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BASIS RESEARCH ON NOISE CONTROL OF HEAD-FEEDING TYPE COMBINE HARVESTERS USING SOUND INTENSITY METHOD

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ABSTRACT

We researched on the noise control of a head feeding type combine harvester. It is a kind of combine harvester developed in Japan. And at present, it is used by most Japanese farmer.

For a head-feeding type combine harvester it is very difficult to determine the sources of noise because it is a combination of reapers and automatic, threshers and several running parts.

However we succeeded in finding out the sound sources of combine harvesters and analyzing their sound by the using sound intensity method. The sound intensity Method is a very up-to-date method to measure and analyze Sound Intensity levels and sound directions at several measuring points in a specified area. In this research, first a conventional sound level measurement method is used and secondly the sound intensity method. The first method shows a rather great limitation in allowed exposure duration. The second method shows pin-points the engine itself as being the main source of noise, causing sound flows across the operator's seat.

Key Word : Head-feeding combine harvester, Noise control, Sound intensity method

INTRODUCTION

In one way agricultural machinery has improved efficiency of human labor but on the other hand it has caused a rise in production costs and a decline in safety and comfort. Some of the negative effects are increasing operator's fatigue, less concentration, loss of working efficiency and psychological defects , such as emotional instability and over sensitivity. In the long run the hearing organ is effected by excessive sound.

In our research, we have dealt with the problem of noise in a Japanese head-feeding type combine harvester. In a head-feeding type combine harvester, it is very difficult to determine the sources of noise because of a combination of reapers, automatic threshers, transportation chains, a binder or chaff cutter, a fan and several running parts. So besides a conventional sound level measurement method, we also used sound intensity method. This method is a very suitable one to locate the different sound sources and to analyze this complex combination of sound sources.

SOUND INTENSITY METHOD

Sound intensity method is able to represent sound (power) level and sound directions as vectors and is thus able to locate and analyze several sound sources. In our research we used the "Two Microphone Method" which is one of the sound intensity methods and far more accurate than the conventional sound level measurement method.

The theory of sound intensity method

Sound intensity is defined by the time average of multiplication between sound pressure " $p(t)$ " and particle velocity " $\vec{u}(t)$ ". General equation is given by :

$$\vec{I}=\overline{p(t)\cdot\vec{u}(t)} \tag{1}$$

with : $p(t)$ = sound pressure
$\vec{u}(t)$ = particle velocity

We measure sound pressure by using two microphones and calculate particle velocity from the distance between them by using the Euler equation :

$$\rho\frac{\partial u_r}{\partial t}+\frac{\partial p}{\partial r}=0 \tag{2}$$

with : u_r = particle velocity of r direction
ρ = density of air

$$\frac{\partial p}{\partial r}\fallingdotseq\frac{p_2(t)-p_1(t)}{\Delta r} \tag{3}$$

$$u_r(t)\fallingdotseq\frac{-\int[p_2(t_1)-p_1(t_1)]dt_1}{\rho\Delta r} \tag{4}$$

with : Δr = distance between two microphones
$p_1(t),p_2(t)$ = sound pressure of each microphone

The measuring device consists of two open end microphones situated at an 180 degree angle with their open ends towards each other (face to face). The distance between these two microphones determines the frequency reach of the multiple microphone. We calculate sound intensity by using the sound analyzer of the sound intensity method device.

The advantages of sound intensity method

Sound intensity method has a number of advantages in comparison with the conventional sound measuring method. Firstly, this method is hardly influenced by background noises and reflected sound because of it's high selective discrimination ability and thus eliminates the need of a reverberation or anechoic chamber. Secondly, this method creates a spectrum of sound intensity which represents the incoming and outgoing of sound in an optional point. Thirdly, it is possible to determine the flow of sound in a multi-dimensional plane. Fourthly, it is possible to measure the power level of several sound sources and determine the frequencies of their sounds.

RESEARCH SET-UP

The object of research was a head-feeding type combine harvester, Kubota NX2000, with Kubota D 950-C Engine of 20 ps at 3000 R.P.M.. We took our measurement at this rotation speed of 3000 R.P.M.. The combine has an ability of three row harvesting. At first the research set-up of both methods will be explained respectively.

