Development of Detachable Surface Damper for Stepping Motors

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1. Introduction

With no need for a feedback loop to control the speed and position, the stepping motor finds its applications in a wide range of OA equipment such as printers, and copiers.

As there is the growing preference for a quieter office environment, there is an increasingly tougher demand for low-vibration and low noise motors used in such equipment.

To meet such a demand, we have developed our unique "Detachable surface damper" (hereafter referred to as "damper") using rubber, which is a good vibration-reducing material.

This damper is to be mounted on a stepping motor to reduce motor vibration and noise effectively.

This article describes the shape, features, and performance of the damper as well as the theory on vibration isolation.

2. Background to Development

Detachable dampers are commercially available but in many cases, they are not compatible with Sanyo Denki motors. In addition, they are too expensive to be used extensively for our motors.

We already had vibration-isolation “rubber-flanges” commercially available where a motor flange is integrated through rubber with the customer-side mounting panel. With an increasing number of customers wanting only a damper replaced while reusing a motor, the “rubber-flanges” are no longer able to meet this customer need.

With this background, we needed to develop our own unique damper to be attached to Sanyo Denki’s motors, which could be easily detached from the motor while ensuring sufficient vibration-isolation performance. To make this damper commercially viable at lower cost, we focused on its shape.

The damper is available in two types for the most popular two motor sizes, 42mm sq. and 56mm sq.

3. Theory on vibration isolation

Following is how the motor with a damper runs vibration isolation. By installing rubber between the motor and the device, vibration produced by the motor is prevented from being transmitted to the equipment. Additionally, vibration produced by the equipment is also prevented from being transmitted to the motor.

The ratio of the vibration force from the motor to the force transmitted through the rubber is called vibration transmission ratio.

Transmission ratio τ is given by the following equation.

$\tau = P/P_0 = 1/\,|\,1-(f/fn)^2\,|$ ---- (1)

P: Vibration force from motor (N)
P_0: Force transmitted to device (N)
f: Vibration frequency of motor and device (Hz)
fn: Characteristic frequency when damper is installed (Hz)

f/fn is called frequency ratio. The vibration is effectively reduced when the vibration transmission ratio τ is 1 or less, and the frequency ration is $\sqrt{2}$ or more. But the frequency ratio is normally set to 2 to 3 beyond which the weight of the support can no longer be supported. From Equation (1), the relationship between frequency ratio and transmission rate is as shown in Fig. 1.

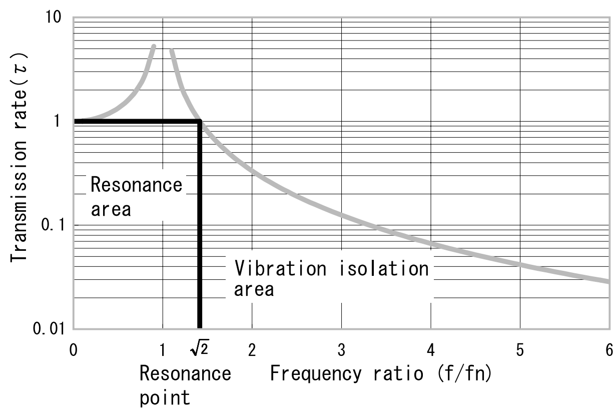

Fig. 1 Relationship Between Frequency Ratio and Transmission Rate

On the other hand, if we look at the motor's torsional direction, the characteristic frequency fn is given by the following equation:

$$fn=(1/2\pi)\times\sqrt{K/I} \text{ ------ } (2)$$

Solving Equation (2) for K, we have

$$K=(2\pi fn)^2 I \text{ ------ } (3)$$

K: Torsion spring constant (N・m/rad)
I: Moment of inertia (N・m・s^2)

Selecting a damper that is approximate to the spring constant obtained from Equation (3) will provide the desired vibration isolation effect.

4. Appearance and Features of the Damper

4.1 Appearance

Fig. 2 is the appearance of the two dampers with the left for 42sq. mm and the right for 56sq. mm. The rubber is glued between the two sheet metals by means of vulcanization. Fig. 3 shows a damper secured to the motor. With the damper fixed to the motor with screws, the motor will be installed in the customer's system.

