Spectral Analysis on the Noise of Automobile Ball Bearing Plant

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Abstract: Hearing loss caused by exposure to industrial machine noise results in devastating disability that is mostly preventable. And recent researches indicate that the noise may also induce hypertension and cardiovascular disease. In addition the sleep polygraph provides many indicators of sleep disturbance by the noise. In this paper we make an analysis on ball bearing machine noise, a kind of the industrial noise. The analysis of its power spectrum is based on FFT(Fast Fourier Transform). And then the spectral results of the noise are compared with that of the spectrum for an auditory signal. The signal is measured from the pronunciation of two Koreans. Finally we suggest the most important stratagem to prevent the noise for worker's health and efficiency.

1. Introduction

Hearing loss caused by exposure to industrial machine noise results in disability that is mostly preventable. The noise-induced hearing loss is a sensorineural hearing deficit at the higher frequencies (3,000 to 6,000 Hz) that begin as a result of chronic exposure to excessive sound noise level[1]. And a recent research indicates that it may also induce hypertension and cardiovascular disease[2]. In addition the sleep polygraph provides many indicators of sleep disturbance by industrial machine noise. The disturbance includes the prolonged sleep latency, the increased number of awakenings, the decreased slow-wave sleep, and the increased stage shift. The slow-wave sleep is termed deep sleep. And the prolonged sleep latency and the increased number of awakenings are the increased movement time by body movement and the time from the commencement of a planned sleep to its actual sleep onset respectively. These indicators should be characterized in terms of dose-effect relationships or by minimum effective dose of noise on sleep in environmental health[3].

The machine noise in workplaces also affects the efficiency of labor[4]. However, in this paper, we make a spectral analysis for the noise spectrum, which are based on the FFT(Fast Fourier Transform) of the measured noise.

The measuring system was designed in our laboratory. The original noise was generated from an automobile ball bearing plant. And then the results by the FFT are compared with that of the spectra for a common example of auditory signals. The signals are measured from the voice sound, which is pronounced by a woman and a man who are Korean.

In the computer simulation results for the measured noise, we can show that noise power spectrum has all the frequency components in the 0 ~ 5kHz range. These spectrum looks like white noise. Finally we suggest what are the most important stratagem, putting on special earplug, to prevent the noise for worker's health and efficiency.

2. Spectral Analysis of Machine Noise

The power spectrum is defined as the Fourier transform of the auto-correlation function of a signal and/or noise. There are three methods of obtaining power spectrum: Periodogram, Fourier transform of auto-correlation function, and Model-based method. The magnitude of the FFT squared for a signal is called power spectrum and a plot of power versus frequency is periodogram[5-7]. In this work, we have introduced the periodogram because it can be easily obtained from the FFT of a signal or noise.

For a set of sampled vector data, Fourier analysis is performed using discrete Fourier transform (DFT). The FFT is an efficient algorithm for computing the DFT of a sequence [7]. For length N input sequence x, the DFT is a length N vector, X. The FFT makes implementation with relationships:

$$X(k) = \sum_{n=1}^{N} x(n) \exp\{-j2\pi(k-1)\frac{n-1}{N}\}, \quad 1 \le k \le N \qquad (1)$$

$$x(n) = \sum_{k=1}^{N} X(k) \exp\{j2\pi(k-1)\frac{n-1}{N}\}, \quad 1 \le n \le N \qquad (2)$$

The power spectrum of a signal is the squared magnitude of Fourier transform as mentioned before. That is, the calculation of the power spectrum of a signal is performed simply by calculating DFT, usually using the FFT algorithm, and summing the squares of its real and imaginary components at each frequency. This gives a measure of the contribution to the signal or noise by each of its sinusoidal wave components.

3. Experimental Results

Here we performed experimental simulations to analyze the power spectrum of ball bearing machine noise and human's voices, The simulation result will afford the characteristic of the power spectrum of the noise generated by the bearing machines. The human's voices are introduced for relative spectral comparison to the machine noise.

The noise are generated by 40 sets of the machines in a factory, and measured by our developed machine. The noise from ball bearing production machine was measured by the measuring system with 16kHz sampling frequency because of a restriction of our laboratory. The measuring positions of the noise were selected at two points, a point with about 1 meter distance from a microphone to the nearest machine and a point with about 3 meter from the microphone to the nearest machine. The latter point is one position of pathway and the former point is a common position of workers.

Fig. 1 shows our measuring system, which is composed of personal computer, data acquisition board, and microphone. The acquisition board is equipped in the PC. The set of the material above the PC main body is an interface board, which is used for checking the input/out data. And the microphone is shown in the front of the PC main body. The noise measuring system of Fig. 1 is composed of personal computer, data acquisition board, and microphone.

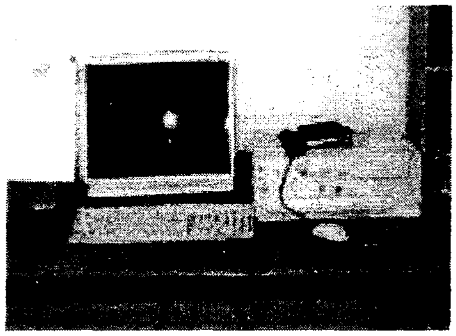

Figure 1 The noise measuring system: personal computer, data acquisition board, and microphone.

The Fig. 2 and Fig. 3 are the experimental results for the noises, which are measured at a point with about 1 meter from a microphone to the nearest machine and a point with about 3 meter distance from the microphone respectively.