Conventional sound level meter set-up

We used a conventional sound level meter in combination with a FFT analyzer to determine sound levels at several measuring points. These measuring points were numbered one to five and located at different points (see for this Figure 1). Four measuring points were located at a distance of 1 meter from the combine harvester and 1.2 meter from the ground. The fifth measuring point was located at a distance of 0.5 meter from the operator's seat. These measurements were taken on a day, with cloudy weather and a temperature of 23.2℃. We measured a background noise level of 61.5 dB. Measuring parameters were sound level and frequency characteristics. The purpose of the analysis was to compare the parameters with given literature guidelines for exposure limits.

Sound intensity method set-up

Now we will explain how we use the multiple microphone to measure sound intensity. First, we assume a hexahedron, with dimensions of 3.4 meters long, 1.5 meters wide and 1.8 meters high surrounding the combine harvester. We define all the planes of the hexahedron as planes +X,+Y,+Z,-X,-Y,-Z and measure sound intensity at five planes. The -Z plane cannot be used because it's under the combine harvester. A square grid of 0.35-meter is constructed into each plane, and measurements of sound intensity are taken at each point of the grid (see for this Figure 3). Secondly, at each measuring point, the microphone is pointed alongside the three axis in order to pick-up sound intensity in three directions (X,Y,Z). Lastly, we have the computer to generate four kinds of graph in each of the five planes. These graphs are a mesh graph, contour graph (an ISO-pressure area graph), vector graph and an octave-band graph. The computer calculates the values between the measuring points. By analyzing the mesh and contour graphs, we can determine the locations of sound sources. By analyzing the vector graph, we can determine the sound intensity level and sound directions. Analysis of the octave-band graph provides information about sound levels at different frequencies. We analyze a frequency range between 300 Hz and 10000 Hz because the observational error for the multiple microphone is the least in this range.

RESULT AND DISCUSSION

Before we start discussing the results of both methods we would like to point out a few minor limitations of this research. First, all of the measurements were taken when the combine harvester was parked at a concrete workshop area. Since real operation will take place on soil in the field we have to admit that due to a difference in reflection aspects between concrete and soil (concrete is likely to have a higher reflection rate) real operation might show some minor differences in sound measurements. Secondly, during these measurements the binder was not operating and this may add a little to sound intensity values in field operation.

Conventional sound level results

We performed an 1/3 octave analysis by using the FFT analyzer and compared the data of the 5 measuring points (see Figure 2.1) with sound level limits as a function of frequency and exposure time given by the Japan Industrial Health Association (see for this Figure 2.2). At the location of the operator's ears we measured a sound pressure level of 100 dB(C) and a sound level of 93 dB(A) (measuring point 5 figure 2.1). Figure 2.2 shows a decrease in allowed exposure time between 2000 Hz and 4000 Hz. At this interval damaging effects to the human ear are most likely. In our research, we found a sound pressure level of 77.3 dB around 2000 Hz, and of 78 dB around 3000 Hz, measured at the assumed location of the human ear. This sound pressure level is over the fatigue-decreased proficiency boundary of 120 minutes, as figure 2.2 shows. Figure 2.2 shows that sound pressure levels further exceed the fatigue-decreased proficiency boundary in lower frequency regions (94dB at around 300 Hz).

Sound intensity method results

At first the results of sound analysis of the left side, facing the engine and operator's seat will be discussed, i.e., the + Y plane. Figure 4.1 shows the mesh graph of the + Y plane featuring a rise in landscape above the cut level at the location of sound sources. From the figure, we can see at first sight that the dominant sound source is located around the engine area. Figure 4.2 shows the contour graph of the left side (+ Y plane). It shows areas of equal sound intensity levels in the total measuring area. We can see clearly and in more detailed, especially in combination with the mesh graph, that at the location of the engine we measure a sound intensity level area of 96 dB(I) and of 93 dB(I) at the operator's seat. Figure 4.3 shows a vector graph of the left side (+ Y plane). The vectors indicate the flow and directions of the sound in the + Y plane. They show the sound direction with the arrow and the sound intensity level by their length. The figure reveals quite a severe sound flow across the operator's seat and the presumed location of the ears. This sound flow is coming mainly from the location of the engine.

