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ABSTRACT

This study is on the application of the base noise measured at the actual compressors operated in air with suction muffler and upper shell removed. There were two significant peaks in the noise spectrum, the 500 Hz (1/3 octave band) and the 4000Hz high frequency band. Spectrums of the base noise and a typical compressor noise were compared and a good correlation was found. Base noises were utilized as a reference in modifying the design of suction muffler and compressor shell. Two kind of suction muffler, expansion volume type and tail pipe type, were tested in view of pressure drop in the suction process and noise attenuation characteristics. The pressure drop in a expansion volume type was less than that of a tail pipe type. But higher order modes occurred at lower frequency and high frequency noises were not fully attenuated in the expansion volume type.

Dynamic responses of the upper shell and the discharge pipe were improved to compensate for the insufficiency of suction muffler in attenuating high frequency band noise.

It was concluded that this kind of design modification was effective in developing low noise, high EER compressors.

INTRODUCTION

Current technical issues in the refrigeration compressor industry is the development of alternative refrigerant application technique and improvement of compressor EER from the point of environment protection.

The EER level of reciprocating compressors is getting higher than 5.0 these days at the ASHRAE test condition although it has been 4.5 at best.

But there still remains unsolved noise problem in these high EER compressors compared with old models. This noise problem was mostly generated in modifying suction muffler to reduce pressure drop in suction process. It is the purpose of this study to review and revise the design of noise-related parts of high EER compressor such as suction muffler, discharge pipe, hermetic case in view of compressor noise characteristics although they have been considered sufficient in the normal EER compressors. Suction noise emitted from the suction muffler, cavity resonance, vibration transmission through discharge pipe, mechanical noise were assumed as possible noise sources.

Suction noise emitted from the suction port without suction muffler was measured. This noise will be called base noise and will be used as a reference in modifying the design of suction muffler and shell.

Dynamic response of upper shell was also studied whether it is effective in shielding the pressure pulsations within the shell.Discharge pipes were compared in view of vibration isolation characteristics.

NOISE SOURCES / TRANSMISSION PATHS

There are many previous studies on the noise transmission paths of hermetic compressors. The transmission paths can be classified as shown in Fig. 1

Each noise source will be briefly discussed here.

Base noise

The base noise consists of the valve impact noise and the gas pulsation noise.

Authors believe that the main noise source of a reciprocating compressor is the valve noise impacting the valve stoppers.

The spectrum of the valve noise will be different in every compressor model as it is influenced by the stiffness and damping of the valve system. Measurement of the base noise was done by operating actual compressors in air. Suction muffler was removed in the test compressor. Upper shell was also removed to prevent cavity resonance and test compressors were placed at the anechoic chamber. Discharge pressure was 1.2 Mpa, suction pressure was 0 pa.

There were two peaks in the noise spectrum, 500 Hz low frequency band and 4000Hz high frequency band. The spectrums of a typical compressor noise and the base noise were compared in Fig.2 There was a good correlation between two spectrums.

Cavity resonance

Internal gas cavity resonates at the natural frequencies by the excitation of base noise. It generally occur at 500 Hz band in fractional horse power compressors. Helmholtz resonators are generally used in the suction line to eliminate the exciting source but there is a possibility of mis-tuning as the natural frequencies of gas cavity drift with operating temperature. Expansion volume type suction muffler whose lower cut off frequency is much below 500 Hz is considered in this study to prevent cavity resonance.

Mechanical noise

Mechanical noise occuring at the lubricating surfaces were measured by operating actual compressors in anechoic chamber. Upper shell and suction and discharge valves are removed. Instead, external 3.0 Mpa gas pressurized the cylinder. There was no remarkable peak in the noise spectrum and it was concluded that this noise had no remarkable contribution to the peaks of compressor noise. Vibrational excitations due to the load fluctuation and discharge gas flow are measured by accelerometers at the surface of a compressor shell. It is assumed that proper design of discharge pipe will reduce the excitational energies.

