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<https://doi.org/10.5109/24046>

出版情報：九州大学大学院農学研究院紀要. 38 (1/2), pp.137-145, 1993-12. Kyushu University
バージョン：
権利関係：



Distribution and Spectrum Analysis of Noise on a Combine Harvester

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(Received August 9, 1993)

It is important to comprehend the characteristics of the noise occurring from combine harvesters in order to reduce the noise. In this study, estimation of noise at the operator's head, the measurement of noise distribution, and the spectrum analysis of noise at the operator's head were performed. As a result, at the operator's head, A-weighted sound pressure level was 87dB(A) in the time domain, and A-weighted sound pressure levels at 160Hz and 330Hz were 72dB (A) and 71dB (A) in the frequency domain. So the operator feels uncomfortable in this working environment. It was found through the measurement of noise distribution that many noise sources and forms of parts constituting a combine harvester characterized the distribution and levels of the noise occurring from a stationary combine harvester. It was found through the spectrum analysis of the noise at the operator's head that the engine exhaust would characterize the frequencies of the spectrum peaks of the noise at the operator's head.

INTRODUCTION

Noise occurring from agricultural machinery hurts human bodies. Noise sources have increased with mechanization of agricultural work. However, optimum design considering noise reduction has not been achieved sufficiently. Therefore, effective countermeasures are required to realize a comfortable and useful working environment, prevention of accidents, and reduction of fatigue from the point of view of human engineering.

The object of this study is noise reduction on Japanese combine harvesters which have many noise sources and a harmful working environment. In this study, estimation of noise at the operator's head, the measurement of noise distribution, and the spectrum analysis of noise at the operator's head were performed in order to comprehend the characteristics of noise occurring from a combine harvester.

These measurements were performed in a field without building within a radius of 100m at the Kyushu University Farm, on fine and windless day. Background noise could be ignored, because it differed by 10dB from object noise in the time and frequency domain. Specifications of the experimental combine harvester are shown in Table 1.

Table 1. specifications of the experimental combine harvester.

Total width	3.260m
Total length	1.680m
Total height	1.605m
Total weight	1075kg
Engine exhaust	669cc
Engine output	10.30kW
Engine Revolutions	2700rpm

METHODS

Measurement of noise distribution

The horizontal distribution of noise was measured at the operator's head, at a height of 1.8m, and the vertical distribution of noise was measured in the longitudinal plane, at the operator's position, on a stationary combine harvester. Both of the noise distributions were measured in order to comprehend the three-dimensional distribution, especially in the neighborhood of the operator's head.

Sound level meter (Rion NA-20) was used for the measurement. The dynamic characteristic sensitivity of the sound level meter was set to "FAST". Mean values of three replicates of measurements taken at each point were recorded as sound pressure level and A-weighted sound pressure level. The microphone was oriented towards the direction producing the maximum level.

Measuring points were divided into a mesh, composed of 0.5m interval on the horizontal section and 0.2 or 0.25m interval on the vertical section. However, areas with greatly declining sound levels were measured in finer mesh. The number of measuring points was 77 on both sections. Measuring conditions are as follows;

- 1) only engine working.
- 2) all working units (threshing section, reaping section, and cutter section) driven, reaping section set to 6th speed.

Spectrum analysis of noise at the operator's head

A combine harvester has many noise sources, because it has many working machines and has a complex structure. However, Miyazawa and Irie (1987) reported that noise sources could be identified in the frequency domain by the acoustical holography method. In this study, spectrum analysis of noise at the operator's head on a stationary and reaping combine harvester was performed in order to identify noise sources.

The sound level meter (Rion NA-20) and the data recorder (TEAC R-61) and the FFT analyzer (A&D AD-3525) were used for this analysis. The sound level meter was placed at the operator's head. The experimental rice field conditions are shown in Table 2. The measuring conditions are as follows;

Table 2. Experimental rice field conditions.

Cultivars	Hinohikari
Strips spacing	0.300m
plants spacing	0.180m
Trunk length	0.826m
Number of ears on a plant	21
Number of grains on a plant	74.6
Harvested quantity	0.825kg/m ²

[Measuring conditions on a stationary combine harvester]

- 1) Only engine working.
- 2) Threshing section and cutter driven.
- 3) All working units (threshing section, reaping section, and cutter section) driven, reaping section set to 2nd speed.
- 4) All working units (threshing section, reaping section, and cutter section) driven, reaping section set to 4th speed.
- 5) All working unit (threshing section, reaping section, and cutter section) driven, reaping section set to 6th speed.