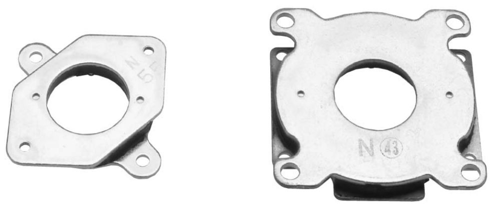

Fig. 2 Dampers

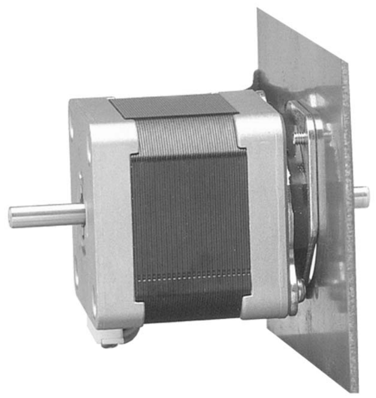

Fig. 3 Mounted Damper

4.2 External Dimensions

Fig. 4 and 5 show the external dimensions of the two dampers, with Fig. 4 for 42square mm, and Fig. 5 for 56square mm. Also available is a type with a positioning protrusion provided on the sheet metal of the customer's device.

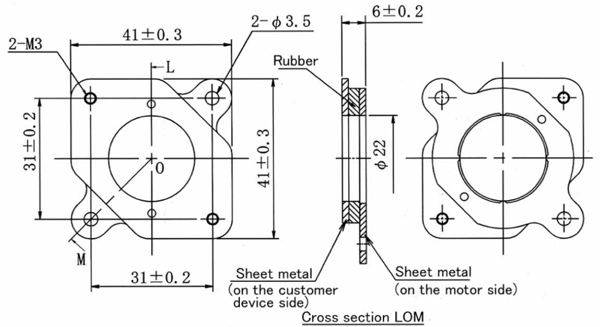

Fig. 4 External Dimensions of the Damper (for 42sq. mm)

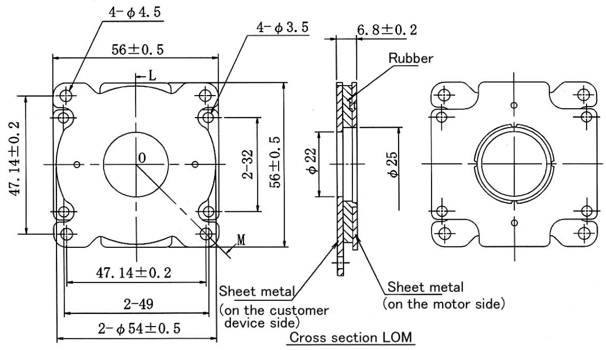

Fig. 5 External Dimensions of the Damper (for 56sq. mm)

4.3 Property

Table 1 shows the types of damper recently developed as products and their properties Dampers for 42sq. mm and 56sq. mm come in three different types according to the hardness of the rubber.

The standard rubber material is NBR (nitrile rubber) known to have excellent thermal resistance and oil resistance as well as extensive range of hardness to select from so that it can be applied to products having an extensive range of characteristic frequency. It should be noted that if weather resistance is required, CR (chloroprene rubber) is most suitable, and if high attenuation characteristics are required, IIR (butyl rubber) is the best suited.

Table 1 Types of Damper and Their Properties

Size	Rubber material	Rubber hardness (degree)	Torsional spring constant (N·m/rad)
For 42sq. mm	NBR	45	43
		55	55
		63	67
For 56sq. mm		43	154
		55	217
		63	363

4.4 Advantages

The damper has the following properties:

(1) Damps an extensive range of vibrations and noises

NBR used as the rubber material provides an extensive range of hardness to select from so the damper can effectively reduce a wide range of vibrations and noises that occur under various conditions.

(2) Specially designed mold to reduce the cost

The mold for rubber is a simple design, consisting of only upper and lower parts, with the outer diameter of the damper rubber built to be the same as that of the sheet metal. This simplifies the molding process and reduces the cost of the mold.

