original article

Noise pollution of air compressor and its noise reduction procedures by using an enclosure

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ABSTRACT

Aims: The aim of this study is to find manners of noise abatement to reach to its allowable values by which the noise caused by compressors can be reduced, and if use of enclosure is an effective alternative.
Materials and Methods: In the study, analysis of noise caused by the compressor and how distribution of sound frequencies with and without the use of enclosure was done, and then compared with standard values to help choose the best absorber material. This method is in accordance with the *in situ* assessment techniques for noise generated by different sources. A second order analyzer was use to study the recorded sound pressure level (SPL) values, and to demonstrate which frequencies can be more important in designing the enclosure. A sheet metal was used for enclosing the compressor, and this was lined with an absorber material to achieve a better sound reduction. SPL levels, before and after the enclosure of the compressor with the sheet material, were measured and compared.
Results: There was a reduction in the level of noise produced for all frequencies due to use of the enclosure, a difference of 10 to 50 dB of reduction was recorded for all the frequencies. For higher frequencies in the range of 500 Hz to 4000 H, the SPL showed a similar reduction. A reduction of 50 dB in the produced noise below the standard was seen for the frequency of 63.5 Hz in octave band frequencies. There was also a permissible limit for higher frequencies of noise produced by the compressor, but with a gap of 10 dB of its standard limit at the frequency of 500 Hz.
Conclusions: An overall noise reduction by 25 dB with the use of mineral wool as an extra liner on the inside of the enclosure, suggests that the effectiveness of the enclosure can be increased by using such absorber materials.

Key words: Compressor, enclosure, frequency analysis, noise pollution

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INTRODUCTION

Compressors are used widely throughout the world in household appliances, air conditioning systems, vehicles, and industrial machinery in various different designs and working on different mechanisms. Compressors are also used in health-care applications such as a dentist's drill and

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breathing apparatus in hospitals.[1] It is clear that control of noise and vibration is crucial in these applications. The compressor design adopted for each application depends upon several factors, such as, the gas or working fluid that must be compressed, and the discharge pressure and flow rates that need to be achieved.

There are two basic types of compressors: (1) Positive-displacement compressors including reciprocating piston and rotary types, and (2) Dynamic compressors including axial and centrifugal types. The noise produced by the rotary type compressors depends upon factors such as the rotational frequency and multiples, numbers of rotating elements and other flow factors such as flow capacity. The noise generated by centrifugal and axial compressors also depends upon rotational frequency, the number of rotating compressor blade elements, flow speed, and volume flow rate.[2] Often the main task is to keep the sound energy inside the enclosure and dissipate it by means of sound absorption. In some situations, such as with personnel booths or automobile and aircraft cabins, the main task is to keep the noise outside and to minimize the sound pollution on the inside.[3]

The aim of this study is to find the role of a compressor in noise pollution, the procedures by which and enclosure can be effectively used to control the propagated noise levels. In fact, this study would aid scholars in recognizing the noise properties that propagate from a compressor and the ways by which the noise can be effectively controlled. Often the main task is to keep the sound energy inside the enclosure and dissipate it by means of sound absorption. The main objective is to reduce propagated noise from compressor to the environment by means of enclosing the compressor and using a lined enclosure of absorber material.

MATERIALS AND METHODS

The evaluation of noise from a compressor can be done by using different types of sound and vibration analyzers. One of the most famous companies in the assessment of noise and vibration in workplaces or environments is Bruel and Kjaer. In the present article, the SPL values have been measured by Bruel and Kjaer sound level meter 2231 model, and an with an analyzer 1625 model, built by the same company. The mentioned sound and vibration analyzer is a powerful device for measuring and analyzing the sound and vibration parameters produced by different machines, and also for studying the different types of sounds produced. Frequency analyzers can also be used and give data of SPLs in different frequencies of the octave and 1/3 octave band. The measures have been recorded as SPL in decibel, with the frequency weighting and time weighting switched to A and slow situation.[4] The compressor used for the study is a AIRMAC compressor, with a power of 11 kilowatt or 15 horse powers, operating at 2900 revolutions per minute (rpm). In the energy model for an enclosure, it was assumed that the reverberant sound field produced within the enclosure was added to the direct sound field produced by the sound source being enclosed. The sum of the two sound fields gives the total sound field within the enclosure, which is responsible for the sound radiated by the enclosure walls. If the smallest distance l between the machine surface and the enclosure walls is greater than a wavelength λ ($l > \lambda$), for the lowest frequency of the noise spectrum of the machine (noise source), then the enclosure can be considered large enough to assume that the sound field within the enclosure is diffuse (the sound energy is uniformly distributed within the enclosure). The enclosure is designed in accordance with the ISO 15667 and ISO 11546 standards.

