DEVELOPMENT OF 2 DOF LINEAR OSCILLATORY ACTUATOR FOR VIBRATION CONTROL

F. Kitayama[1,a], R. Kondo[1,b]

[1] *Department of Mechanical System Engineering, College of Engineering, Ibaraki University, Japan*
[a]*fumiya.kitayama.amayatik@vc.ibaraki.ac.jp*, [b]*ryou.kondo.piyashiri@vc.ibaraki.ac.jp*

Abstract. In automobiles, multi axis vibrations were generated by many mechanical parts. So, vibrations were actively controlled by using some linear oscillatory actuators. In the paper, we propose a 2 degrees of freedom linear oscillatory actuator to reduce vibrations, that achieves downsizing and weight saving of the system. First, the basic construction and operation principle are described. Next, the characteristics are clarified through measurements on prototype.

1. Introduction

It is well known that an automobile is a multimode system that generates multidimensionally undesirable vibrations. Also, some 1 DOF active control devices [1] are set on the automobile to reduce one or some dimensional vibrations. In this study, a 2 DOF inertia mass shaker as 2 DOF active control devices, that generates two-dimensional inertia force expressed as a product of acceleration and mover's weight by a 2 DOF linear oscillatory actuator, are developed in order to reduce two-dimensionally undesirable vibrations in a smaller number of devices. In this paper, the 2 DOF linear oscillatory actuator with lightweight movers is proposed.

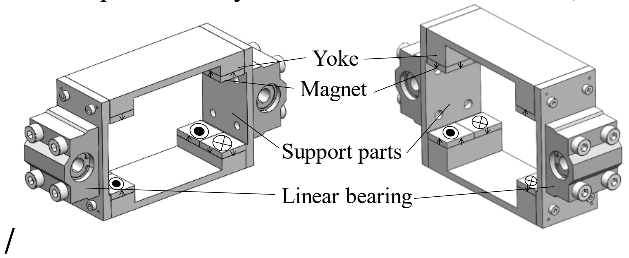
2. 2 DOF linear oscillatory actuator for vibration control

First, a target amplitude and drive frequency range of inertia force are determined as 30 N and 25-100 Hz at two dimensions, and limited current is 3A. The target inertia force is achieved by oscillating lightweight movers at large acceleration and strokes. Target mover's weight, acceleration and stroke are determined as 300g, 100m/s^2 and 10mm.

The proposed actuator is shown in Fig. 1. External dimensions of the main part are 78 x 78 x 61mm, that is almost the same as an actuator of the 1 DOF inertia mass shaker. The proposed actuator mainly consists of eight springs, a stator and two movers called as X mover and Y mover. Four springs are connected between the X mover and stator, and other springs are connected between the Y mover and stator. The stator is composed of two coils called as X coil and Y coil, yokes made from soft iron, and support parts made from non-ferromagnetic materials. The X mover is composed of yokes, eight square-shaped magnets, support parts and linear bearings that supports on the Y and Z axes. The Y mover is also configured like the X mover. Magnets magnetized at the positive Z direction and magnets magnetized at the negative Z direction are alternately arranged as shown in Fig. 1 (b) and (c). In order to constantly keep thrust at large stroke, relationships of position and size between magnets and the stator yoke are determined as referring to a 1 DOF actuator [2], and isosceles triangle-shaped notches are made in the stator yoke. Since current is applied to the X coil, a part of the stator yoke facing the X mover is magnetized, and it is repulsed and attracted with magnets of the X mover, consequently, the X mover is moved. Also, the stator yoke facing the Y mover is magnetized since current is applied to the Y coil, and it is repulsed and attracted with magnets of the Y mover, consequently, the Y mover is moved.

