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Experimental Characteristics of Frequency Modulated Noise of Compressor

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ABSTRACT

The electric motor, pump system and acoustic cavity resonances are the noise sources of a hermetic reciprocating compressor and there are radiated from inside to outside of the compressor. In the compressor, Frequency Modulated Noise (FMN) occurred, like a pure tone and sweeps from a frequency band to other frequency band. The FMN affects the sound quality of some acoustic field so it has to control the FMN to increase the sound quality of household compressor.

In this study, the characteristics and radiating mechanism of FMN are identified by experimental methods, such as analysis of the acoustic frequency response characteristics of a compressor according with the change of the amount of oil, and those of the transmitted vibration from the motor and pump to the supporting snubber on the lower-shell. We can controlled the FMN characters by some modifying or eliminating the source and paths of compressor. Especially, it is revealed that the higher mode as a local cavity resonance of the compressor due to the oil surface pattern is the main source of the FMN.

INTRODUCTION

Frequency Modulated Noise (FMN) generating mechanism is the connection path composed of cylinder-block → oil amount → compressor-shell. In the compressor, Frequency Modulated Noise occurred, like a pure tone and sweeps from a frequency band to other frequency band. The changes of dynamic characteristics, gas pressure pulsation, and shell cavity resonance etc. affect to FMN[1],[2]. The Frequency Modulated Noise affects the sound quality of some acoustic field, so it is necessary to cancel the FMN to increase the sound quality of household compressor. In this study, willing to investigate the generation mechanism of FMN a point of compressor shell cavity resonances.

SOURCE IDENTIFICATION

- SPECTROGRAM and SHARPNESS

Generating Frequency Modulated Noise, like a pure tone, sweeps from higher frequency band to lower one. So the sound pressure level changes like a slanting line in time-frequency space. We've to analyze the changes of sound pressure levels in time-frequency space to spectrogram to find...
occurrence of Frequency Modulated Noise from reciprocating compressor which works constant rotating speed normally. Fig.1 (a) shows the phenomena of Frequency Modulated Noise in a compressor, which works normally. The longitudinal x-axis in Fig.1 (a) represents the frequency, and vertical y-axis means time(second) axis, and the intensity with white and black indicates the sound pressure levels each times and frequencies. We can find the region of white move to left upward like a slanting line. The physical meaning of this kind of phenomena is that sound pressure levels over 45dB(A) moves from high frequency to low one as time passed. As shown in Fig.1 (a), the Frequency Modulated Noise generated 4 times for 40 seconds (3~9sec, 8~13sec, 13~25sec and 30~35sec), and starts at 2.5kHz band and sweeps to 1.5kHz band, and disappeared. The duration times of Frequency Modulated Noise are different each other.

Fig.1 (b) is the single slice of 2kHz frequency band from Fig.1 (a). It designates the changes of sound pressure levels at 2kHz frequency band with the lapse of time. We can find that the sound pressure level of 2kHz fluctuates 4 times abruptly from 40 dB(A) to over 50 dB(A) in Fig.1 (b).

Fig.1 (c) shows the single trace from Fig.1(a). Those are typical cases in Fig.1(c). One is Frequency Modulated Noise occurred(8.6sec) and the other is not occurred(1.6sec). We can recognize that the sound pressure levels of the frequency band around 2.2kHz ~ 2.5kHz dominant frequency band of FMN are different severely in two cases.

Fig.2 indicates the band power that from 1kHz to 5kHz, each frequencies are the center frequencies and each bandwidths are 500Hz, in case of FMN occurred as compared with not occurred. When the Frequency Modulated Noise occurred, there is 8dB differences, center frequency is 2.3kHz and bandwidth is 500Hz as compared with neighborhood frequency band(fc=1.6kHz and BW=500Hz). And the other case(i.e. FMN not occurred) is 4dB. IF the difference of band power over 5 or 6dB, human evaluates the sound quality to poor sensory pleasantness. Because, it is perceived as noticeable difference.

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(a) Frequency Modulated Noise Spectrogram
It is found that the amount of oil in the compressor affected on the Frequency Modulated Noise of compressor. Generally, initial oil amount is very important for the noise characters, but the varying of the amount of oil in the compressor influenced on the variation of the volumetric cavity consist of compressor, pump and oil surface shape.

First of all, it requires that we've to identify the energy flow path of the sudden variation of sound pressure as the Frequency Modulated Noise occurred.

