Noise Source Identification of Reciprocating Air Compressor in a Normal Operating Condition using Spatially Low-Resolution Sound Measurement

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Abstract

Due to its compact size and economic reasons, reciprocating air compressor is widely used in the site where compressed air source is needed. However, sound radiation from the reciprocating compressor is irritating to many workers and also to other people in its environment. However, accurate noise source identification usually requires complete measurement of the sound source with fine resolution. In present work, sound radiation from the reciprocating compressor was measured in both near-field and far-field to identify the major noise source with relatively low spatial resolution. Sound pressure and intensity were reconstructed on the surface closer to the source from the measurement. Also, the amplitude of source was estimated from the measurement. As results, major noise source was shown and effective noise reduction strategy for refining design of the air compressor could be established.

Keywords: Noise, Reciprocating Air Compressor, Sound Radiation

1. Introduction

Due to its compact size and economic reasons, reciprocating air compressor is widely used in the site where compressed air source is needed. However, sound radiation from the reciprocating compressor is irritating to many people working and also to other people in its environment. High level of noise is not only threat to the health of workers but may increase the risk of other accidents due to ineffective communication and alarming. In present work, sound radiation from the reciprocating compressor was measured with relatively low spatial resolution in both near-field and far-field to identify the major noise source. Sound pressure and intensity were reconstructed on the surface closer to the source from the measurement. Also, the amplitude of source was estimated from the measurement. As results, major noise source was shown and effective noise reduction strategy for refining design of the air compressor could be established.

Accurate noise source identification usually requires complete measurement of the sound source with fine resolution. For preliminary measurement to design more detailed measurement, relatively few measurements can be taken with low resolution to reduce both cost and time for the measurement. However, acoustical holography for reconstruction of the acoustic property and wave superposition for source amplitude estimate were implemented for more accurate noise source identification.

Noise source amplitude can be estimated from the near-field pressure measurement by application of the principles of wave superposition¹⁻⁹. Also, acoustic properties can be reconstructed on the surface closer to sources from the near-field pressure measurement by application of the near-field acoustical holography (NAH)¹⁰⁻¹⁵. For the accurate reconstruction of acoustic properties requires complete measurement of sound radiation from sources. However, accurate reconstruction can be improved for spatially limited measurement by avoiding spatial Fourier transform¹³⁻¹⁵.

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2. Measurement Description

2.1 Compressor Details

Reciprocating air compressor used in sound radiation measurement is shown in Figure 1. The air compressor with the motor cover removed is also shown. Location of the motor, fan, and capacitors is clearly shown. The motor is directly connected to fan and crankshaft. Reciprocating air compressor is powered by 2.5 hp (1.84 kW) 4-pole AC motor. The nominal rotating speed of the motor is 1750 rpm. Approximate size of the compressor is 50 cm by 60 cm in width and height. The pressure of the compressor air tank was automatically maintained in range of 5.5 to 8kgf/cm² (5.4 to 7.8 MPa) by switching on and off the compressor motor. The above air tank pressure was considered as the normal operating condition of the air compressor and used for all measurement shown in present work. The normal operating condition of the air compressor is assumed to be slightly nonstationary.

2.2 Measurement Setup

The sound field of the compressor operating at normal condition was measured with two microphones at the semi-anechoic room as shown in Figure 1. The size of the semi-anechoic room was approximately 3.3 m square. One stationary reference microphone was located very close to the left side surface of the compressor approximately 50 cm high. The stationary reference microphone

was located at the same position throughout the entire measurement.

Both near-field and far-field measurements were taken with one scanning microphone as shown in Figure 1. Near-field measurement was at a plane approximately 15 cm in front of the compressor with 10 cm spacing in both horizontal and vertical direction. The size of measurement plane was 60 cm by 70 cm in width and height. Coordinate origin was located at the bottom left side of the air compressor. Far-field pressure was measured on a line 1 m high, 20 cm from the left side of the compressor, from 30 cm to 1 m from front of the compressor at 10 cm spacing.

Measurement pressure was sampled at a rate of 44.1 kHz while the compressor was operating in normal condition. Hann window and anti-aliasing filter was used.

3. Measurement Results

Reference measurement of the compressor is shown in Figure 2. Major peaks in reference measurements are 432 Hz, 1008 HZ, 3256 Hz, 3448 Hz, 8356 Hz, 9272 Hz, etc. Highest peaks are 432 Hz and 1008 HZ, which are the 15th and the 35th order of motor rotation speed. Also, far-field measurement at 1 m is shown in Figure 3, which indicates that 432 Hz and 1008 HZ are the major noise sources similar to the reference measurement result. It is not shown here, but far-field measurement results shown in Figure 3 except relative level. Nine frequencies are considered in present work for major source identification,



Figure 1. Compressor measurement setup and compressor with motor cover removed.



