Proceedings of the 6th JFPS International
Symposium on Fluid Power, TSUKUBA 2005
November 7-10, 2005

Development of a New Pneumatic Silencer to reduce unpleasantness of a sound

Hisami MURAMATSU* , Hirokazu ONO ** , Masaaki ADACHI ***

* Department of Mechanical Engineering, Numazu College of Technology
3600 Ooka, Numazu, Shizuoka, 410-8501 Japan
(E-mail : muramatu@numazu-ct.ac.jp)
** Department of Mechanical Engineering, Faculty of Engineering, Mie University, Student
1577 Kurimamachiya, Tsu, Mie Japan
*** Mechanical and Electrical Engineering Course, Advanced Engineering Course,
Numazu College of Technology, Student
3600 Ooka, Numazu, Shizuoka, 410-8501 Japan

ABSTRACT

A high performance pneumatic silencer to reduce unpleasantness of the noise is newly developed in this paper. It is shown that a sound effect of fade-in found by consideration of results from ergonomics is obtained by the silencer. The silencer consists of three kinds of silencers and a device. The device uses artificial muscle utilized a shape memory alloy. It is cleared that sound power level of the silencer is very low.

KEY WORDS

Pneumatics, Noise reduction, Sound power level, Artificial muscle, Shape memory alloy

Introduction

Noise radiated from pneumatic system causes discomfort to us. Especially when the pneumatic system is applied to medical and welfare apparatus, a new consideration about the noise reduction is necessary. Granted that A-weighted sound pressure level is low, a comfortable sound environment is not provided for people in a room. It has been reported that a sound effect of fade-in reduces annoyance by simulations [1][2]. The fade-in is an acoustic characteristic that the A-weighted sound pressure level gradually increases.

In this paper, a high performance pneumatic silencer having an effect of the fade-in is developed. Artificial muscle is used as an actuator in the fade-in device. The number of artificial muscle and conditions of electrical power supply to it are investigated. The acoustic characteristics of the silencer are examined.

Nomenclature

L_A : A-weighted sound pressure level [dB(A)]
L_{wA} : A-weighted sound power level [dB(A)]

B.G.N. : Back grand noise [dB(A)]
t_0: Time at which a spool starts to move [s]
t_1: Time at which the spool stops [s]
Q : Volume flow rate through a restriction [L/min]

Experimental apparatus

Figure 1 shows a high performance pneumatic silencer and noise measuring system. The noise occurs aerodynamically when compressed air flows through a restriction in a pipe. A pneumatic silencer installed downstream from the restriction reduces the noise. Diameter of the restriction is 2.0mm. The silencer combines a silencer T1, a silencer T2, a speed controller, and a fade-in device. The silencer T1 is composed of a silencer HPS[2] and a silencer NS. The silencer T2 is used a silencer SHPS[2] instead of silencer HPS. The silencer HPS and SHPS consist of three different types of silencers; blow-off type, resonator type, interference type, and expansion chamber. Silencers NS having sound absorbing material are connected to them in series, respectively. Effective areas of them are $58.4mm^2$ (NS), $30.3mm^2$ (HPS), $37.2mm^2$ (SHPS). The fade-in device is set on a position e in Fig.1 and a speed controller on a point f.

A condenser microphone is put at the position of 1m away from the high performance pneumatic silencer and at 45 degrees to the center line of the silencer[3]. A-weighted sound pressure level L_A is measured. The level of back grand noise *B.G.N.* in the anechoic room, which is defined as A-weighted sound pressure level measured when air isn't supplied to the silencer, is 27dB(A).

The high performance pneumatic silencer is surrounded by a measurement surface as shown in Figure 1. A-weighted sound power level L_{wA} based on the sound intensity through it is calculated. A sound intensity probe sweeps on the measurement surface with a constant speed. The sound intensity probe containing a matched microphone pair is constructed on a face-to-face design.

