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A Study on the Noise Reduction of Reciprocating Type Air Compressors

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Abstract : This paper deals with the noise evaluation technique of a reciprocating air-compressor and its noise reduction. The reciprocating air-compressors are widely used in the small, medium sized industrial firms, and lots of their employees are affected and irritated by their noise in the workplace. Thus, noise control actions should be taken appropriately by considering the hearing loss due to the occupational noise exposure. Lead-wrapping techniques are employed to identify the contribution of principal noise sources which are generally known as motor, belts, suction/discharge valves, moving pistons, and flow-induced noise caused by edges or discontinuities along the flow path e.g. expansions, contractions, junctions and bends etc.. As a result, main noise sources of the air-compressor can be categorized by the suction/discharge noise, valve noise, and compressed-air tank noise. Based on the investigations, mufflers are designed to reduce both the suction/discharge noise and the compressed-air tank noise. Instead of the conventional valve plate, polyethylene resin is used as a new one for the reduction of valve impact noise. In addition, attempts are made to reduce the valve noise propagation to the cylinder head and the compressor tank by using the insulation casings. As a result of the countermeasure plans, it can be achieved that the noise reduction of the air-compress is up to 10 dB.

Key words: noise reduction, air compressor

1. Introduction

The international trend toward more stringent environmental noise control in the factory has made it increasingly important to reduce the noise level of a reciprocating air-compressor since it is widely used in the small/ medium sized industrial firms and their employees are irritated by the noise in the workplace. To achieve minimal machinery noise, noise control actions should be taken appropriately by considering the characteristics of each noise source and its contribution to the overall noise.

Here, the goal of the study is to find the contributions of the reciprocating air-compressor noise sources and then to reduce its noise. For these purposes, noise measurements of a reciprocating air-compressor are carried out to verify the principal noise characteristics. Simultaneously, experimental decoupling techniques such as a selective lead-wrapping and selective operation tests are incorporated. These methods are known as powerful tools for achieving complicated noise source identification when the numerical modeling of noise sources and transmission paths is difficult. Finally, the contribution of each noise source is evaluated and a couple of countermeasure plans are proposed for the noise reduction.

2. Measurement of Air-Compressor Noise

2.1. Overview of Noise Sources

The reciprocating air-compressor noise is basically generated by motor/belt vibration, crankshaft vibration, air suction/

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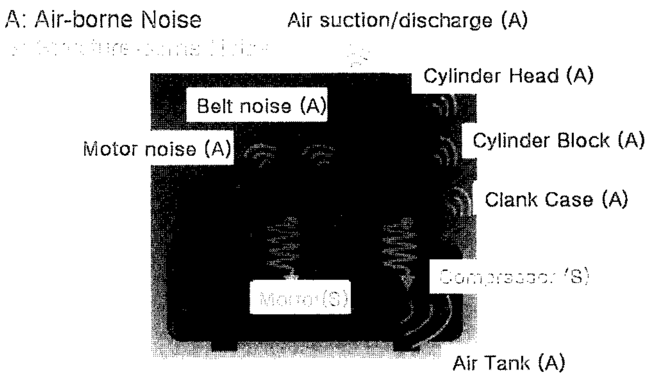


Fig. 1. Noise sources of reciprocating air-compressor.

discharge and piston/valve movement. For the generation of internal noise the situation is somewhat different, as noise transfer is happened via the structure and directly via air. As illustrated in Fig. 1, air-borne noises are generated by motor, belt, air suction/discharge, cylinder head/block, and crank case. The most dominant structure-borne noise is transferred to the compressed-air tank due to the vibration of the motor and compressor as depicted in Fig. 1. Therefore, the compressed-air tank vibration is composed by the structure-borne noise and the air-borne noise generated by the compressed air discharge to the tank.

