Noise source identification on rolling tires by sound intensity measurement

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The sound radiation characteristics of actually rolling tires with three types of the tread patterns were measured by the 2-microphone sound intensity technique. The measurements were performed at a test course in Japan Automobile Research Institute, in which a special trailer equipped with an automatic microphone scanning system was used and the normal sound intensity distribution in a plane parallel to the sidewall of a tire was measured during actual running. The results show that it is possible to identify the source positions on a tire actually rolling on a road surface by means of the sound intensity technique. In the case of a rib tire, the noise was mainly generated from the leading and the trailing edges, not from the contact patch, while in the case of a lug tire, the main source position was the contact patch. The noise radiation pattern varied according to the difference of tread pattern. Further, the sound power radiated by three kinds of tires were compared. A-weighted sound power level of the lug tire is the biggest among them.

Keywords: Tire noise, Sound intensity technique, Source position, Sound radiation pattern, Sound power level

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1. INTRODUCTION

Noise radiated from a running vehicle consists mainly of engine noise, exhaust noise, and tire noise. Particularly, it is well known that the tire noise becomes dominant when a vehicle is running at a high speed. Therefore, to reduce the tire noise is very important for the noise abatement of road vehicles. For this purpose, it is necessary to investigate the sound radiation mechanisms and characteristics of actually rolling tires in detail.

For this kind of measurement, laboratory tests using drums are often performed,\(^{1,2}\) but the texture of the drum surface is rather different from that of actual road surfaces.\(^{3}\)

In this study, therefore, noise radiated from tires actually rolling on a road surface was measured by using 2-microphone sound intensity technique to investigate the source positions on a tire and noise radiation patterns. Besides, in order to examine the differences in sound power level due to the difference of tread pattern of tires, the sound power levels radiated by three kinds of tires were compared.

2. EXPERIMENTAL METHOD AND TEST CONDITION

2.1 Experimental Method

In the measurement, a large-sized trailer equipped with an automatic microphone scanning system shown in Fig. 1 was used. This microphone scanning system is capable of moving the intensity probe at a constant speed of about 20 mm/s and generates a pulse for every movement of 50 mm. This pulse
is used for the identification of the probe position and also used as the trigger signal for subsequent laboratory analysis.

As the intensity probe, two 1/2 in. condenser microphones in side-by-side configuration (microphone gap: 20 mm) were used. To reduce the influence of wind noise, nose cones were attached to the microphones.

The block diagram of the measurement system is shown in Fig. 2. In the running test, sound pressure measured by the 2-microphones and the pulse signals from the scanning system were recorded on a PCM tape recorder. The recorded signals were analyzed later by using the B & K 3360 Sound Intensity Analyzer.

2.2 Test Conditions

The measurements were performed at the test course in Japan Automobile Research Institute. The pavement surface of the test course is dense asphalt concrete with maximum chipping size of 20 mm. In the measurements, truck tires of about 1 m in the diameter were used and the normal sound intensity was measured at an interval of 50 mm in a plane parallel to the sidewall of the tire under test. The size of the measurement plane was 1 m x 1 m, and the distance between the measurement plane and the sidewall of the tire was 100 mm (see Fig. 1).

Since tire noise is greatly affected by various conditions such as road surface texture, load, inflation pressure and atmospheric temperature, the noise radiation pattern is very sensitive to the change of these conditions. Therefore, the measurements for each tire were conducted under almost constant conditions shown in Table 1.

3. EXPERIMENTAL RESULTS

In this study, three types of tires were tested. The tread patterns of these are shown in Fig. 3.

3.1 Frequency Range for Intensity Measurement

The intensity probe used in this study can measure the sound intensity in the frequency range from 80 Hz to 4 kHz under the normal condition. In this study, however, it is necessary to check the effect of wind on the measurement accuracy especially

<table>
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<tr>
<th>Table 1</th>
<th>Test conditions.</th>
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<tr>
<td></td>
<td>Tire</td>
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<tr>
<td>Bias tire</td>
<td>6.75</td>
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<tr>
<td>Radial tire</td>
<td>7.25</td>
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![Fig. 1 Automatic microphone scanning system.](image)

![Fig. 2 Block diagram of measurement system.](image)
in low frequency range. To examine this point, the coherence function between the output signals of the two microphones was observed.

