A Photographical Sound Visualization Method Using Light Emitting Diodes*

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This paper describes a sound visualization method using three color-light-emitting diodes; the distribution of sound pressure levels around each sound source obtained actually by this method; and the comparison of this method with one using a plotter for recording the measured results. In this sound visualization method, the distribution of sound pressure levels is measured with a sound visualization device built as a trial. This device consists of an auto-scanning device of a microphone with three color-light-emitting diodes; an indicator of sound pressure level which switches on or off those diodes at each instance when the sound pressure level changes by 5 dB; and a photographing set for recording the color-lights emitted from those diodes on a film. The results show that properties of sound field, such as the distribution of sound pressure levels or sound diffraction can be precisely obtained by this method.

Key Words: Sound, Measurement, Sound Field, Sound Visualization, Light Emitting Diode, Sound Pressure Level, Sound Level, Plotter, Photographic Film

1. Introduction

For the measurement of machinery noise, some particular methods can be used, through which properties of a sound source or a sound field around it can be obtained visually. For example, acoustical holography⁽¹⁾ can be applied to sound source detection; the method of acoustic intensity measurement⁽²⁾⁽³⁾ can be used for showing the direction of sound propagation as a vector map; and a sound visualization method can be used for recording the distribution of sound pressure levels or sound levels photographically on a film through converting those levels into lights emitted from an illuminant, such as neon glow lamp or light emitting diode(LED). In this case, a neon glow lamp is used only for recording qualitatively the distribution of sound pressure levels on a film as the difference in brightness⁽⁴⁾. In a sound visualization method⁽⁵⁾ using a light emitting diodes, the diode is switched on or off according as the sound pressure level is over a reference level or not. Therefore this method is not suitable for obtaining the distribution of sound pressure levels as a whole. The distribution of sound pressure levels is usually expressed as contours of equal sound pressure levels through measuring those levels at many points in a plane for measurement. But when those contours are drawn with a plotter, it takes a good deal of time to average and integrate sound pressure values over a frequency band used, at each measured point. Moreover, in

case of a complicated sound field, it is difficult to measure the distribution of sound pressure levels precisely though its accuracy depends on how to decide the distance between measured points.

In this study, a three color-light-emitting diode system is used as a sound visualization method for obtaining the distribution of sound pressure levels around a sound source in detail. Based on this method, the distribution around each sound source used is actually measured with a sound visualization device built as a trial. The availability of this method is evaluated based on the obtained results.

2. Sound Visualization Method

In this study, a sound visualization method is used for measuring the distribution of sound pressure levels around a sound source precisely and in shorter time than the other methods take. In this method, sound pressure levels are measured automatically and continuously through a microphone with three color-light-emitting diodes(red, yellow, and green), and those diodes are switched on or off at each instance when the sound pressure level changes by 5 dB. The distribution of sound pressure levels can be visualized by recording the color-lights emitted from those diodes photographically on a color film. A sound visualization device built as a trial based on this method consists of an indicator of sound pressure level, an auto-scanning device of a microphone, and a photographing set. Each device is explained in detail in the following.

2.1 Indicator of sound pressure level

This indicator is used for switching on or off three color-light-emitting diodes installed on a microphone at each instance when the sound pressure level changes by 5 dB, and it works as shown in Fig. 1. That

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is, when sound waves arrive at a microphone, the sound pressure is converted into AC voltage in proportion to it through a sound level meter, and furthermore into DC voltage in proportion to the effective value level of AC voltage through a level converter. This DC voltage is compared with each reference voltage of an interval of 5 dB through a level comparator and according to the input voltage to it, a digital signal is transmitted from the level comparator to LED switching circuit. After these conversions, three color-light-emitting diodes are switched on or off in sequence according to each digital signal. The lighting range of those diodes is shown in Table 1. The value S is an attenuator setting level of the sound level meter. When A-weighting network of it is used, the distribution of sound levels also can be measured in exactly the same manner.