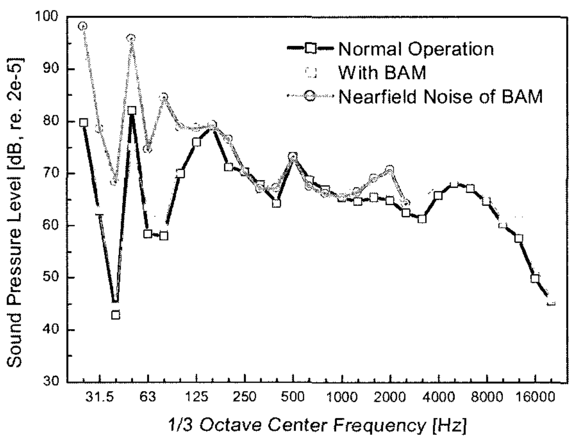
2.2. Noise Source Identification

All of the noise measurements were carried out as described in ISO 1680/1 [1]. Here, 5 microphones were placed at locations of 1 m from the rectangular envelope which just encloses the air-compressor. In the beginning, to identify the effects of intake noise on overall compressor noise, the intake noise was reduced and redirected to the opposite side of the microphone by using the big auxiliary muffler(BAM) which was designed to reduce the sound transmission in the duct using high sound absorbing materials. As shown in Fig. 2(a), air-compressor noise was measured during the operation and compared with the test result of normal operation. At the same time, attaching the microphones to the near-field of suction noise, measurement was carried out to measure the intake noise characteristics. The intake noise has low frequency components between 125-315 Hz corresponding to the harmonic orders of moving piston.

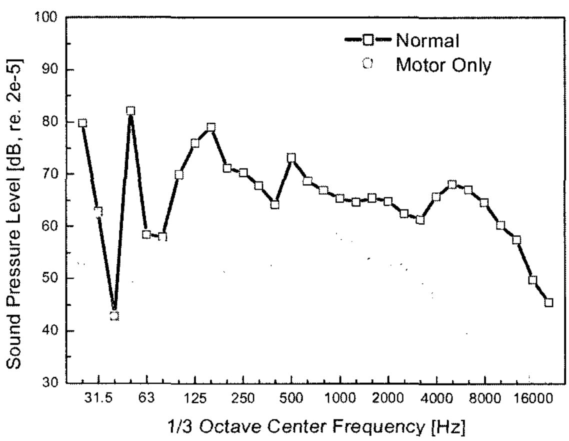
Selective operation technique was performed for evaluation of motor noise by removing the belts. There was an assumption that no appreciable change in operation and performance of the motor would occur due to the disconnection. Fig. 2(b) shows that the effect of motor noise on the overall noise is negligible since the motor noise is extremely small compared with the air-compressor noise all over the frequency range of interest.

In order to evaluate the valve noise, measurements were carried out after removing suction/discharge valves. Fig. 3(a) shows that the air-compressor noise was greatly reduced all over the frequency range of interest. Therefore, it can be concluded that the valve is the most important noise source of the air-compressor. Another test for evaluating the tank radiation noise was performed. In this test, the compressed-air tank was lead-wrapped to reduce the radiation noise from the tank as depicted in Fig. 4(a). Fig. 3(b) shows that the air-compressor noise was reduced in the frequency range between 500-8000 Hz as a result of high transmission loss of the shell.

To reduce the radiation of the cylinder head and cylinder block, the lead wrapping was applied to the outside of the compressor as shown in Fig. 4(b). As a measurement result, it is found that the main frequency compo-

