy is dissipated as Joule heat. However, if the resistance used here is extremely large or small, only a slight amount of energy is dissipated and damper function will not be effective. Therefore, dissipation of vibrational energy reaches the highest rate when the maximum heat is generated.

The dissipated energy is maximized when the connected resistor R is equal to the impedance of the ceramics:

$$R = 1/\omega C \tag{1}$$

At that time the total impedance of the whole circuit is 2R, and the energy dissipated by R should be equal to a half of induced electrical energy. Therefore the efficiency in transforming the electrical energy induced by vibration into heat energy can be 50%. Considering the electromechanical coupling coefficient k^2, the damping rate γ in amplitude of vibration in a cycle can be expressed by

$$\gamma = (1-k^2/2) \tag{2}$$

EXPERIMENT

A piezoelectric bimorph is a typical example of a combination of a vibratory object (metal plate) and piezoelectric ceramics (Fig. 1). Figure 2 shows the block diagram of a mechanical vibration measuring system used for the experiment. Firstly, the bimorph is bent mechanically by an electromagnetic pulse motor. Then an eddy current-type non-contact displacement sensor (KAMAN, SDP-2300) was used to measure the tip displacement of the bimorph. The output from the sensor is amplified and stored in an oscilloscope. The damping constant is evaluated from the ringing characteristics.

RESULTS AND DISCUSSIONS

Figure 3 shows change of ringing characteristics with external resistance. The damping rate in the amplitude of vibration in t[sec] can be expressed as follows:

$$e^{-t/\tau} = (1-k^2/2)^{t/To} \quad (3)$$

where, τ denots as a damping constant and To is a resonance period. Figure 4 shows the relation between the damping constant and the external resistor. It can be seen that the damping constant was minimized around 8kΩ region.

Practically, the bimorph involves mechanical loss, so that the total value of damping constant can be expressed as follows:

$$1/\tau_{total} = 1/\tau_s + 1/\tau \quad (4)$$

where τ_s denotes a damping constant when circuit was shorted.

CONCLUSIONS

An attempt was made to apply piezoelectric ceramics to mechanical dampers. A resistor was connected to a piezoceramic in order to convert the mechanical energy into heat energy, through piezoelectric effect. The relationship between the damping constant and the resistor was examined. As results:

1)Piezoelectric ceramics are highly effective for controlling vibrations.
2)The damping constant can be varied continuously by changing the resistor connected externally.
3)The damping constant is evaluated using an electro-mechanical coupling factor k.

In order to obtain quicker damping, an increase of k is generally required. Therefore, the efficiency of vibration damping can be improved when a transverse vibration mode (k_{31}) or a longitudinal vibration mode (k_{33}) are used.

REFERENCE

K. Uchino and T. Ishii: Mechanical Damper Using Piezoelectric Ceramics, J. Ceram. Soc. Jpn. Inter. Ed. 96 843-847 (1988)

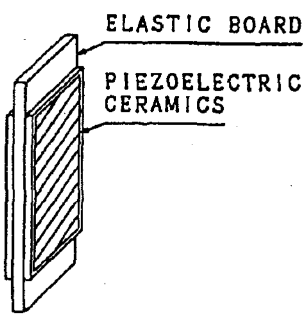

Fig. 1 Construction of bimorph.

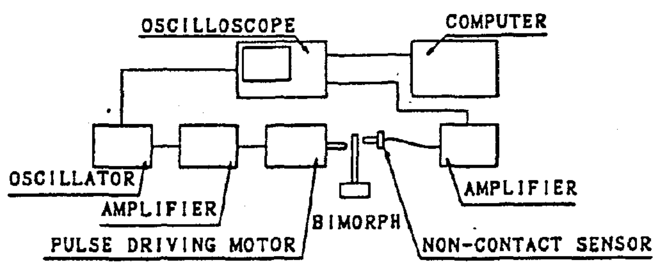

Fig. 2. Mechanical vibration measuring system.

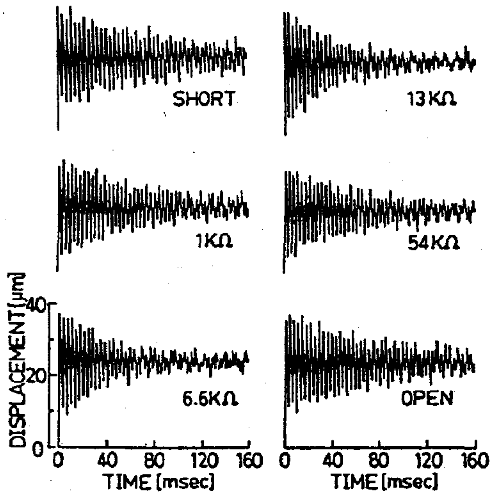

Fig. 3. Change of ringing associated with resistor change.

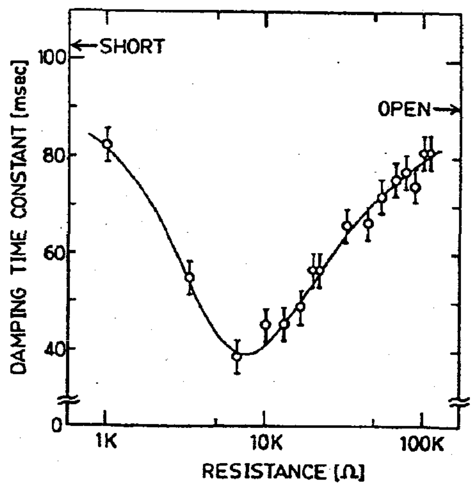

Fig. 4. Relationship between damping time constant and external resistor.