SUCTION MUFFLER

It is the ideal of suction muffler design to completely attenuate two peaks in the base noise. The lower cut off frequency of suction muffler is kept below 500 Hz to attenuate lower frequency band noise and to prevent 500 Hz cavity resonance. Attenuation of higher frequency band noise is obstructed due to the generation of higher order mode in the expansion chamber. The generation of higher order mode is related with the size and shape of expansion chamber and location of inlet and outlet tubes. As a rule of thumb, equation (1) is used as a simple estimation.

$$\frac{\lambda_i}{4} > l_{max} \qquad (1)$$

where, λ_i is the wave length of interest frequency and l_{max} is the maximum dimension of a suction muffler.

suction mufflers may be classified into two types, the expansion volume type and the tail pipe type. The expansion volume type is constructed by a large expansion volume and a short tail pipe while the tail pipe type is constructed by a small expansion volume and a long tail pipe.

The comparison of a expansion volume type muffler and a tail pipe type muffler in view of pressure drop and noise attenuation is shown in Table 1 and Fig. 3.

The pressure drop in a expansion volume type is less than that of a tail pipe type. But higher order modes occur at lower frequency and high frequency noises are not fully attenuated in a expansion volume type.

HERMETIC CASE

Hermetic case is the final noise filter in a hermetic compressor. Effective shielding of high frequency band noise is the goal of hermetic case design. Three different cases having different radii of curvature are compared in actual compressor operation. Suction mufflers were removed in the test compressors to exclude its effect. The comparison of noise spectrums is shown in Fig. 4. Relatively minor change in the dynamic response of hermetic case may yield a significant difference in the radiated noise as the natural frequencies of hermetic case are very close to the high frequency band of internal gas pressure pulsations.

DISCHARGE PIPE

Vibrational excitation and gas pulsation excitation are transmitted to the case through discharge pipe in reciprocating compressors. Although there also exist transmissions through support springs, its contribution to the excitation of case in high frequency band is negligible. The vibration isolation characteristics of a discharge pipe was estimated by measuring vibration at the surface of a case. An example comparing the effect of vibration isolation characteristics of two discharge pipes is shown in Fig. 5

CONCLUSION

The base noise could be a more adequate noise source than the white noise in estimating the noise attenuation of a suction muffler as there were low and high frequency peaks in the base noise.

It was found that expansion volume type suction muffler was better in view of compressor EER and worse in attenuating high frequency band noise.

A new design procedure was introduced, confining the functional requirement of a suction muffler to attenuate 500Hz low frequency band alone with less pressure drop and controlling the dynamic characteristics of a hermetic shell focusing on the high frequency pulsations of the base noise and it was concluded that this approach was effective in developing a low noise, high EER compressor.