2.2 Auto-scanning device of a microphone

In some other sound visualization methods, such as described in Chapter 1, traverse method is generally used as a technique for running a microphone. That is, a rotating arm is used, moving round its supporting point. In some cases, however, this method is not adequate to obtain the distribution of sound pressure levels. Accordingly, in this study an auto-scanning device of a microphone built as a trial is used which can run the microphone in three directions perpendicularly intersecting each other. This device is shown in Fig. 2. The microphone is moved in the direction of x axis by means of an induction motor, piano wire, and its take-up pulley to avoid noise generation, and in the direction of y or z axis by means of a step motor and geared system. All the motors are driven through a controller. The maximum size of each scanning plane is 1200 x 900 mm in x - y plane, 1200 x 1000 mm in x - z plane, and 900 x 1000 mm in y - z plane. When the y - z plane is used, the measurement can be made intermittently in its plane accordingly to necessity. The microphone used is a nondirectional one of 1/2 in. in diameter which can be set up in an arbitrary

direction. The effect of sound reflection from the device can be ignored except when a pure tone of frequency over 1 KHz is measured.

2.3 Photographing method

In this sound visualization method, the color-lights emitted from three diodes are recorded photographically on a film. Photographing is made in an easy anechoic room by a camera with the aperture stop at the open end. When it is necessary to examine photographing conditions or some measured results on the site, it will be more convenient to use a Polaroid camera. When a camera angle to a scanning plane is chosen suitably, each distribution of sound pressure levels in several parallel planes can be recorded on one film as a spatial distribution.

3. Sound Visualization Results

Using the sound visualization method

Table 1 Lighting range of LED

SPL	Lighting color
$S + 15$	Red
$S + 10 - S + 15$	Yellow
$S + 5 - S + 10$	Green
$S - S + 5$	Red
$S - 5 - S$	Yellow
$S - 10 - S - 5$	Green
$S - 15 - S - 10$	Red
$S - 20 - S - 15$	Yellow
$S - 20$	Green

S : Attenuator setting level

Fig. 1 Composition of LED indicator

Fig. 2 Auto-scanning device of a microphone

described in Chapter 2, we measured actually the distribution of sound pressure levels around each sound source used. Some results are shown in the following.

3.1 Sound radiated from circular apertures

Fig. 3 and Fig. 4 show, respectively, the distribution of sound pressure levels around a rectangular enclosure with a speaker inside and one or two apertures of 22 mm in diameter on its surface. These results

Fig. 3 The distribution of sound pressure levels around an enclosure with a circular aperture

Fig. 4 The distribution of sound pressure levels around an enclosure with two circular apertures

are obtained in the horizontal plane containing the center of circular aperture. The inside of the enclosure made of veneer board is lined with lead sheets to prevent the sound radiation through the vibration of side plates. In Fig. 3, the dimensions of the rectangular plate with a circular aperture are 400 x 300 mm and 24 mm in thickness. In this case, pure tone of 315 Hz with power of 1 watt is used for the speaker input. From this result, properties of the sound field around the enclosure, i.e., the distribution of sound pressure levels and the state of diffraction, can be precisely obtained. This visualization result is composed of four photographs taken in the horizontal plane containing the center of the aperture. These photographs are actually

Fig. 5 The spatial distribution of sound pressure levels around an enclosure with a slit

Mode(5,3) , 2520 Hz , L= 10 mm

Fig. 6 The distribution of sound pressure levels in a plane 10 mm away from a vibrating plate in a resonant mode

clear colored ones and the time taken for each measurement is about 15 minutes. In Fig. 4, the rectangular plates with a circular aperture are both 470 x 350 mm in dimensions. In this case, the 1/3 octave band noise at a center frequency 6300 Hz with power of 1 watt is used in phase for each speaker input. As is evident from this result, the distribution of sound pressure levels is very complicated but almost symmetric with respect to the diagonal plane of the enclosure at the same distance from each of the two apertures. Furthermore the state of diffraction is shown distinctly. Fig. 5 shows a result for the case when each distribution of sound pressure levels in the three scanning planes is recorded on a film the camera angle set suitably. In this case, a slit of 40 x 126 mm is used in place of a circular aperture shown in Fig. 3. Those planes are horizontal and they contain the center of a slit, top and bottom of the enclosure, respectively. The 1/3 octave band noise at a center frequency 400 Hz is used for a speaker input. From this result, the spatial distribution of sound pressure levels can be grasped to some degree.