Transmission loss

The conventional measure of sound insulation produced by panels and partitions is the transmission loss (also called sound reduction index), which is the ratio of incident to transmitted sound power in logarithmic form.[5] Thus, the transmission loss can be used as a rough guide to the insertion loss (IL) of a sealed enclosure, only if allowance is made for the sound absorption inside the enclosure. The transmission loss of an enclosure is normally dominated by the mass/unit area m of the enclosure walls (except in the coincidence-frequency region).[6] This is because, the stiffness and damping of the enclosure walls are actually unimportant, and the response is dominated by inertia $m\ (2\pi f)$, with f as the frequency in hertz. The transmission loss of an enclosure wall for sound arriving from all angles is approximately

$$TL = 20\log(mf) - C \text{ in (dB)}$$

Where m is the surface density (mass/unit area) of the enclosure walls and $C = 47$ if the units of m are Kg/m^2 and $C = 34$ if the units are lb/ft^2.

Noise reduction

If the sound fields are assumed to be reverberant both inside and outside thus achieving a completely sealed enclosure (typical of a machine enclosure in a machine shop), the noise reduction (NR) is given by

$$NR = Lp_1 - Lp_2 = TL + 10\log \frac{A_2}{S_e}$$

Where, Lp_1 and Lp_2 are the sound pressure levels on the transmission and receiving sides of the enclosure. $A_2 = S_2\alpha_2$ is the absorption area in square meters or feet in the receiving space material where α_2 is the average absorption coefficient of the absorption material in the receiving space averaged over the area S_2, and S_e is the enclosure surface area in square meters or feet.[7] To evaluate the acoustical impact of mechanical equipment rooms, detailed knowledge of the acoustical emission levels of the mechanical equipment is required. The best source for these data is the equipment manufacturer.[8] These data for compressors are presented in Table 1 in the form of normalized octave band SPLs at a distance of 0.9 m.

RESULTS

Figure 1 shows that the measured values in the form of octave band sound pressure level at a distance of 0.9 meter are less than the compressors manufacturer values. In this figure, high frequency noise of compressor is also compared to low frequency noise. For high frequency, sound pressure levels have a similar limit from 500 Hz to 4000 Hz frequencies. By using enclosure, as we expected, sound pressure level reduced from 85.5 dB to 79.5 dB overall. The prediction was a noise reduction for all frequencies outside of the enclosure as what is seen in Figure 1, with a difference gap of 10 to 50 dB in the amount of reduction for low and high frequencies. For high frequency, sound pressure levels have a similar limit from 500 Hz to 4000 Hz frequencies.

In comparison to standard values, the results demonstrate the lower values of noise compressor. As can be seen, the measured values especially for low frequencies are in the lowest values compared with their standard limits. Figure 1 shows a level of 50 dB of produced noise below its standard limit for the frequency of 63.5 Hz in octave band frequencies. However, there was also a permissible limit for higher frequencies of noise produced by the compressor, but with a gap of 10 dB of its standard limit at the frequency of 500 Hz. Table 1 shows the values of sound pressure level in dB of air compressors according to their power in kilowatt for a frequency range of 31 to 8000 in Hertz overall and A weighting response. These values are defined as permissible sound of varies types of air compressors which are usable to compare with measured values of other types of air compressors while working *in situ*.

A comparison of noise reduction when enclosing a compressor by means of a sheet metal and mineral wool absorber can be seen in Figure 2. A noise reduction of 7 dB to 25 dB overall is taken by installing an enclosure on the compressor. It seems that enclosing the compressor will be more important in preventing noise transmission from the inside of the enclosure to the outside than lining by means of absorbent material. Of course, transmission loss is a main factor of enclosing to control the noise transmission through a barrier in which absorption coefficient is vital parameter of absorbent material used for lined enclosure.[9]