[Measuring conditions on a reaping combine harvester]

- 6) Traveling velocity set to 0.28m/s.
- 7) Traveling velocity set to 0.36m/s.
- 8) Traveling velocity set to 0.46m/s.

RESULTS AND DISCUSSIONS

Estimation of noise at the operator's head

A-weighted sound pressure level in the time domain at the operator's head was 87dB(A). In this working environment, the operator must shout to converse (Ohshima, 1972). In addition, since the level causing deafness is 90dB(A) in the time domain (Nakano, 1990), the noise occurring from the combine harvester doesn't deafen the operator.

The spectrum of A-weighted sound pressure level at the operator's head is shown in Fig. 1. The levels at both 160Hz and 330Hz are highest. In this working environment, loudness reaches about only 0.3~0.6m, telephoning becomes difficult, and the operator feels uncomfortable (Morgan *et al.*, 1972).

Therefore, this working environment must be improved.

Measurements of noise distribution

The horizontal distribution of A-weighted sound pressure level is shown in Fig. 2 and Fig. 3. The horizontal distribution of sound pressure level is shown in Fig. 4 and Fig. 5. The vertical distribution of sound pressure level is shown in Fig. 6 and Fig. 7. Since the horizontal distribution of A-weighted sound pressure level is greatly different from that of sound pressure level, both of the results are shown in order to compare.

When the threshing section is driven, the sound levels above the threshing section

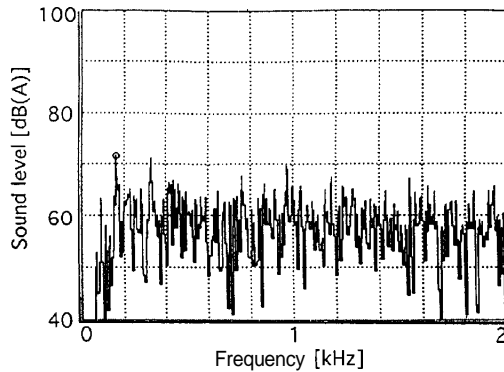


Fig. 1. Spectrum of A-weighted sound pressure level at the operator's head on a reaping combine harvester; traveling velocity set to 0.46m/s.

become high. The levels on the right side of the combine harvester are comparatively higher, because the noise radiated from the forward directed air intake of the engine cooling fan influenced this area. The area on the left back side of the operator has low levels on the horizontal distribution of A-weighted sound pressure level, because the levels in the range of frequency from 500Hz to 8kHz are reduced.

The vertical distribution of sound pressure level indicates that the levels above the hopper are much reduced due to the form and position of the hopper. When the cutter is driven, low position distribution on the rear of the combine harvester changes and levels increase.

After all, the layout of each section, selection of forms, and materials of the parts would characterize noise distribution and levels. However, noise sources must be identified for noise reduction, so the acoustical intensity method or the acoustical holography method will be suitable.

Spectrum analysis of noise at the operator's head

The spectrum peaks are concentrated in the range of frequency from 0Hz to 500Hz under all measuring conditions as shown in Fig. 8 to Fig. 15. When the working units are driven, the levels at 160Hz are higher and the levels at 270Hz are lower. When the combine harvester reaps fields, the levels at 90Hz are lower. The frequencies of spectrum peaks are constant as a whole. Moreover, each frequency is a multiple of 22.5Hz.

Now, frequencies of infrasound radiating from the engine exhaust are given by the following equation (Nakano 1990).

$$f = \frac{Rm}{60k} \text{ Hz } (m = 1, 2, 3, \dots)$$

where R : Engine revolutions (rpm)

k : $k = 1$ in case of a 2 cycle engine, $k = 2$ in case of a 4 cycle engine

When this equation is applied to the above results, the frequencies become 22.5, 45.0, 67.5, 90.0, 112.5, 135.0, ... Hz. These frequencies correspond to almost all spectrum peaks