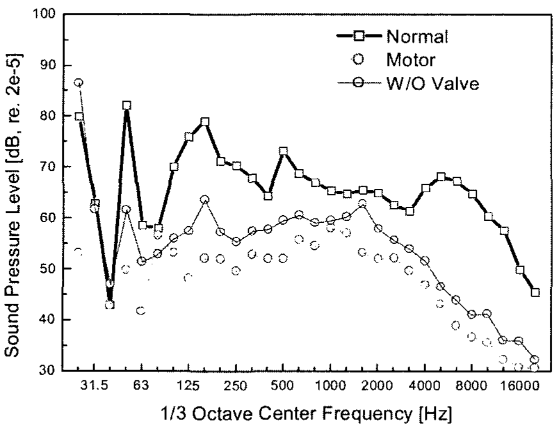


(a) Normal Operation With BAM Nearfield Noise of BAM

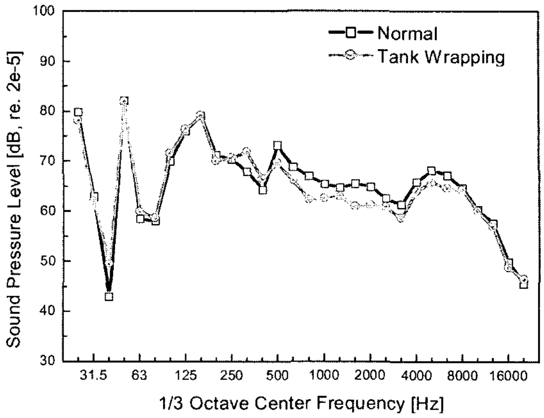


(b) Normal Operation Motor Noise

Fig. 2. Evaluations of (a) intake noise, (b) motor noise.

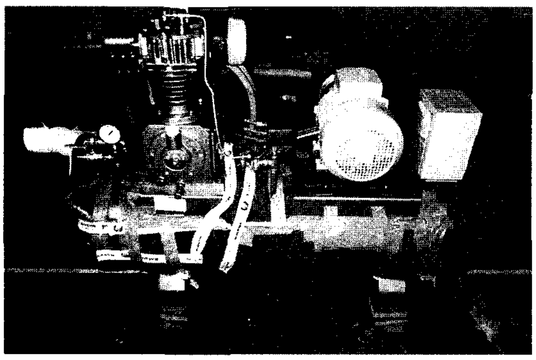


(a) Normal Operation Without Suction/Discharge

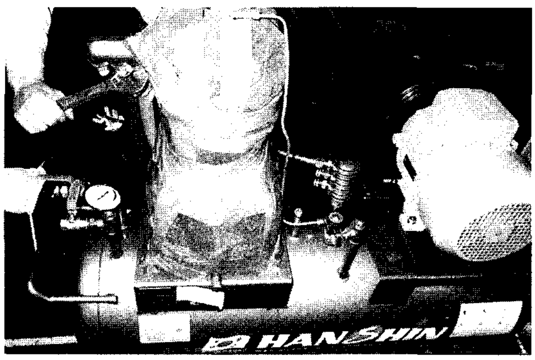


(b) Normal Operation Without Tank Radiation

Fig. 3. Evaluations of (a) valve noise, (b) tank radiation noise.

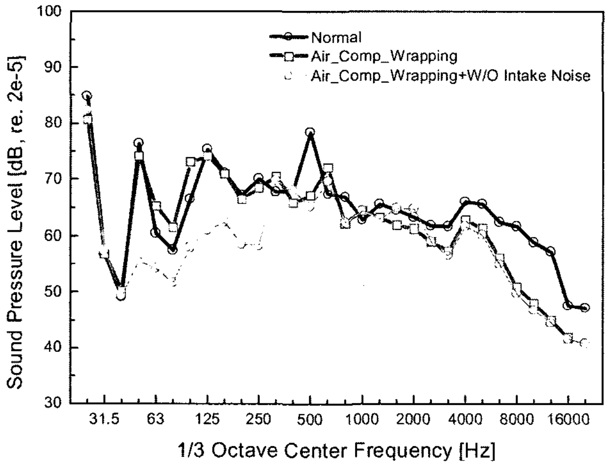


(a)



(b)

Fig. 4. Lead wrapping of (a) compressed-air tank, (b) cylinder head and block.



Normal Operation Without cylinder Head/Block radiation

Fig. 5. Evaluations of cylinder head/block radiation noise.

nents are around 500 and 4000-8000 Hz as depicted in Fig. 5.