(3) Smooth and precise installation on the motor

The protrusion provided on the inner diameter side of the sheet metal on the motor side allows the damper to be mounted on the motor's flange with high precision. It allows a point-contact coupling with a flange, thereby it can be mounted more smoothly.

(4) Shape of sheet metal specially designed to improve productivity

To prevent sheet metals from overlapping with one another in the washing process of the production of the sheet metal for this damper, protrusions are provided on both surfaces, one on the customer' device side and the other on the motor side. This also makes washing easier and more reliable.

(5) Allows rubber flange to be replaced

Conventional-type rubber flange can be replaced without changing the total motor length, while keeping the motor's anti-vibration capability.

(6) Easy-to-recycle detachable type

Damper, to be screwed to the motor, can be replaced without having to replace any other parts of the motor to be recycled.

5. Vibration Isolation Characteristics

Following is the description of the vibration-isolation characteristics of this damper mounted on a stepping motor. More specifically, a comparison was made between the motor without the damper and the motor with the damper and the resulting noise and vibration characteristics (speed variation characteristics).

5.1 Noise Characteristics

Fig. 6 compares noise. The motor with the damper has its noise level 10 - 15dB lower than the motor without the damper, proving the effective noise reduction.

5.2 Vibration Characteristics

Fig. 7 compares vibration (speed variation). In the motor without the damper, the speed rapidly increases when a certain frequency is exceeded, causing the motor to go out of synchronism, resulting in stopping rotation.

In contrast, the motor's vibration is controlled by damper's vibration-reduction means, even when the frequency is increased. Thereby it will continue to rotate at a higher speed without going out of synchronism.

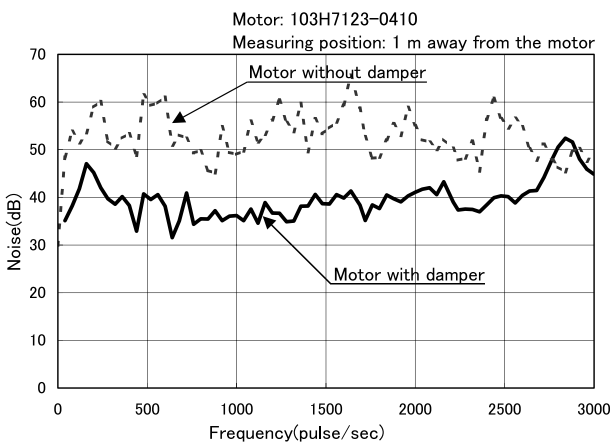

Fig. 6 Noise Characteristics

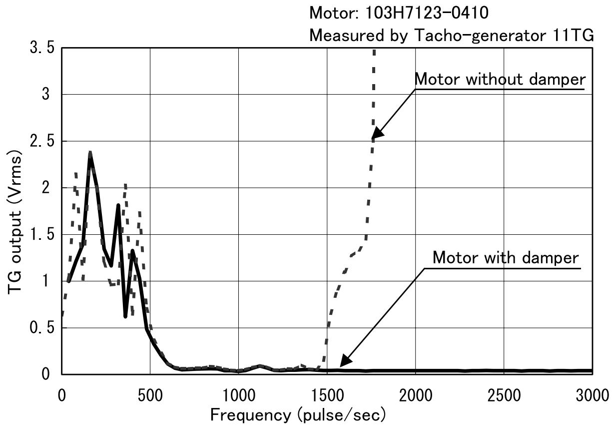

Fig. 7 Vibration Characteristics

6. Conclusion

We have discussed the newly developed detachable surface damper. With an ever-growing demand for low vibration and low noise systems, the vibration-isolation damper is becoming more and more indispensable. Dictated by concern for the environment, the old "rubber flange" type seems to be on its way out, to be replaced by the detachable type, which allows the motor to be re-used.

The stepping motor, large or small, is used for many devices under numerous different conditions and environments. Under such circumstances, it is desirable to be able to select the damper that suits the motor when vibration needs to be reduced.

Therefore, we think it is necessary to develop dampers highly capable of vibration isolation that fits not only the 42sq. mm or 56sq. mm motor size, but other sizes also.

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