Next, the results of sound analysis of the top side of the combine harvester, facing the automatic threshers, (main thresher and second stage thresher), and the exhaust pipe, i.e., the + Z plane will be discussed. In particular, this side is the plane where the operator actually works. Figure 5.1 shows the mesh graph of the + Z plane. It is seen right away that the area of the highest sound intensity is the location of the main thresher and thus is acting as main source of noise. A high level of sound intensity at the location of the exhaust pipe is also seen. Figure 5.2 shows the contour graph of the + Z plane. It shows a sound intensity level area of approximately 95 dB(I) at the location of the main thresher and of approximately 93dB(I) at the location of the operator's seat. Combined with the analysis data of the left side plane (+ Y plane) we conclude a sound intensity level area of 93dB(I) at the operator's seat. Also this combination shows us that the higher the measuring points, the lower the sound intensity level caused by the engine. The data on the left side shows a sound intensity level of 96 dB(I) and top side analysis data shows a sound intensity level of 92 dB(I) at the location of the engine. Furthermore, a high sound intensity level area at the location of the main thresher is seen. Figure 5.3 shows the vector graph of the top side. From this we see that most of the thresher sound is directed outward to the left and most engine sound crosses the operator's seat.

CONCLUSIONS

Since harvesting work is often performed in a short period of time resulting in long working hours and working days, the results of conventional sound level measurement indicate a relatively high negative influence on the human body. Especially since these results exceed the fatigue, there is decreased proficiency boundary of 2 hours.

Sound intensity method shows us mainly that the sound from the engine crosses the operator's seat on its way to the front side. However the sound from the main thresher appears to be directed to the left side, going outward, away from the operator's seat. Since the main thresher is determined as being the main source of noise in the + Z plane, we conclude that due to its sound direction, it is of less importance to the operator's seat.

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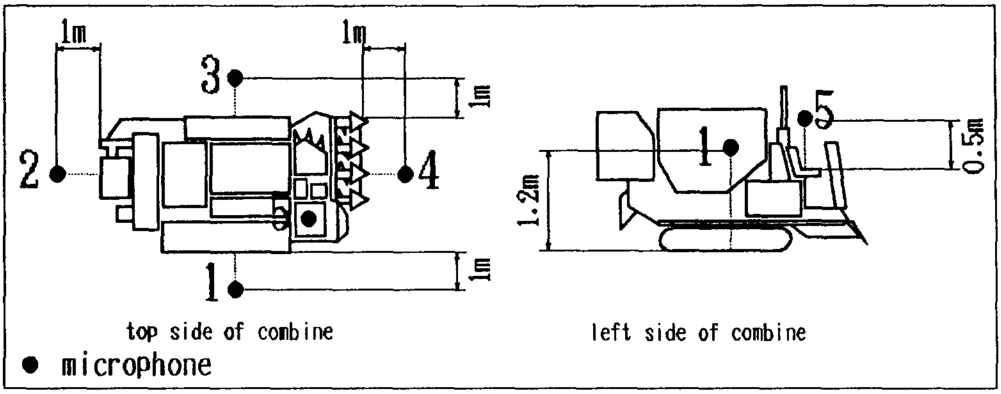