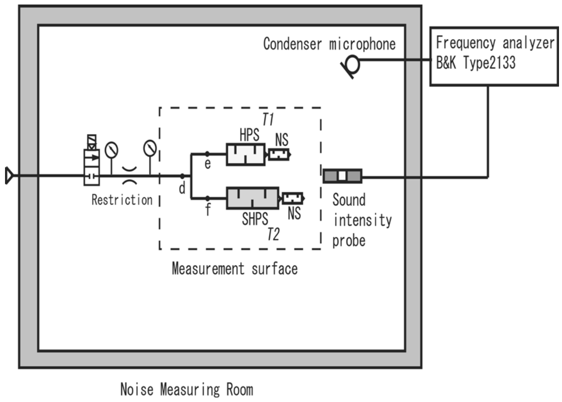

Figure 1 Noise measuring system

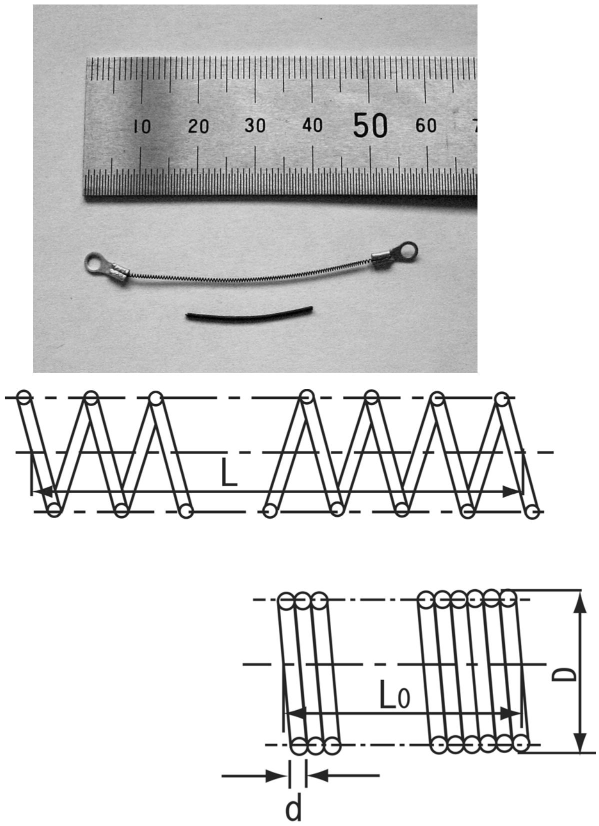

Figure 2 Artificial muscle

Table 1 Dimensions of artificial muscle

	Original dimensions	Stretched dimensions
Diameter of coil D mm	0.85	0.75
Diameter of wire d mm	0.20	0.20
Stretched Length L mm	-	42
Original Length L_0 mm	20	-
Number of turns n	85	85

Design of a high performance pneumatic silencer

Artificial muscle utilized a NiTi shape memory alloy is used as an actuator in the fade-in device for control of spool movement. Table 1 shows dimensions of the artificial muscle got into a spiral shape. The artificial muscle is stretched from the original length as shown in Figure 2. Heat is produced by running direct current through the artificial muscle and it shrinks to. The artificial muscle returns again to the stretched length if it is cooled.

Figure 3 represents the experimental setup to determine the number of the artificial muscle and helical extension spring. The springs and the artificial muscles are attached to a spool in a tube. The spool is returned to the initial position by the springs after breaking in a circuit. Spring constants of the spring A and spring B are 88.8N/m and 97.6N/m, respectively.

Figure 4 shows on/off pattern and displacement of the spool. Table 2 shows time t_0 at which the spool starts to move and time t_1 at which the spool stops under four tests using the spring A. According to increase of the number of the spring, time t_1 -t_0 is getting long. Times, however, are short for the fade-in[1]. Table 3 shows time t_1 -t_0 under two tests using the spring B. By using the spring B in return for the spring A, stick-slip is occurred in Test 5. The stick-slip is avoided by increasing the number of the artificial muscles in Test 6 though time t_0 is 2.2sec.

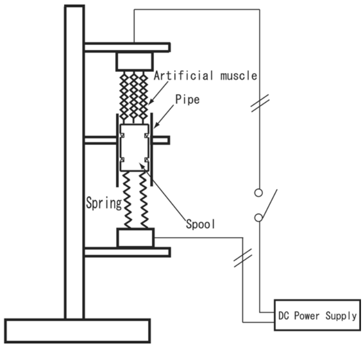

Figure 3 Artificial muscles attached to a spool

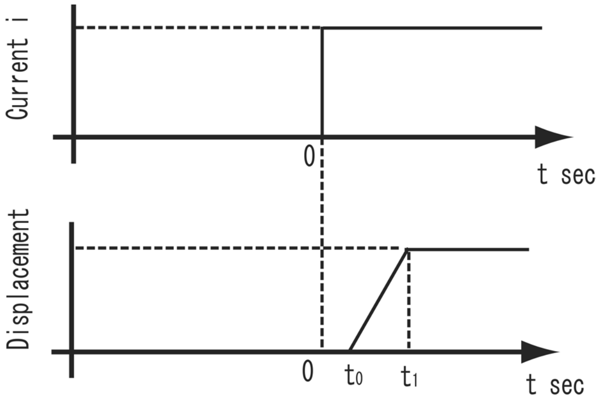

Figure 4 Displacement of the spool

Table 2 Conditions of tests and time for displacement

	Experimental condition		Operating condition		Results		
	Number of A.M.	Number of spring A	Total electric power W		t_0 sec	t_1 sec	t_1-t_0 sec
Test1	6	1	7.2	→	1.0	2.5	1.5
Test2	6	2	7.2	→	1.0	3.2	2.2
Test3	6	3	7.2	→	1.0	3.4	2.4
Test4	6	4	7.2	→	1.0	3.8	2.8

Table 3 Conditions of tests and time for displacement

	Experimental condition		Operating condition		Results		
	Number of A.M.	Number of spring B	Total electric power W		t_0 sec	t_1 sec	t_1-t_0 sec
Test5	6	4	7.2	→	1.9	6.7	4.8
Test6	12	4	10.0	→	2.2	6.6	4.4

Figure 5 shows an improved on/off pattern. The spool remains stationary in preliminary run because total electric power is small. The time t_0 is improved to 1.1sec, as shown in Table4. It is expected that temperature of the artificial muscle will rise and time for deformation of the coils will be shorten.