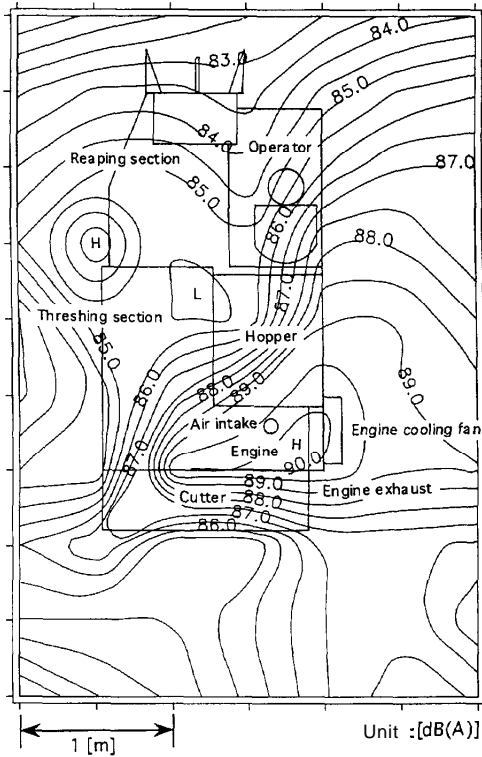


Fig. 2. Horizontal distribution of A-weighted sound pressure level at the operator's head, at a height of 1.8m, on a stationary combine harvester; only engine working.

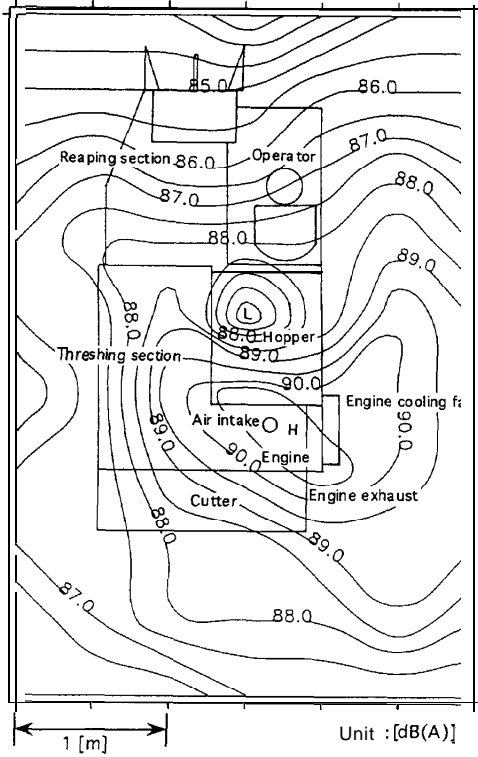


Fig. 3. Horizontal distribution of A-weighted sound pressure level at the operator's head, at a height of 1.8m, on a stationary combine harvester; all working units driven, reaping section set to 6th speed.

illustrated in Fig. 8 to Fig. 15. Therefore, the engine exhaust would characterize the frequencies of the spectrum peaks. However, the peaks at 166Hz which have comparatively high levels don't correspond. Therefore, it is considered that the peaks may not be influenced by the engine exhaust. However, this equation is usually applied to infrasound radiating from the engine exhaust, so this consideration must be examined further.

In future, noise sources must be identified. Moreover, noise source contributions must be analyzed.

ACKNOWLEDGEMENTS

We wish to thank Mr.Moses Frank Oduori for assistance with the English form of the manuscript.

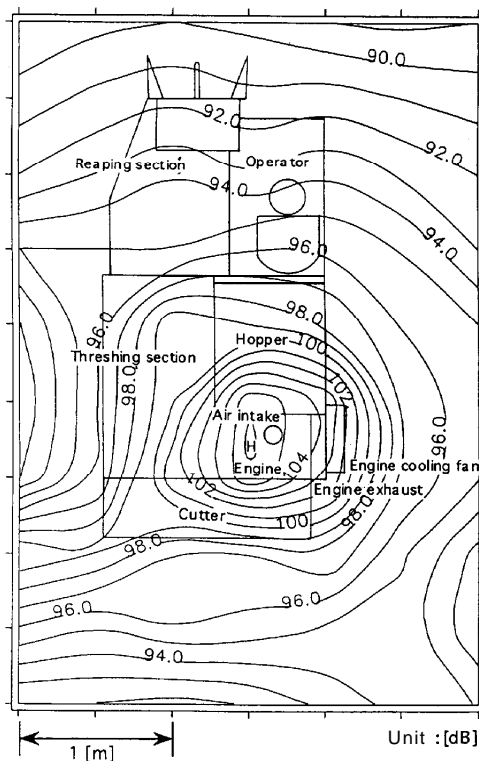


Fig. 4. Horizontal distribution of sound pressure level at the operator's head, at a height of 1.8m, on a stationary combine harvester; only engine working.