Figure 2. Reference measurement.



Figure 3. Far-field measurement at 1 m.

which are, 288 Hz, 432 Hz, 1008 HZ, 3256 Hz, 3488 Hz, 6124 Hz, 6416 Hz, 8356 Hz and 9272 Hz.

Near-field pressure measured on plane 15cm from the compressor. Source amplitude is estimated using wave superposition on plane 10 cm from the compressor. Also, sound pressure and intensity is reconstructed using NAH on plane 10 cm from the compressor. Measurement pressure, source amplitude estimate, sound pressure and intensity reconstruction at nine frequencies are shown in Figures 4 to 11. Sound power is estimated from the reconstructed sound intensity and shown in Table 1. Also, possible noise sources and sound power rank of each frequency is shown in Table 1. Consistent with reference and far-field measurement and sound power estimate from reconstructed sound intensity, 432 Hz is ranked the first among major noise sources. Probably, motor cover resonance due to structural vibration or internal flow is the major cause of noise source at 432 Hz. However, to identify the more accurate cause of noise at 432 Hz, the more detailed investigation is required.



Root mean square of near-field pressure measurement averaged in frequency from 60 Hz to 10 KHz is shown in Figure 12. Also, frequency averaged root mean square source amplitude estimate at plane 10 cm from the compressor for frequencies 60 Hz to 10 KHz is shown in Figure 12. Root mean square measurement pressure indicated that the motor was the major noise source. However, root mean square source amplitude estimate indicated that the top of the motor cover was the major noise source. Thus, frequency averaged root mean square source amplitude estimate is more consistent with sound intensity and source amplitude estimate at each frequency. By using only near-field pressure measurement may present the misleading result of source location in general.

4. Conclusions

Both near-field and far-field pressure of a reciprocating compressor was measured. Reference measurement from the location close to sources represented far-field reasonably well in frequency for the major sources. Sound intensity and source amplitude estimated from near-field measurement indicated that the possible major source was the top part of the motor cover. Probably, motor cover resonance due to structural vibration or internal flow was the major cause of noise source at 432 Hz. However, to identify the more detailed cause of noise of motor cover at 432 Hz, further investigation is required. Frequency averaged root mean square source amplitude estimate was more consistent with sound intensity and source amplitude estimate at each frequency. As a conclusion, by using only near-field pressure measurement may present the misleading result of source location in general. Both



Figure 4. Near-field measurement at 15 cm and reconstructions at 288 Hz.



Figure 5. Near-field measurement at 15 cm and reconstructions at 432 Hz.



Figure 7. Near-field measurement at 15 cm and reconstructions at 3256 Hz.



Figure 8. Near-field measurement at 15 cm and reconstructions at 3488 Hz.



Figure 9. Near-field measurement at 15 cm and reconstructions at 6124 Hz.



Figure 10. Near-field measurement at 15 cm and reconstructions at 6416 Hz.



Figure 11. Near-field measurement at 15 cm and reconstructions at 8356 Hz.



Figure 11. Near-field measurement at 15 cm and reconstructions at 9272 Hz.

Frequency	Sound Power	Rank	Possible Noise Source
288 Hz	39.2 dB	3	Fan blade passage frequency
432 Hz	57.7 dB	1	Motor cover resonance (structural or internal)
1008 Hz	50.0 dB	2	Crankcase
3256 Hz	30.8 dB	4	Muffler, air filter, exhaust
3488 Hz	28.7 dB	5	Muffler, air filter, exhaust, crankcase
6124 Hz	24.8 dB	6	Crankcase
6416 Hz	16.3 dB	8	Muffler, air filter, exhaust
8356 Hz	13.0 dB	9	Crankcase, muffler, air filter, exhaust
9272 Hz	21.3 dB	7	Crankcase, muffler, air filter, exhaust

 Table 1.
 Sound power and noise source estimate

near-field and far-field pressure of a reciprocating compressor was measured with the low spatial resolution to reduce both cost and time for the measurement. Near-field acoustical holography for reconstruction of the acoustic property and wave superposition for source amplitude estimate were implemented for more accurate noise source identification. Using a limited number of measurement is useful for preliminary investigation of the noise source, especially for very large noise source. However, the more detailed investigation is required for the more accurate source identification.

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Figure 12. Root mean square pressure and amplitude estimate averaged in frequency up to 10 KHz.

6. References

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