3.2 Sound field near a vibrating plate

Fig. 6 shows a visualized distribution of sound pressure levels in a scanning plane parallel to a rectangular plate vibrating at a resonant frequency 2520 Hz and at a distance 10 mm from its surface. The plate is a steel one with its dimensions 400 x 300 mm and 3 mm in thickness. This plate is fixed to one side of a steel enclosure with bolts along all its edges and excited through a speaker installed inside the enclosure. In this case, the rectangular plate is vibrating in a resonant mode(5,3) with four nodal lines parallel to its short edge and two

No-load running, 1600 Hz 1/3 octave-band

Fig. 7 Cleaner noise

parallel to its long edge. As is obvious from this result, considerably higher mode shapes of a vibrating plate can be obtained from visualization measurement such as described above.

3.3 Cleaner noise

When the distribution of sound pressure levels around a noisy machine is measured with respect to 1/3 octave-band pressure level besides overall, properties of noise sources of a machine can be known from the measured results. Thus with respect to a cleaner noise, Fig. 7 shows the distribution of 1/3 octave-band sound pressure levels at a center frequency 1600 Hz in a horizontal plane containing the center line of the side of a cleaner. This result shows the effect of two air outlets at both sides of the back part of the cleaner.

4. Comparison with Plotted Contour Map

In another method for obtaining the distribution chart of sound pressure levels, a plotter can be used. In this method, however, many measured points are required for obtaining precisely the distribution of sound pressure levels in a complicated sound field. Furthermore the time required for measurement is much longer. To compare with the sound visualization method using three color-light-emitting diodes, a result for the case when a plotter was used is shown in Fig. 8. In this case, the enclosure used is the same one as shown in Fig. 3 and the 1/3 octave-band noise at a center frequency 6300 Hz with power of 1 watt is used for a speaker input. The scanning plane for measurement is divided into many lattices of 50 x 50 mm in dimensions with 539 lattice points. The

Fig. 8 Plotted contour map of the distribution of sound pressure levels

sound pressure level at a lattice point is obtained by averaging the sound pressure for five times and integrating it over the frequency range of the $1/3$ octave-band noise used. The time required for measurement at a lattice point is about 37 seconds including the time for moving a microphone. Therefore in case of Fig. 8, the total time is about 5 hours and 30 minutes. In the sound visualization method using three color-light-emitting diodes, however, the time required for measurement is only about one hour even for the case of such a complicated sound field as shown in Fig. 4. If a plotter is used in that case, it will take about 12 hours.

5. Conclusions

In this study, a sound visualization method using three color-light-emitting diodes is described in detail as a method for measuring precisely the distribution of sound pressure levels around a sound source. With respect to several sound sources, the distribution was measured actually by using this method. Furthermore a visualization result was compared with a contour map made with a plotter for the distribution of sound pressure levels. From these results, the following conclusions are obtained:

- (1) Properties of sound field, such as the distribution of sound pressure levels or the state of sound diffraction can be obtained precisely by this sound visualization method.
- (2) As compared with the method using a plotter, the time required for measurement can be reduced considerably when applying this sound visualization method.
- (3) By setting a camera angle suitably and measuring the distribution of sound pressure levels in several scanning planes, the spatial distribution can be obtained.
- (4) When measuring the distribution of sound pressure levels in a plane near and parallel to a vibrating plate by this sound visualization method, modal shapes of vibration of a plate can be obtained.

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