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IDENTIFICATION OF VIBRATION-INDUCED NOISE RADIATED FROM COMPRESSOR SHELL

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ABSTRACT

The noise level of refrigerating units is getting more important to the manufacturer and the user of the product. Invariably, the compressor is a significant contributor to the overall noise level of refrigerating units. And a major portion of the compressor noise radiates from the vibration of the compressor shell.

This paper presents an approach to relate the dynamic characteristics of the compressor shell with the noise radiation properties.

To relate the dynamic characteristics of the compressor shell with the noise properties, ordinary coherence function between vibration on the compressor shell and radiated sound were measured with the running compressor. And then based on the results of these tests, correlation between the shell vibration characteristics and the noise radiation properties are identified.

It was found that the vibration characteristics of the compressor shell were strongly correlated with that of the radiated sound in certain frequency bands. Hence vibration measurement on the compressor shell with running compressor will allow one to predict the noise radiation properties of the compressor shell. And this result applied to the quality control in factory.

NOMENCLATURE

H_{ij} : Frequency Response Function between i and j
$S_{xx}\{f\}$: Auto Spectral Density Function of $x(t)$
$S_{xy}\{f\}$: Cross Spectral Density Function of $x(t)$ and $y(t)$
$S_{yy}\{f\}$: Auto Spectral Density Function of $y(t)$
$x_k(t)$: $k-th$ Time History Records of Input
$X_k(f,t)$: Fourier Transform of $k-th$ Time History Records of Input
$y_k(t)$: $k-th$ Time History Records of Output
$Y_k(f,t)$: Fourier Transform of $k-th$ Time History Records of Output
$\gamma_{xy}^2(f)$: Ordinary Coherence Function of $x(t)$ and $y(t)$

1. INTRODUCTION

Compressor noise is caused by many factors, and among other things the noise radiated from compressor shell is a primary factor. In certain frequency band noise and vibration are strongly correlated . Therefore, we can estimate the characteristics of noise radiated from compressor shell by vibration measurement on the compressor shell when we know the correlation between them. And this result can be applicable to quality control for compressor noise at final test process in factory.

In this study, ordinary coherence function was used to identify the correlation between radiated noise and vibration on the compressor shell. And experimental modal test was performed to identify the relations between spectrum of vibration and frequency response function on the compressor shell.

2. BASIC THEORY

The spectral density function is used to describe the feature of stationary random signal in time series.

$$S_{xx}(f) = \lim_{T \to \infty} \frac{1}{T} E[\ X_k^*(f,t)\, X_k(f,t)\ ] \qquad (2.1)$$

$$S_{xy}(f) = \lim_{T \to \infty} \frac{1}{T} E[\ X_k^*(f,t)\, Y_k(f,t)\ ] \qquad (2.2)$$

Equation (2.1) is called auto-spectrum and equation (2.2) is called cross-spectrum. $E[\ ]$ means average about exponential k as expectation and $X_k(f,t)$ means Fourier transform of finite region $(0 < t < T)$ of sample record $x_k(t)$ which is sampled from stationary random process $\{x_k(t)\}$.

Following equations are constituted for ideal single-input/single-ouptupt linear system.

$$S_{yy}(f) = |\,H(f)\,|^2 S_{xx}(f) \qquad (2.3)$$

$$S_{yy}(f) = H(f)\, S_{xx}(f) \qquad (2.4)$$

$H(f)$ is Fourier transform of impulse response function $h(\tau)$ and is called frequency response function. Equation (2.3) is used for the signal which has high S/N ratio and equation (2.4) is used. for the signal which has low S/N ratio.

From those relations ordinary coherence function is defined as follows.

$$\gamma_{xy}^2(f) = \frac{|\,S_{xy}(f)\,|^2}{S_{xx}(f)\, S_{yy}(f)} \qquad (2.5)$$

Ordinary coherence function reveals the linearity(correlation) between input and output signal. In this study we try to identify the linearity between noise and vibration by use of ordinary coherence function.

3. EXPERIMENT

3.1 Measurement of Coherence Between Noise And Vibration

For analysis of correlation between noise and vibration, accelerometer is attached to compressor shell to measure the vibration of compressor shell and microphone is used to measure the noise of compressor.

To identify the correlation between radiated noise and vibration on the compressor shell, auto-spectrum and cross-spectrum of the noise and vibration signal is measured. From auto-spectrum and cross-spectrum we can calculate ordinary coherence function by eqn. (2.5). (Ordinary coherence function also can be measured directly.)

Apparatus for measuring coherence between noise and vibration is in Fig. 3.1.

3.2 Experimental Modal Analysis of Compressor Shell

Experimental modal analysis is performed to find out the natural frequencies and mode shapes of compressor shell. Compressor shell lay on the soft sponge to simulate free-free boundary condition and impact hammer is used for excitation.

4. RESULTS AND APPLICATIONS

4.1 Coherence Between Vibration and Noise

Coherence function between noise and vibration is obtained as Fig.4.1. We recognize that noise at 2000-2500Hz band is structurally borne by the vibration of compressor shell from ordinary coherence function between noise and vibration on the compressor shell.

4.2 Experimental Modal Analysis of Compressor Shell

Experimental modal analysis was performed for verification of dynamic characteristics of compressor shell. The results were shown in Fig.4.2 and Fig.4.3. Fig.4.2 shows the frequency response function and Fig.4.3 shows mode shape of 1st natural frequency(2310Hz).

4.3 Application of Results

From the result of coherence analysis and experimental modal analysis certain frequency bands strongly correlated about noise and vibration. This result applied to quality control for compressor noise at final test process by measuring of vibration level on the compressor shell.

5. CONCLUSION

From this study we come to the conclusion as follows.