Figure 6 illustrated a fade-in device installed in the high performance pneumatic silencer. When the current is supplied to the artificial muscles using the conditions of Test 8, they pull the spool and small holes are covered.

Acoustic characteristics

Figure 7 shows A-weighted sound power level calculated by sound intensity against flow rate Q through the point d in Figure 1. Two conditions in Figure7 indicate that the holes in Figure 6 are either closed or opened fully. A-weighted sound power levels L_{wA} of the high performance pneumatic silencer kept in fully opened and closed conditions are very small, compared with that of the silencer NS.

Figure 8 shows variation of A-weighted sound pressure level L_A. The flow rate Q supplied to the silencer is 150 L/min. A-weighted sound pressure level L_A is gradually increased except for steeply rise from the level of back grand noise *B.G.N.* soon after valve at

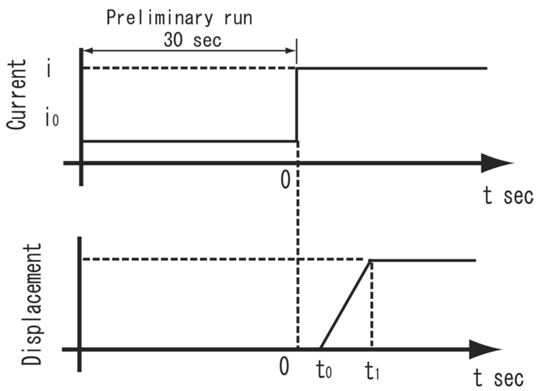

Figure 5 On/off pattern and displacement of the spool

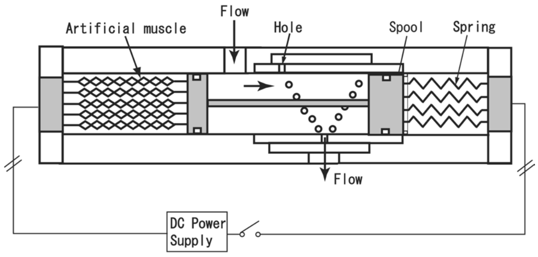

Figure 6 Fade-in device

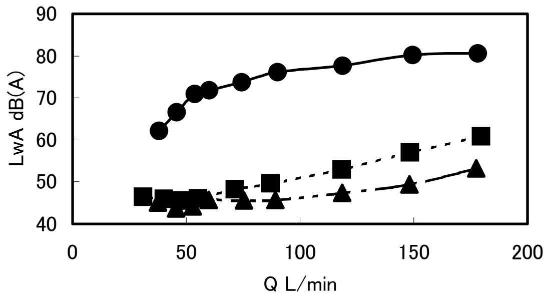

Figure 7 A-weighted sound power levels against flow rate

●NS, ▲Silencer in fully opened condition,

■Silencer in fully closed condition

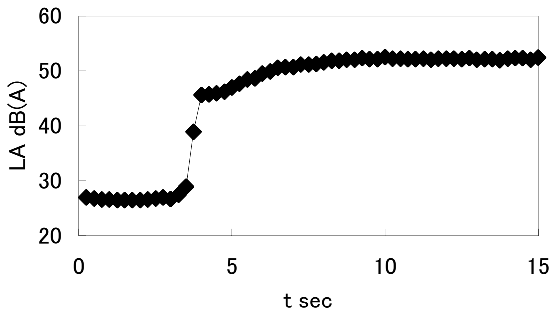

Figure 8 Variation of A-weighted sound pressure level

Table 4 Conditions of tests and time for displacement

	Experimental condition		Condition of preliminary run	Operating condition		Results
	Number of A.M.	Number of spring B	Total electric power W	Total electric power W		t_0 sec
Test7	12	4	0.6	10.0	→	1.9
Test8	12	4	1.5	10.0	→	1.1

the upstream position is opened. A-weighted sound pressure level L_A reaches an asymptotic value 53dB(A) and increase of L_A is 7dB(A).

Conclusion

A high performance pneumatic silencer was developed. It was found that the sound effect of the fade-in was made. The number of artificial muscle and conditions of electrical power supply to it were determined. It was cleared that the noise was reduced remarkably.

Acknowledgements

This work is supported in Japan by Grant-in-Aid for Scientific Research (C). The authors would like to thank Mr. M. Katahira, a student at the Toyohashi University of Technology and Mr. K. Shoubu, a student at the Yokohama National University, for their corporation on making silencer HPS and silencer SHPS.

References

1. H. Muramatsu, Pneumatic Noise Reduction Based on Ergonomics, Spring symposium on fluid power JFPS, 1993, pp.107-109. (in Japanese)
2. H. Muramatsu, M. Katahira, K. Shoubu, Reduction of Noise Radiated from Pneumatic Silencer, Spring symposium on fluid power JFPS, 1994, pp.64-67. (in Japanese)
3. Japanese Industrial Standard B 8379 Pneumatic circuit-Silencers 1995.