Fig.1 Points of measurement of the sound level

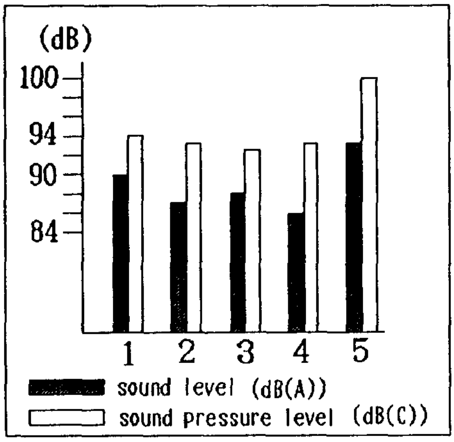

Fig.2.1 Results at measuring points

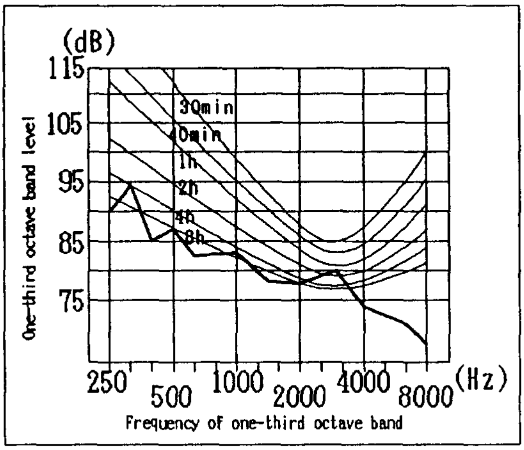

Fig.2.2 Comparison with exposure limits

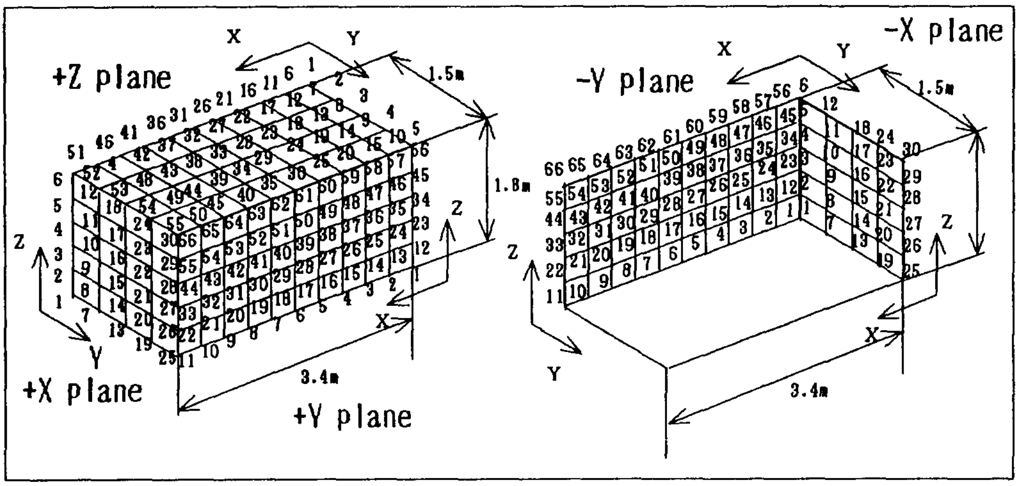

