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The Analysis on the Discharge Muffler in the Rotary Compressors

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ABSTRACT

The choice of muffler is the major factor not only in the noise induced from cavity resonance mode but also the noise induced from pressure pulsation. The new muffler having better concept for acoustic cavity resonance and high frequency is proposed. The position of muffler outlet hole is determined to minimize cavity resonance. The fine tuning of the muffler is not necessary with the new concept muffler.

1. INTRODUCTION

The noise of a rotary compressor can largely group into two categories which are air-borne and structural-borne. However, the mechanism of noise generation is fully coupled because of the hermetic shell and several weld points. One of the major part participating in the noise characteristics in the rotary compressor is discharge muffler since it is the last barrier to the full acoustics system. The pressure pulsation which might be a major source of structural-borne noise can be changed with the shape and volume of muffler. Also, the muffler can be a major noise source of the total cavity system in a rotary compressor and the total noise spectrum is changed with the position and size of muffler outlet hole. Therefore, the choice of muffler is the major factor not only in the noise induced from cavity resonance mode but also the noise induced from pressure pulsation.

Fig.1 The schematic shape of cavity resonance mode in a typical rotary compressor (Top)
2. CAVITY RESONANCE

The major part of the air-borne noise is the acoustic cavity resonance in the hermetic shell. There are infinite numbers of acoustic cavity resonances and the most important one is the di-pole type cavity resonances since they can easily excite the rigid body shell. The Fig.1 and Fig.2 shows the typical type of cavity modes in the top and iso view. The region for cavity mode is shown in the Fig.3. The dark lines in the Fig.1 and Fig.2 imply the nodal plane of the modes. The maximum acoustic pressure is indicated in the figures and the maximum acoustic pressure regions are about 90 degree out of phase in the slight different frequencies. Since the di-pole type modes are in the very close frequencies range with the mode shape of 90 degree out of phase, it is hard to control the cavity resonance with the outlet hole of muffler. Practically, it is impossible to put the outlet hole of muffler in the nodal plane of the both modes. One of the solutions for the cavity resonance problem is the ‘phase cancellation’ by putting the pair of holes in the 180 degree apart. It might be a good way to solve the problem only if there is no time delay of the noise between the two holes. Otherwise, the noise induced from cavity resonance will make it worse, like a sound amplifier.

Fig.2 The schematic shape of cavity resonance mode in a typical rotary compressor (Iso view)(By SYSNOISE)
The Fig.4, Fig.5, and Fig.6 show the effects of muffler outlet hole’s position. The differences of the two mufflers is shown in the Fig.4. The standard type muffler has two outlet holes as in Fig.4 (a) and the purpose of two holes is the ‘phase cancellation’. The muffler in Fig.4(b) has 1 outlet hole where the ‘phase cancellation’ is not considered. The Fig.5 shows how the sound pressure level(SPL) is acquired. There are two types of microphones are used for the data acquisition, which are high pressure micro-phone for the measurement of the SPL inside of the shell and
normal microphone for the measurement of noise generated from the shell. The distance of normal microphone is about 30cm from the shell. The Fig.6 shows the experimental results for those two mufflers. Even though the reason of having two outlet holes of the standard muffler is for the ‘phase cancellation’, the muffler having 1 outlet hole is better from the experiment. Therefore, the purpose of two outlet hole is not properly working as it is intended. The cavity resonance mode is merely seen from the Fig.6’s inside SPL around the frequency range 600 to 700Hz. The cavity resonance mode of standard muffler is like a gentle slope and of the 1 hole muffler is sharp.

It is found that there are two modes in the frequency range 600 to 700Hz with the very closeness to each other from the numerical analysis. It requires four outlet hole for the ‘phase cancellation’ and it will be a very fine tuning. Therefore, we have a question, “Is there any better and fast way to reduce the noise from cavity resonance?”

3. A PROPOSAL IN A PRACTICAL WAY

As it is seen in the previous section, the tuning of muffler for cavity resonance requires a lot of works to satisfy, and it depends on the case. However, if we take a look at carefully on the characteristics of the cavity modes, we could find some hints. As it is seen from the Fig.7, the position of muffler outlet hole is close to the maximum SPL region of cavity mode, in other words, the cavity mode can be very well activated no matter where the position is. The central region of the cavity has relatively low SPL and it might be better if the hole has the area around the region.

The muffler shown in Fig.8 can be a solution to decrease the noise from cavity modes. The flow and noise path of the muffler system is the central part between the main bearing and muffler. The reason why the central part of muffler is bent down to main muffler is to use the pipe inserting effect which act as if a resonator in the high frequency range.

![Diagram of cavity resonance mode](image)

**Fig.7** The characteristics of cavity resonance mode (Top view)
4. Results

The experimental result with the proposed muffler is shown in Fig.9 in the frequency range from 200 to 20 kHz. The proposed muffler is effective not only in the cavity modes but also in the high frequency range which is higher than 3.15KHz band. It is due to the central discharge for the cavity modes and resonator effects from muffler guide in the high frequency range.
5. Conclusion and Future Work

This paper does not pretend to give a cure-all solution for the rolling piston type compressor's noise problem. I'd like to share the result with compressor engineers.

The discharge system through main bearing and muffler shows very good results not only for the low frequency range but also in the high frequency. The reduced noise level is around 4~5 dBA(SPL) from our experiment. The total volume of the muffler does the key role for the high frequency noise. Therefore, there should be more study on the relation between the volume and high frequency noise. Also, the flow pattern inside the muffler could be a major role for noise.

References