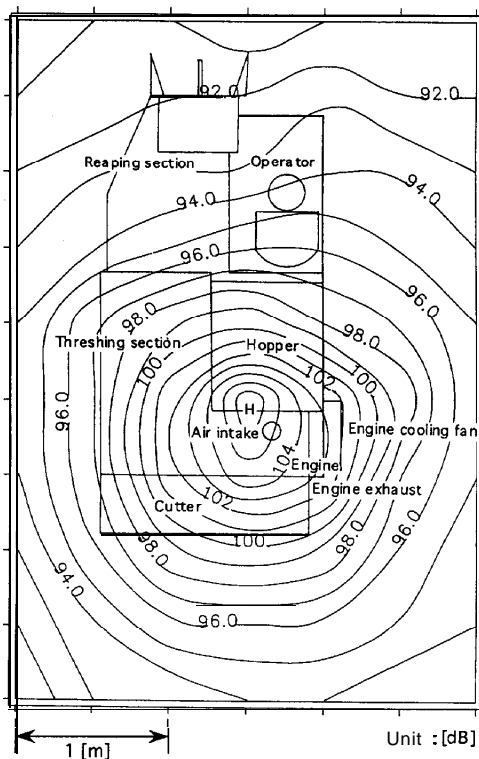


Fig. 5. Horizontal distribution of sound pressure level at the operator's head, at a height of 1.8m, on a stationary combine harvester; all working units driven, reaping section set to 6th speed.

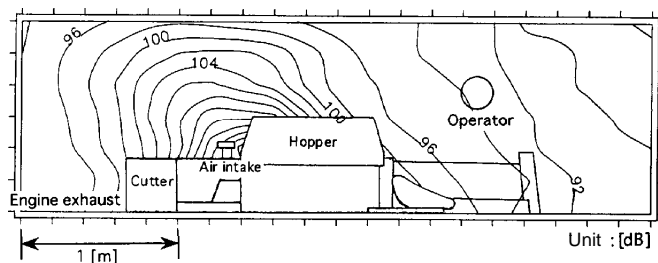


Fig. 6. Vertical distribution of sound pressure level in the longitudinal plane, at the operator's position on a stationary combine harvester; only engine working.

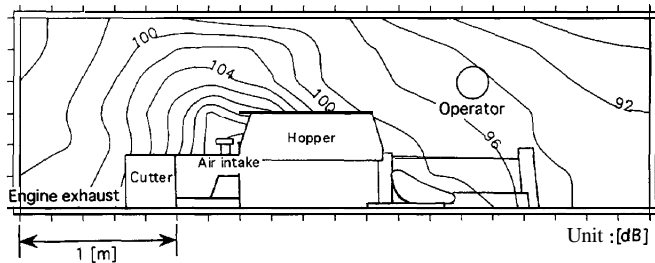


Fig. 7. Vertical distribution of sound pressure level in the longitudinal plane, at the operator's position on a stationary combine harvester; all working units driven, reaping section set to 6th speed.

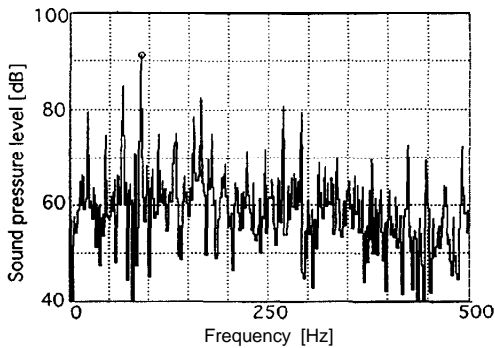


Fig. 8. Spectrum of sound pressure level at the operator's head on a stationary combine harvester, only engine working.

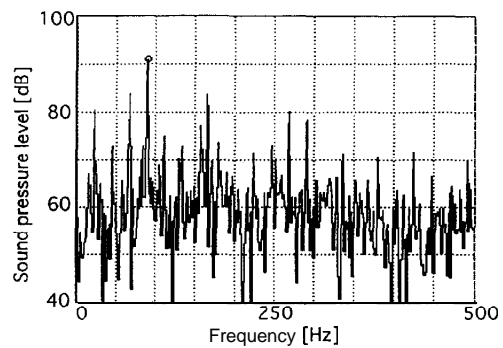


Fig. 9. Spectrum of sound pressure level at the operator's head on a stationary combine harvester; threshing section and cutter driven.