2.3. Noise Contribution Analysis

The acquired data from the previous tests was compared with each other. Fig. 6 shows the contribution of each noise source. It can be found that the principal noise is generated by the suction/discharge valves and the radiation from the air-compressed tank is one of the main noise source in the frequency range between 500-6300 Hz. Additionally, the intake noise is dominant below 315 Hz.

3. Countermeasure Plans

Mufflers were designed to reduce both the suction/discharge noise and the compressed-air tank noise. A simple expansion chamber with an internal partition was used to reduce the suction noise. This is an effective method of reducing low frequency noise over a limited frequency range. In the case of valve noise, instead of the conventional valve plate, polyethylene resin is used

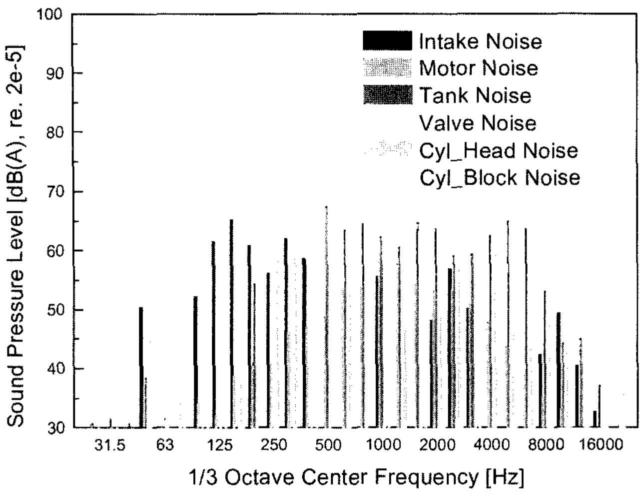


Fig. 6. Contribution of each noise source.

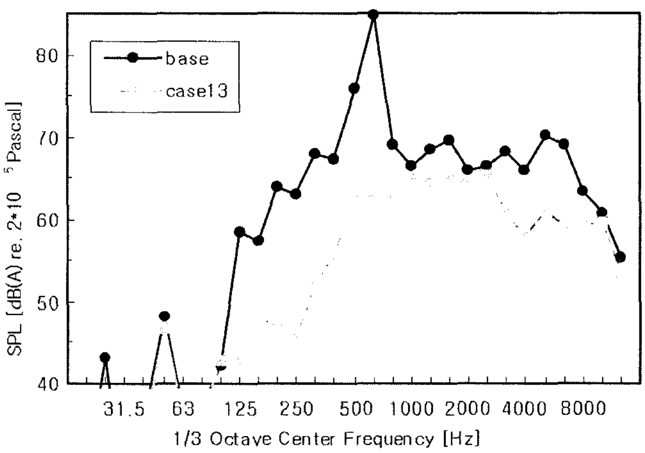


Fig. 7. Comparison of air-compressor noise between the original and new models.

as a new one for the reduction of valve impact noise. In addition, attempts are made to reduce the valve noise propagation to the cylinder head and the compressor tank by using the insulation casings.

Vibration of the tank produced by the motor and compressor needs to be reduced by the isolation. The radiation noise from the tank can be reduced by insulating the vibration transmission from the motor and air-compressor. For this purpose, the rubber mount was placed between the motor/compressor unit and the tank keeping the degree of vibration as low as possible in which the natural frequency of the machine on the tank must be below the normal running speed of the air-compressor.

As a result of the countermeasure plans as mentioned before, it can be achieved that the overall noise reduction of the air-compress is up to 10 dB as shown in Fig. 7.

4. Conclusions

In this paper, the noise contribution analysis of a reciprocating air-compressor was performed. In order to obtain each noise source characteristic, the selective operation and lead wrapping techniques are employed during the operations and the contribution of each noise source was obtained. As a result, main noise sources of the air-compressor can be categorized by the suction/discharge noise, valve noise, and the radiation noise from compressed-air tank. As a result of the countermeasure plans, it can be achieved that the noise reduction of the air-compress is up to 10 dB.

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