Fig.3 Sound Intensity Method measuring points

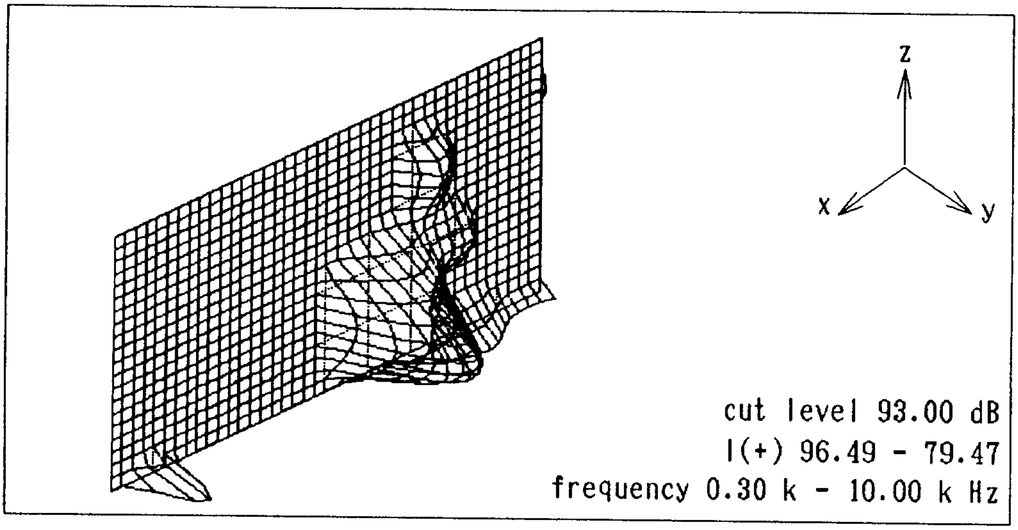

Fig.4.1 Mesh graph left side

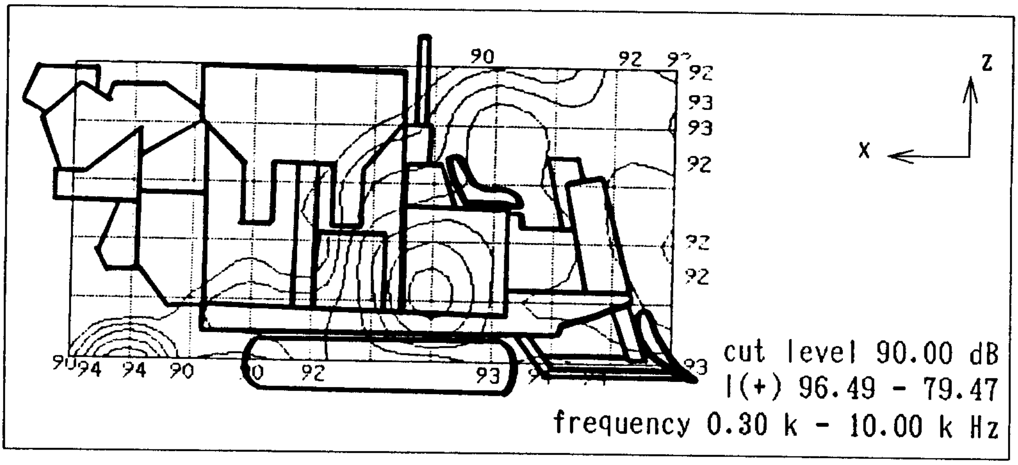

Fig.4.2 Contour graph left side

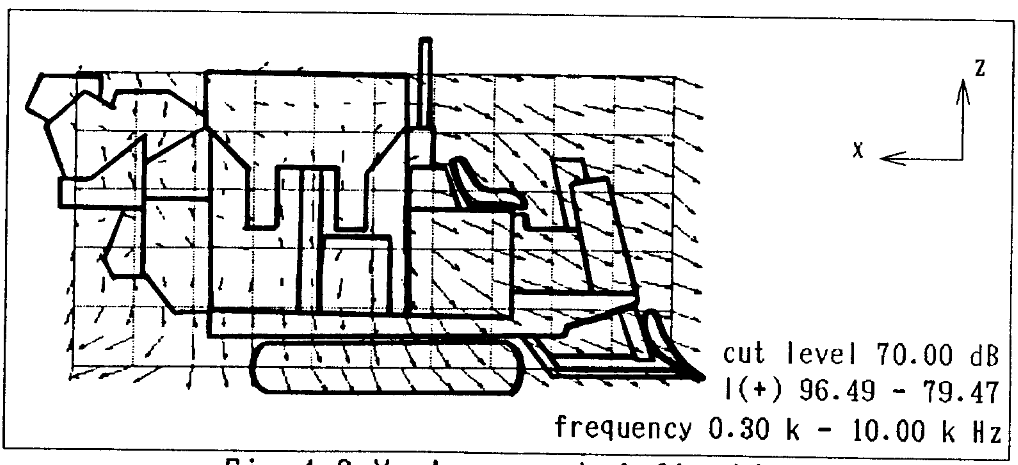