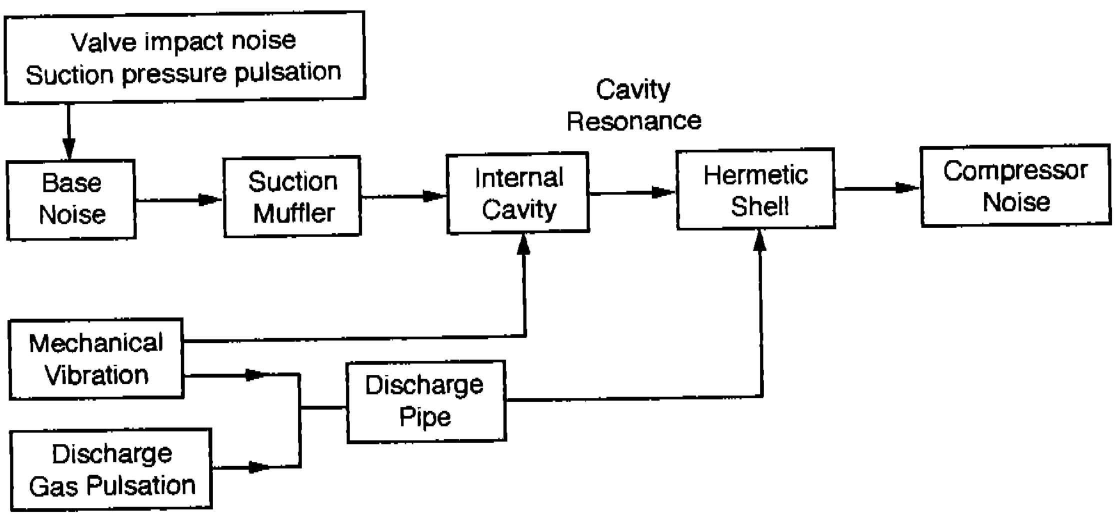

Fig. 1 Noise transmission paths of a reciprocating compressor

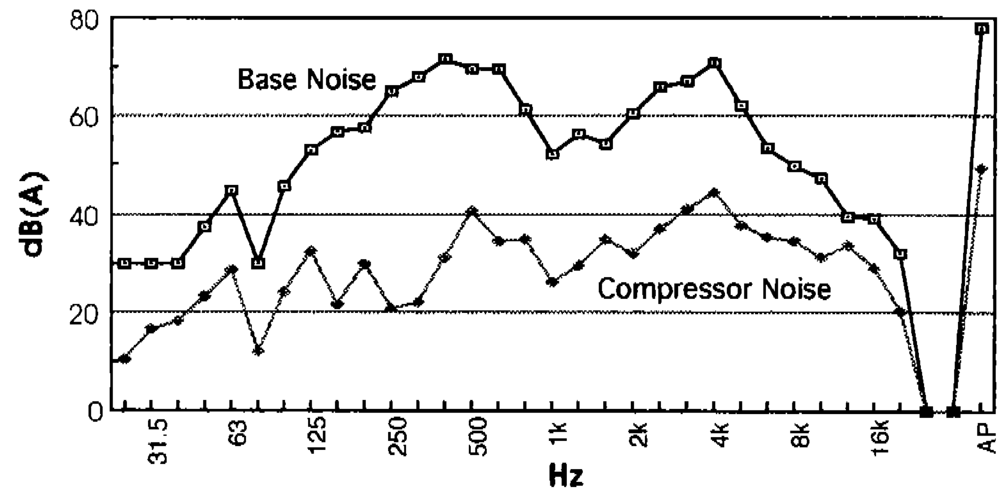

Fig. 2 Spectrums of a typical compressor noise and a base noise

Table 1 Comparison of a expansion volume type muffler and a tail pipe type muffler

	Expansion volume type #1	Expansion volume type #2	Tail pipe type
Volume	3	4	1
Tail pipe	1	2	4
Tail pipe area	1	1.6	1
Lower cut off frequency	425Hz	285Hz	500Hz
pressure drop	1.5	1	4

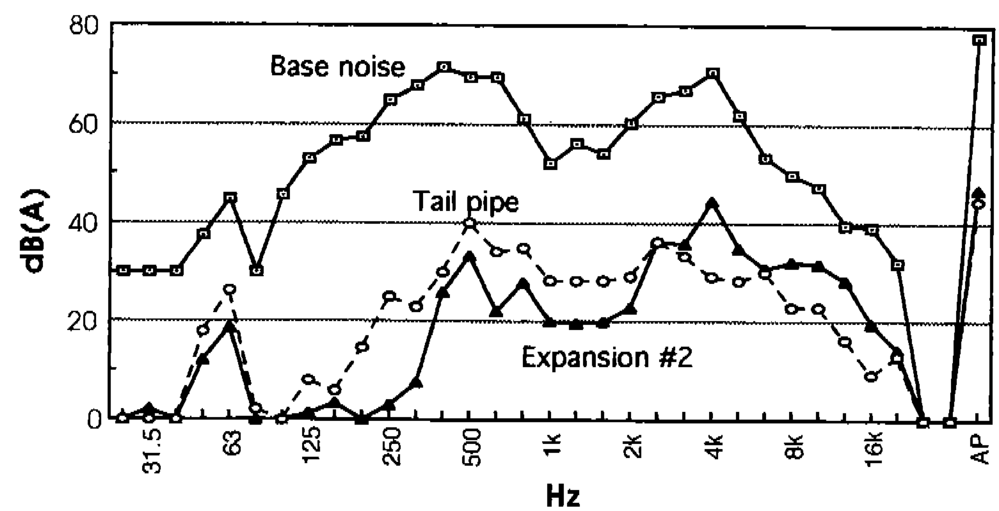

Fig. 3 Comparison of a expansion volume type muffler and a tail pipe type muffler