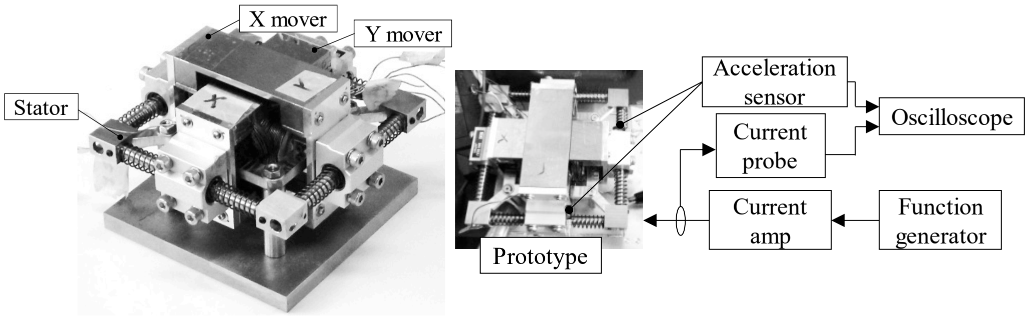
3. Experimental Evaluation by using prototype

A prototype was manufactured to experimentally evaluate the characteristics, as shown in Fig. 2(a).



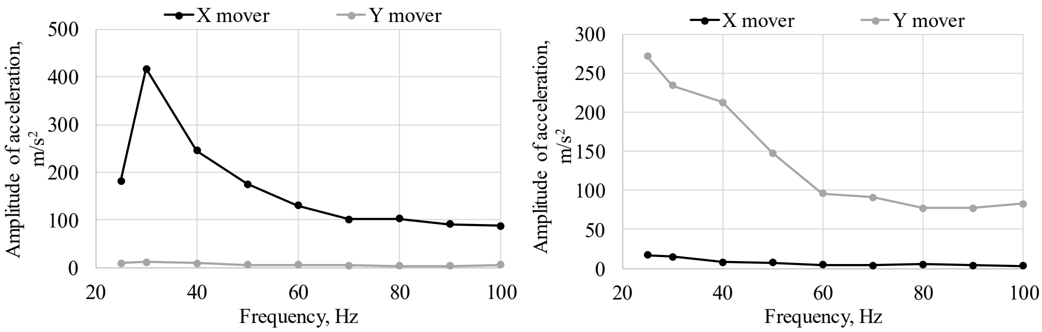
(a) (b) (c)

Fig. 1 Basic constructions: (a) overall; (b) X mover; (c) Y mover



(a) (b)

Fig. 2 Experiments for measuring acceleration: (a) prototype; (b) experimental setup



(a) (b)

Fig. 3 Measured acceleration: (a) current is applied to X coil; (b) current is applied to Y coil

The X mover's and Y mover's weight are 268 and 328 g. The experimental setup is shown in Fig. 2 (b). Sinusoidal current that an amplitude is 3 A and drive frequency is from 25 to 100Hz, was applied to the X coil or Y coil by a function generator (AFG1022, Tektronix) and a servo amplifier. Acceleration of movers and current of coils were measured by using acceleration sensors (NP-3211, Onosokki), current probes (3273-50, HIOKI) and an oscilloscope (LeCroy, 314A). The amplitude of measured acceleration when applying current to each coil was respectively shown in Fig. 3. The X mover was mainly oscillated when applying current to the X coil, and the Y mover was mainly oscillated when applying current to the Y coil. The acceleration amplitude was large at low drive frequency due to mechanical resonance, but minimum acceleration amplitude was $88m/s^2$ on the X mover and $77m/s^2$ on the Y mover. Also, it was observed that the maximum stroke is above 10mm. The inertia force of the X mover was maximum 112N and minimum 23N, and that of the Y mover was maximum 89N and minimum 25N.

Conclusions

- The 2 DOF linear oscillatory actuator that consists of two lightweight movers with surface permanent magnets and a stator yoke with notches, was developed.
- From measured results on prototype, it was verified that movers could be two-dimensionally oscillated at large strokes. Also, the calculated inertia force was satisfied the target value at the low drive frequency range, but the ratio of the calculated inertia force to the target value was from 78 to 90% at the high drive frequency range. In the future, it will be satisfied the target value at all drive frequency range by adjusting the mover's weight and coil conditions.
- In the presentation, measured results will be discussed in detail by comparing with analyzed results.

References

[1] Svaricek F., Bohn C., Marienfeld P., Karkosch H.J., Fueger T. *Automotive Applications of Active Vibration Control*, *Vibration Control*, IntechOpen, 2010, 303-318.

[2] Asai Y., Hirata K., Ota T. Dynamic Analysis Method of Linear Resonant Actuator with Multimovers Employing 3-D Finite Element Method, IEEE Transaction on Magnetics, 2010, 46 (8), 2971-2974.