Fig.4.3 Vector graph left side

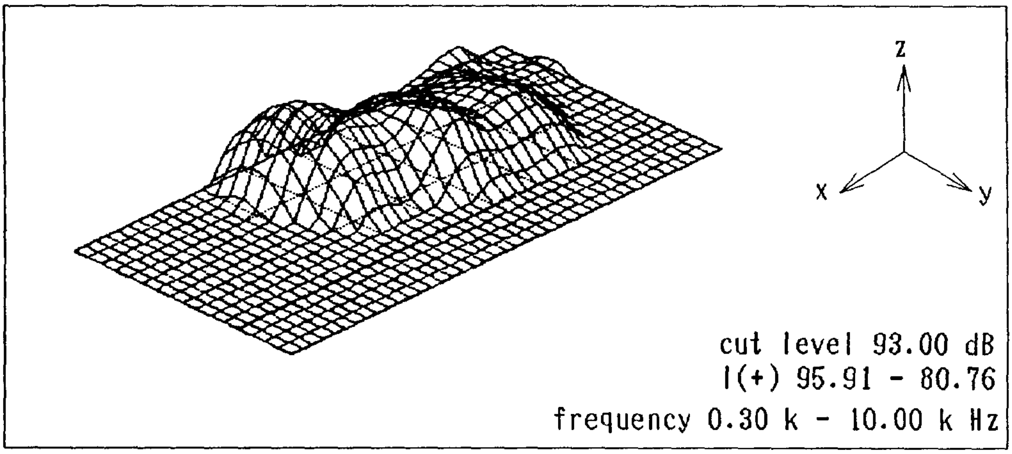

Fig.5.1 Mesh graph top side

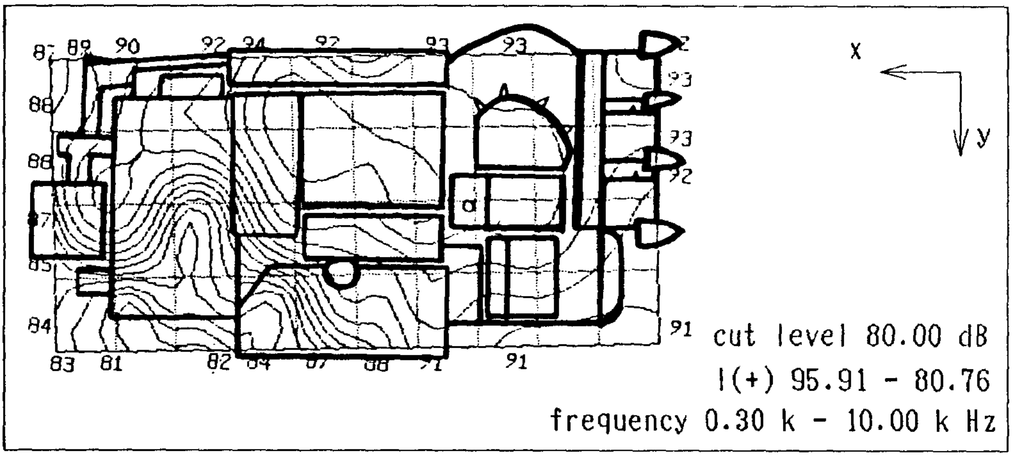

Fig.5.2 Contour graph top side

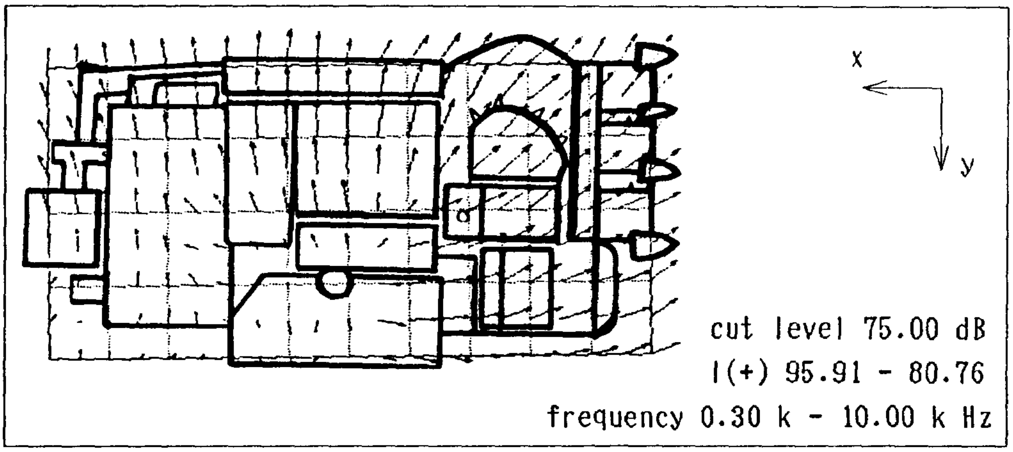

Fig.5.3 Vector graph top side