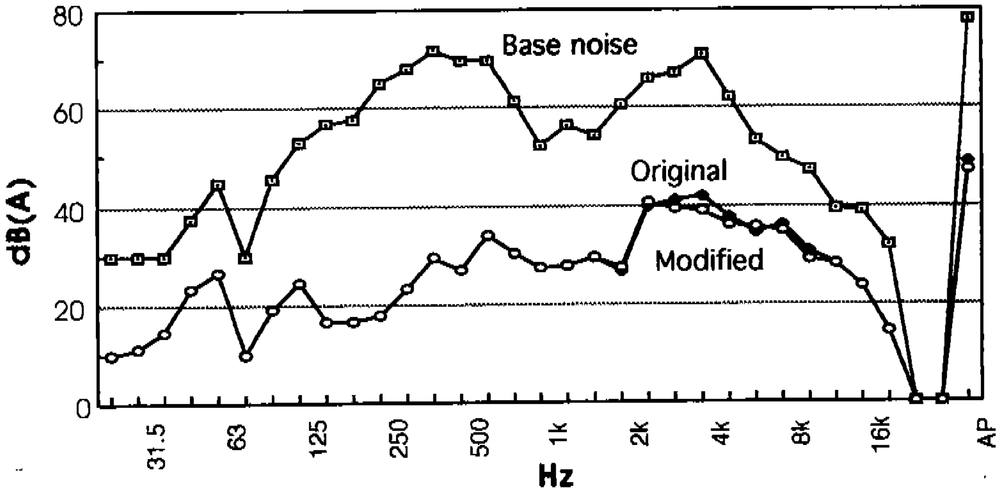

Fig. 4 Comparison of Hermetic cases

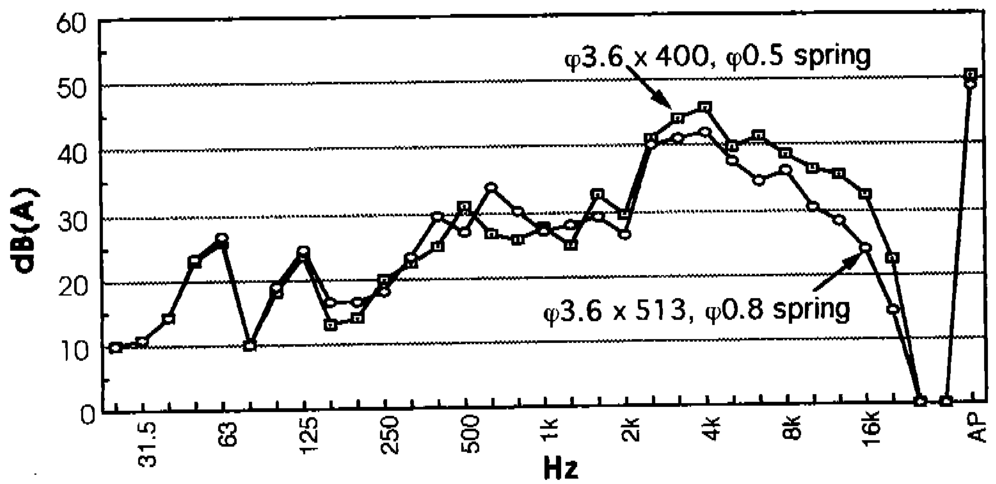

Fig. 5 Comparison of discharge pipes

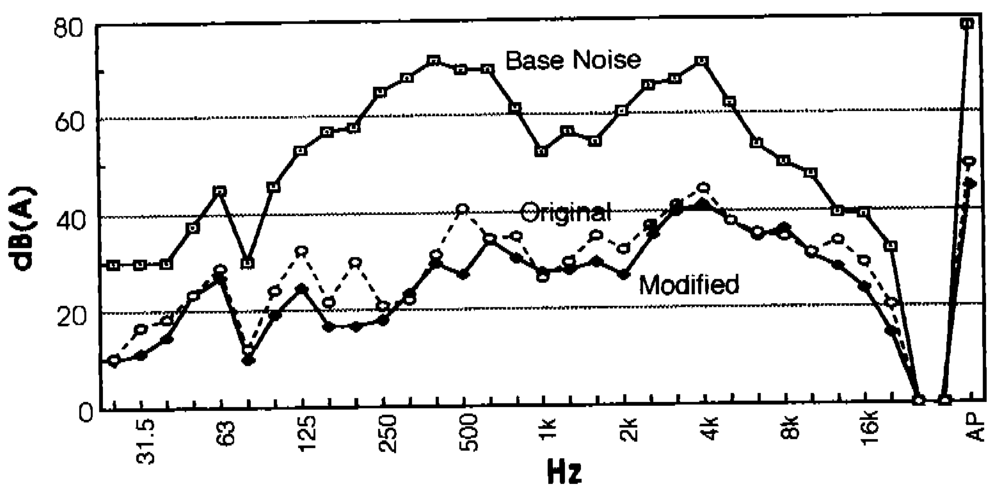

Fig. 6 Modified and Original Noise Spectra