1. Ordinary coherence function method is appropriate for analyzing correlation between noise and vibration of compressor shell.
2. By ordinary coherence function we can find that the ferquency band of vibration-induced noise from overall noise. In this case 2000-2500Hz band noise was vibration-induced noise.
3. These results successfully applied to quality control for compressor noise at final test process.

6. REFERENCES

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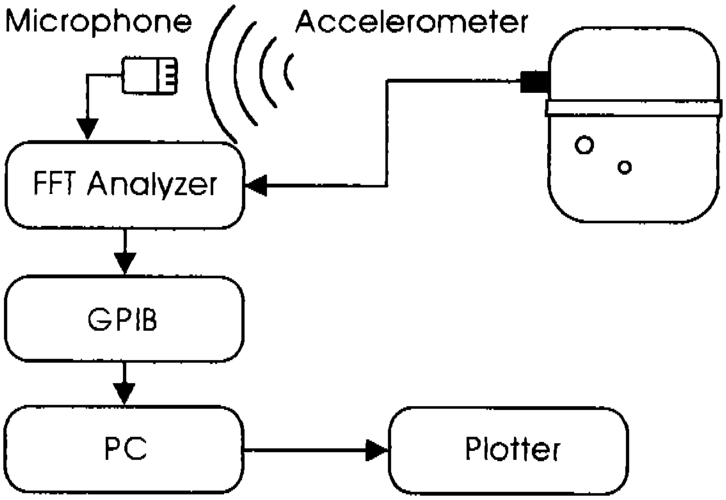

Fig. 3.1 Schematic Diagram of Measurement System for Coherence Function

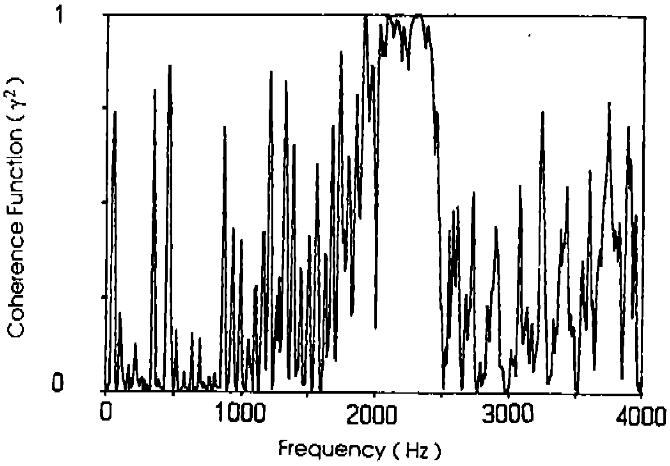

Fig. 4.1 Coherence Function between Noise and Vibration

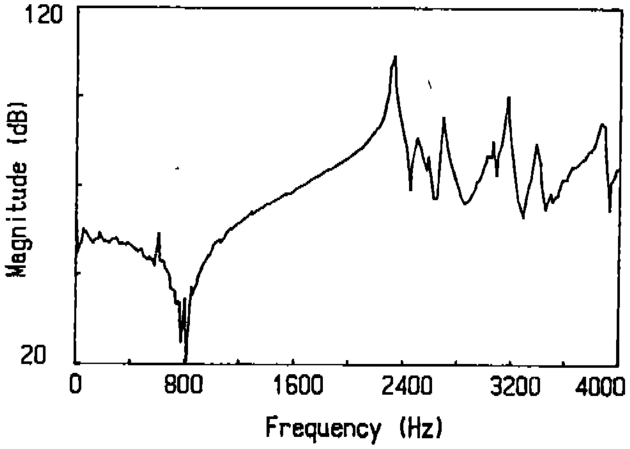

Fig. 4.2 Frequency Response Function

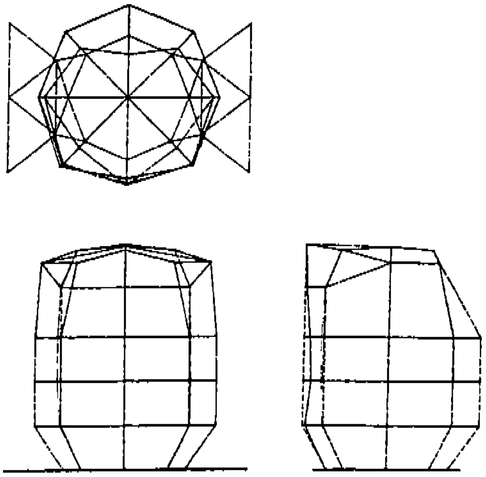

Fig. 4.3 Mode Shape obtained from Modal Test (at 2310Hz)

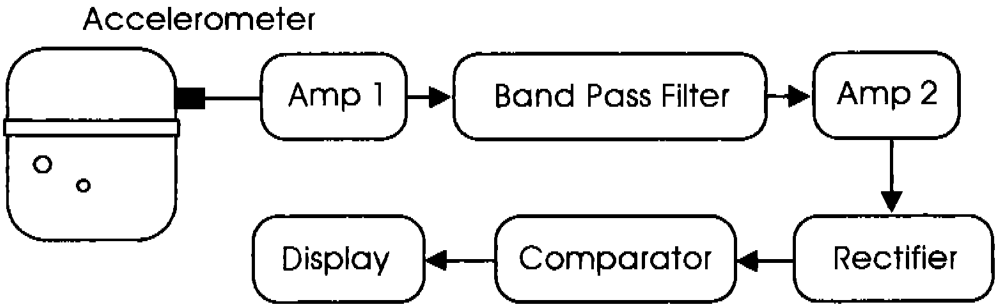

Fig. 4.4 System for Quality Control of Noise