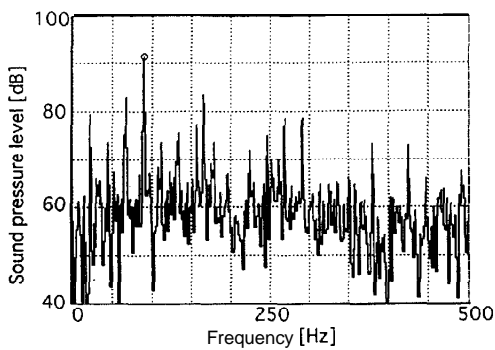


Fig. 10. Spectrum of sound pressure level at the operator's head on a stationary combine harvester; all working units driven, reaping section set to 2nd speed.

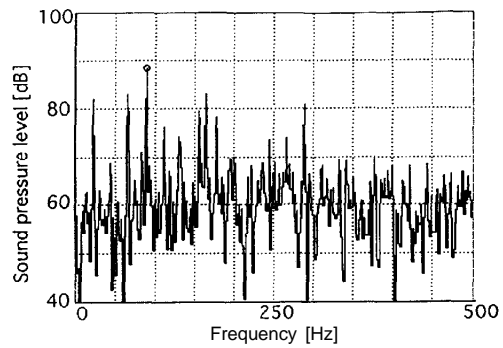


Fig. 11. Spectrum of sound pressure level at the operator's head on a stationary combine harvester; all working units driven, reaping section set to 4th speed.

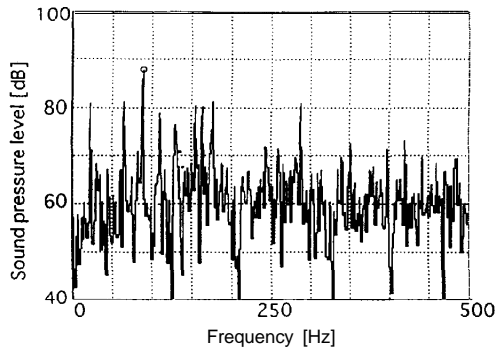


Fig. 12. Spectrum of sound pressure level at the operator's head on a stationary combine harvester; all working units driven, reaping section set to 6nd speed.

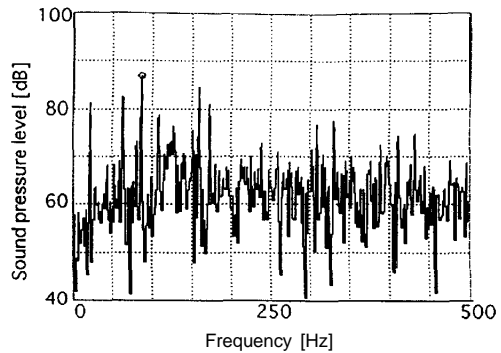


Fig. 13. Spectrum of sound pressure level at the operator's head on a reaping combine harvester; all working units driven, traveling velocity set to 0.28m/s.

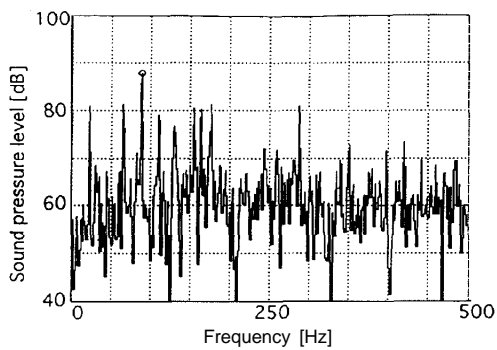


Fig. 14. Spectrum of sound pressure level at the operator's head on a reaping combine harvester; all working units driven, traveling velocity set to 0.36m/s.

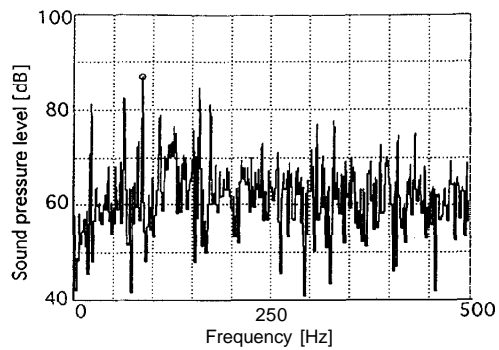


Fig. 15. Spectrum of sound pressure level at the operator's head on a reaping combine harvester; all working units driven, traveling velocity set to 0.46m/s.

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