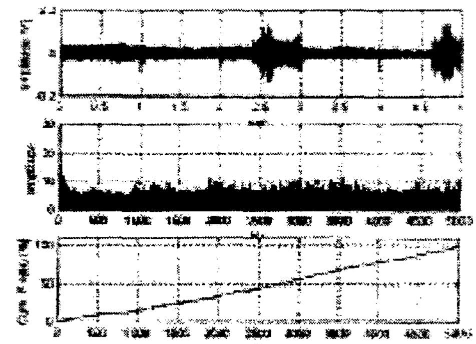

Figure 2 The characteristic of the ball bearing machine noise measured at a point with 1m distance from the nearest machine.

Fig. 2 is composed of three pieces of figures: top, middle, bottom figures. Each piece from the top belongs to measured noise, its spectrum, and the ratio of cumulative power to total power respectively. The three pieces of the Fig. 3 also corresponds to the measured noise, its spectrum, and the ratio as in Fig. 2.

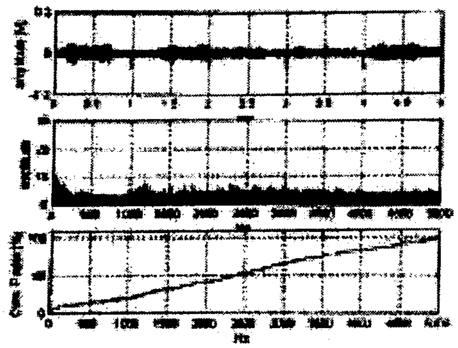

Figure 3 The characteristic of the ball bearing machine noise measured at a point with 3 meter distance from the nearest machine.

From the noise spectrum and their cumulative power ratio, the noise power spectrum of ball bearing machine has characteristic with approximately uniform distribution in accordance to frequencies in the audio frequency band. Therefore the spectrum is similar to that of white noise.

Fig. 4 and Fig. 5 are the characteristics of an example of voice signals, each corresponds to a woman's one and a man's one. The voice signal is the one pronounced as 'Chul-Su Ya, Mua Ha Ni. Eri Onea Ra', and was measured by the same system. The three pieces of figures correspond to the same kinds of pieces as in the Fig. 2 or Fig. 3.

In the Fig. 4 and Fig. 5, the voice power spectrum had mostly distributed in frequencies lower than 1.5kHz.

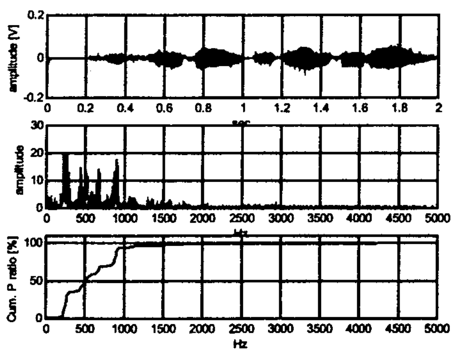

Fig. 4 The characteristic of the voice pronounced by an adult woman for 'Chul-Su Ya, Mua Ha Ni. Eri Onea Ra'

The experimental results have shown that both of the noise power measured at two points in a ball bearing plant has approximately uniformly distributed in the range of 0 ~ 5kHz, whereas the voice power hass approximately uniform distribution in frequencies lower than 1.5kHz.

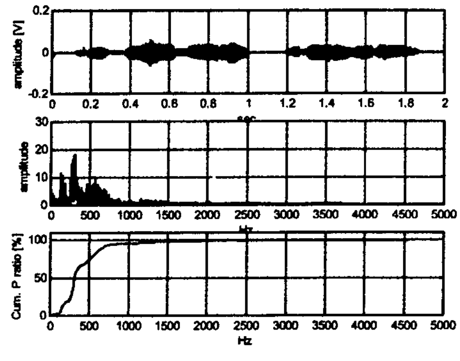

Figure 5 The characteristic of the voice pronounced by an adult man for 'Chul-Su Ya, Mua Ha Ni. Eri Onea Ra'.

More strictly speaking, about 90% of the voice power is distributed in frequencies lower than 1.5kHz whereas the noise power from near dc to 5kHz showed approximately linear characteristic. According to these results, we have definite differentiation between the machine noise power and human voice power even though we are considering that the sampling frequency of our measuring system and kinds of voices are limited.

4. Conclusion

The analysis for the automobile ball bearing machine noise shows that the noise power spectrum of the machine showed approximately uniform distribution in accordance to frequencies in the audio frequency band, which is similar characteristic as white noise. Here we suggest that the workers in workplace put on earplug with filter, which has the high pass characteristics with about 1.5~3kHz cut-off frequency. If they are putting on the earplugs, the machine noise will be greatly reduced to about 90% of the total noise power without inconvenience of hearing worker's voices.

References

[1] Peter M. Rabinowitz, "Noise-Induced Hearing Loss," *American Family Physician*, Vol. 61, No. 9, 2749 – 2758, May 1, 2000

[2] Tomei F, Fantini S, Tomao E, Baccolo TO,

Rosati MV, "Hypertension and chronic exposure to noise," *Archives of Environmental Health*, Vol. 55, Iss. 5, pp.319 – 325, Sept/Oct 2000

[3] Tomoyuki Kawada, Shosuke Suzuki, "Change in Rapid Eye Movement (REM) Sleep in Response to Exposure to All-Night Noise and Transient Noise," *Archives of Environmental Health*, Vol. 54, Iss. 5, pp. 336 – 341, Sept. 01 1999

[4] I. Jeong, *Noise and Vibration* (in Korean), SeGuang Pub., 1999

[5] http://www.mathworks.com

[6] Terry M. Peters and Jackie Williams, *The Fourier Transform in Biomedical Engineering*, Chap. 2, Birkhauser Boston, 1988

[7] The Math Works Inc., *MATLAB: The language of Technical Computing*, Version 5