**PATH ANALYSIS**
- SHELL CAVITY RESONANCE ANALYSIS

It is well known to analyze the transmission path of the Frequency Modulated Noise that shell cavity resonance is analyzed by frequency response function. Fig.3 shows the acoustic frequency response function measured by prove microphone which is placed between the pump and oil surface, and exciting the small speaker for drive unit using the wide band acoustic source inside the compressor shell. Fig.3 and Table 1 show that the acoustic frequency response function of around 2.2kHz ~ 2.5kHz increased 3dB or 7dB as the oil amount increased in the shell. We find that there are local mode of acoustic cavity resonance in the space composed of the side circumference of cylinder-block bore and oil surface.

In case of 1 and 2 conditions for the amount of oil in the compressor, it makes new space between pump and oil surface, and induces increment of acoustic response characteristics by acoustic local mode. The case 2 condition is the oil amount importing normally, and case 1 is less than case 2.

![Fig. 3 Shell Cavity Acoustic Frequency Response Function](image)

**Table 1**  
Band Power for Shell Cavity Acoustic Frequency Response Function

<table>
<thead>
<tr>
<th>oil amount</th>
<th>Band Power (2.2 ~ 2.5kHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>empty</td>
<td>19.7 dB</td>
</tr>
<tr>
<td>case 1</td>
<td>22.6 dB</td>
</tr>
<tr>
<td>case 2</td>
<td>27.0 dB</td>
</tr>
</tbody>
</table>
VIBRATION TRANSMISSION ANALYSIS WITH THE OIL AMOUNT INSIDE THE COMRESSOR

There are many transmission paths that sound transmitted to shell which compressor noise is radiating. We found that it is a very strong possibility that sound is generated by oil importing to shell. We obtained the transmitted vibration characteristics which comes from pump to the snubber supporter of lower-shell with varying the oil amount in the compressor by experiment.

Fig.4 shows the characteristics of vibration transfer response function of the varying of oil amount in the compressor, and Table 2 represents the band power of specific frequency band for same accordance with oil amount. We could identify the vibration characters for the empty, case 1 and case 2 oil amount condition in the compressor. In Fig.4, we found that the oil amount is very important transmitting media. Because the characters of vibration increased 10dB degrees more at the most of frequency bands.

Fig.5 is the sound pressure spectrums in one graph. It is ascertainable that sound pressure levels around 1.8 ~2.7kHz dominant frequency bands of FMN are decreased with decreasing the oil amount inside the compressor. Table 3 shows that the band power around 1.8 ~2.7kHz of the case 1 oil amounts is decreased 4dB vs. the case 2.

Fig 6 is the result of controlled with case 2 oil amount condition by upraise placing position of pump(pump-up) through enlargement of snubber height. It can be apply to an actual state.

![Graph](image)

**Fig. 4 Frequency Response Function (Pump to Lower-shell Snubber with Oil)**

**Table 2 Frequency Response Function Band Power (Pump to Lower-shell Snubber with Oil)**

<table>
<thead>
<tr>
<th>oil amount</th>
<th>Band Power (RMS)</th>
<th>0.1~3.2kHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>empty</td>
<td>35.8 dB</td>
<td>40.8 dB</td>
</tr>
<tr>
<td>case 1</td>
<td>35.6 dB</td>
<td>43.5 dB</td>
</tr>
<tr>
<td>case 2</td>
<td>46.3 dB</td>
<td>54.8 dB</td>
</tr>
</tbody>
</table>

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CONCLUSION

Frequency Modulated Noise (FMN) occurred from reciprocating compressor which normally works constant rotating speed, like a pure tone and sweeps from a frequency band to other frequency band with the lapse of time. FMN occurred like this, were generated and amplified by the acoustic local cavity resonance higher mode of space inside compressor-shell, and transmitted to the compressor-shell through the oil inside compressor and finally radiated to outside of the compressor.

In this study, the transmission mechanism of FMN was examined by experimental methods. That is, it was known that the noise source of FMN was the acoustic local cavity resonance higher
mode of space inside compressor-shell through the analysis of acoustic frequency response characteristics with varying the oil amount inside the compressor, and that the transmission passage was the oil inside the compressor through the analysis of vibration transmission characteristics, which were transmitted pump to the snubber supporter on the lower-shell through oil with varying the oil amount inside the compressor.

Finally, FMN was modified and eliminated through the way to change noise source and transmission passage by separating the parts of pump from the oil inside the compressor.

REFERENCES