Figure 4 shows the coherence function measured near the contact patch of a bias lug tire rolling at a speed of 80 km/h. It can be seen that in the frequency range above 200 Hz, the coherency is almost 1.0, while in the frequency range below 200 Hz, the value is not sufficient. Based on this result, the sound intensity in each 1/3 octave band from 200 Hz to 4 kHz was obtained in the actual running test.

3.2 Sound Radiation Patterns

The running tests were conducted at three steps of running speed of 40, 60 and 80 km/h. Among them, the results measured at the running speed of 80 km/h are presented below because tire noise is serious in high speed running condition.

3.2.1 Bias rib tire

Figure 5 shows 3-dimensional distributions and contour maps of the normal sound intensity radiated from the bias rib tire. The arrows indicate rolling direction of the tire. In the case of A-weighted overall level shown in Fig. 5 (a), the noise was mainly generated from the leading and trailing edges, not from the contact patch. Figure 5 (b) shows the sound radiation pattern in 1 kHz band which was predominant in overall level. This spectral component might be attributed to the pipe resonance in the rib groove.

3.2.2 Bias lug tire

Figure 6 shows the measured results of the bias lug tire. It can be seen that the main noise source for overall level is in the contact patch (This tendency was also observed in the results of 40 and 60 km/h running condition). However, there are also portions with high levels in the sidewall apart from the road surface, and the radiation pattern is a bit complicated. In 630 Hz band in which the 2nd order spectral component of the pattern noise is included, negative intensity indicated by the broken lines is observed at two places in the sidewall about 500 mm above the road surface. This phenomenon might be caused by the vibration of the sidewall of the tire excited by the impact between the tread block and the road surface.

3.2.3 Radial rib-lug tire

Figure 7 shows the measured results of the radial rib-lug tire. In the result of A-weighted overall level, the main source is observed in the leading and trailing edges as in the case of the rib tire. In the
Fig. 5. Normal sound intensity radiated from bias rib tire running at speed of 80 km/h.

Fig. 6. Normal sound intensity radiated from bias lug tire running at speed of 80 km/h.
result of 500 Hz band, negative intensities were clearly observed in lower half part of the disc wheel. This result was also obtained at the other running speeds. This phenomenon might be attributed to the vibration of the disc-wheel.

3.3 Comparison of Sound Power Levels of Three Kinds of Tires

The sound power passing through the measurement plane of $1 \times 1$ m were obtained from the normal sound intensity measured by above mentioned technique and the sound power level radiated by the three kinds of tires were compared.

Figure 8 shows the comparison of A-weighted sound power level in 1/3 octave band of the three tires. It can be seen that the difference in overall level among the three tires is about 6 dB(A) and the power level of the lug tire is the biggest. In the spectral characteristics, the peak levels caused by the pattern noise are observed in 315 Hz band in the
cases of lug and rib-lug tires and in 400 Hz band in the case of rib tire. The arrows and the frequencies described in the figure indicate the frequencies of the tone noise calculated from pitch length of the tread pattern and the running speed. The spectral peaks in the measured results are in good agreement with these calculated frequencies. Especially in the case of the lug tire, the pattern noise in 315 Hz band dominates the overall level.

4. CONCLUSIONS

In this study, sound intensity radiation patterns of tires actually rolling on road surface were measured, and the difference in the sound power level among three kinds of tires were investigated. We may conclude as follows:

(1) The source positions and radiation patterns of tires during actually rolling on road surface can be identified by the sound intensity technique.

(2) In the case of rib tires, noise is mainly generated from the leading and trailing edges, not from the contact patch, while in the case of lug tires, the main source position is the contact patch. The noise radiation pattern much varies according to the difference of the tread pattern.

(3) The sound intensity radiation patterns of lug and rib-lug tires are much more complicated as compared with those of rib tires.

(4) A-weighted sound power level of the lug tire is the biggest among the three kinds of tires.

(5) The peak levels of the pattern noise greatly vary according to the types of the tread pattern. Especially, in the case of the lug tire, the pattern noise is predominant in overall level.

REFERENCES


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