DISCUSSION

As a result of the study, we can see that enclosing the compressor is solely enough to have a maximum reduction of 15 dB, which can be increased to 25 dB after lining by an absorber. The recorded results of noise control on a compressor in this research presented different behavior of noise frequencies after enclosing. The prediction was a noise reduction for all frequencies outside of the enclosure as what is seen in Figure 2 with a different gap of 7 to 25 dB in the amount of reduction for low and high frequencies. However, in many cases when compressors are enclosed it is necessary to locate the enclosure walls close to the compressor surfaces, so that the resulting air gap is small. Such enclosures are termed close-fitting enclosures.[10] In such cases the sound field inside the enclosure is neither reverberant nor diffuse. In the situation that air gap is small, and then a resonant condition may occur where the enclosure wall mass is opposed by the wall and air gap stiffness.[11] In addition, standing-wave

Table 1: The standard sound pressure levels in dB at 3-ft (0.9-m) distance for air compressors

Octave frequency band (Hz)	Sound pressure level (dB) Air compressor power (kW)		
	0.75-1.5	2-6	7-50
31	82	87	92
63	81	84	87
125	81	84	87
250	80	83	86
500	83	86	89
1000	86	89	92
2000	86	89	92
4000	84	87	90
8000	81	84	87
Overall	93	96	99
A-weighted	91	94	97

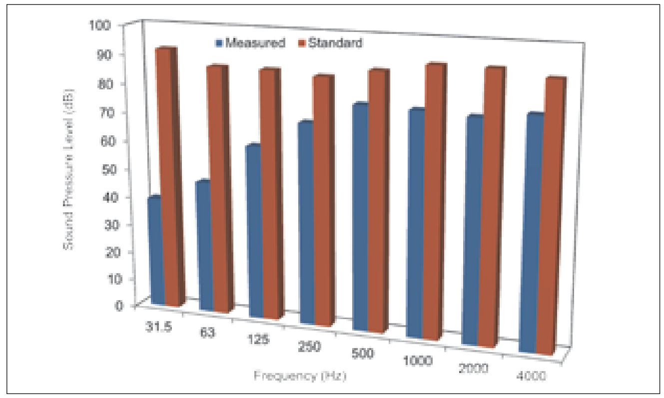

Figure 1: Sound pressure levels of the compressor in comparison to standard values

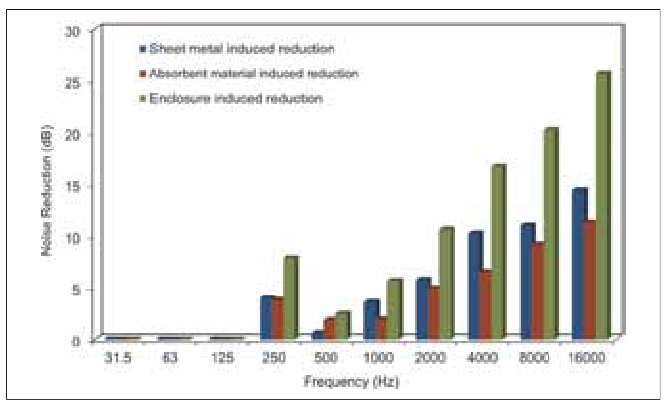

Figure 2: Noise reduction of enclosed compressor with sheet metal and absorbent material

resonances can occur in the air gap at few frequencies. These resonances can be suppressed by the placement of sound-absorbing material in the air gap.[12]

CONCLUSION

One of the most important conclusions was the role of absorber in reduction of high frequency noise in comparison to using sheet metal as an enclosure. In fact, enclosing a compressor is a way of preventing of noise propagation to other points far from compressor location, and lining it with an absorber aids controlling frequencies range of the propagated noise.[13] As can be seen from Figure 2, it seems the role of mineral wool absorber, with a value of 0 dB of noise reduction, was ineffective in preventing low frequency noise propagation. This is a certification of using passive methods and acoustic absorber materials to have noise reduction in high frequencies.[14]

On the other hand, enclosing a compressor is solely valuable for having enough noise reduction, even when a thin sheet metal is used. It means that sometimes the effective parameters in noise reduction are either enclosing or using absorbent material.[15] An overall reduction of 15 dB when using a sheet metal enclosure around the compressor can be a certification of this issue. Further, installing mineral wool as an absorber is a manner of increasing the effectiveness of the enclosure. Reaching a noise reduction to 25 dB by using the absorber material of mineral wool as an extra liner on the inside of the enclosure is a sign of increasing the effectiveness of the enclosure in compressor's noise control. In order to create a better trap for low frequency noise, the thickness and density of absorber should be increased.

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