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ON THE LOUDNESS OF TRAIN NOISE FROM ORDINARY RAILWAY

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1. INTRODUCTION

In Japan, the Environmental Quality Standards for Shinkansen Super-express Railway Noise was promulgated in 1975, in which the Standard values are provided to be applicable to the maximum indication of A-weighted sound pressure level on a sound level meter with "S" detector-indicator characteristic.
As to the existing ordinary railways, on the other hand, which have far longer trackage as compared with the Shinkansen railway, the Environmental Quality Standards have not yet been established because of varieties of problems involved. Namely, the sort and the number of car and operation are very different among various lines and the kind of railway track in most places is of a short-rail construction, so that impact-like sounds add to the steady rolling noise. These should be considered in the noise evaluation of the existing lines.
We reported previously that in the case of ordinary railways we should take the number of operation into consideration, so that some measure based on L_{Aeq24}, WECPNL and suchlike may be appropriate for the evaluation of railway noise [1]. If we express the railway noise by L_{Aeq24}, however, there is the difference of about 5 dB between the Shinkansen and the ordinary railway against the same judgment probability of annoyance, and the judgment for the ordinary lines is severer than that for the Shinkansen. One of the causes of this difference is in the impact noise emitted at he joint of rails in ordinary railways.
In this study we carried out hearing test in order to get information as to how we can reflect the effect of this impact noise on the evaluation of loudness of ordinary railway noise. As a result it is clarified that it can practically be explained by L_{AE}.

2. IMPACT SOUND GENERATED AT A JOINT OF RAILS

There is some difference in ordinary railway noise among individual trains. The measurement of noise generated at the rail joint was carried out, therefore, at the position where the rail construction changed from a short-rail structure to a long-rail one (continuously-welded-rail structure). The place of measurement is located in suburban area of Sendai. We recorded the noise at two points 100 m apart from each other, at the same level with rails and 5 m distant from the center of the track.

Fig.1 shows the examples of noise wave recorded at both short-rail and long-rail sections. The peak level of impact sound generated at the rail joint is 10-20 dB higher than the steady part of noise depending mainly on rail/wheel interaction. The time required for 20 dB rising is about 10 ms in this impact sound, and its change of level is rather slow as compared with many other impact sounds we encounter in out daily life [2]. L_{AE} of train noise emitted in the short-rail section is 4-8 dB greater than that in the long-rail section due to the impact sound.

Fig.2 show the frequency spectrum in terms of the equivalent continuous band pressure level for 1/3 octave band width. The difference in level between short-rail and long-rail section is considered to be caused by the existence of impact sound.


Short-rail section


Long-rail section

Fig. 1 Exsamples of A-weighted sound wave of train noise in ordinary railways. (abscissa : 100 ms/div., ordinate : 10 dB/div.)

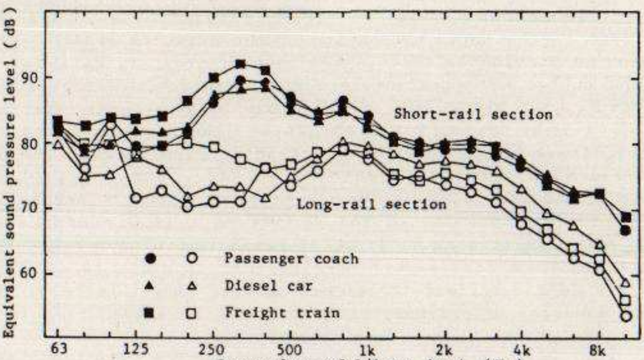

Fig. 2 Exsamples of 1/3 octave band spectra of train noise for short-rail and long-rail sections.

3. EXPERIMENT FOR LOUDNESS EVALUATION OF RAILWAY NOISE

In order to examine the effect of impact sound generated at the joints of rails on loudness of train noise we carried out hearing test of model sounds with different peak-to-steady levels. The stimuli were presented to a subject in an anechoic room through a loudspeaker, and PSE's (point of subjective equality) for their loudness were obtained by adjusting the level of a comparison stimulus. Fig.3 represents the envelope of a pair of stimuli. Test stimuli were synthesized by adding the model impact sounds to the model steady noise as produced in the long-rail section. Duration of steady noise was one second, and two or four impact sounds with rise time of 10 ms and decay time of 40 ms (time intervals required for 20 dB change) were added to it.
Steady noise of a test stimulus and a comparison one were synthesized by amplitude modulation of noise which had a spectrum similar to train noise observed in the long-rail section, while impact sounds were

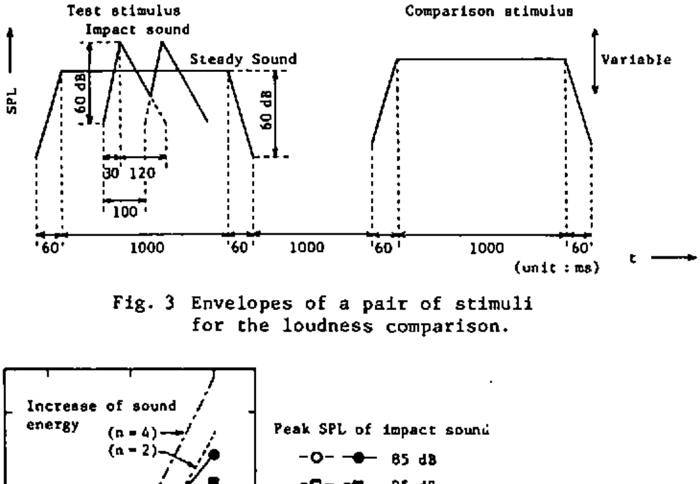

Fig. 3 Envelopes of a pair of stimuli for the loudness comparison.

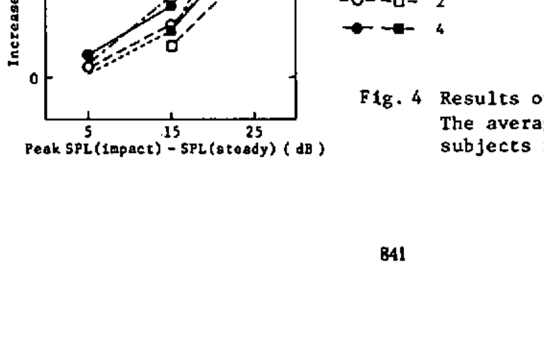

Fig. 4 Results of loudness comparison. The average of the data by six subjects is plotted here.

prepared by amplitude modulation of noise with a spectrum similar to that generated in the short-rail section.
Five kinds of sound pressure level of stimuli were used in the experiment: level of steady part was 70 or 80 dB for the peak level of impact sound of 95 dB, and 60, 70 or 80 dB for the peak level of 85 dB, so that the peak-to-steady ratio was 25 or 15 dB in the former and 25, 15 or 5 dB in the latter.
Fig.4 shows the results of the hearing experiment. In this figure the increase in PSE for loudness due to the addition of impact sounds to steady noise is denoted as a function of the difference in sound level between impact and steady noise (peak-to-steady ratio). It is in the nature of the case that the increase in PSE by adding the impact sounds becomes greater as the peak-to-steady ratio increases. If we compare this increase in PSE with the increase of sound energy, both values are almost the same for 5 dB and 15 dB peak-to-steady ratio, but the former is 3 - 5 dB lower than the latter in the case of 25 dB level difference.

4. CONCLUSION

The peak sound pressure level of impact sounds generated at the joints of rails in ordinary railways is higher by 10 - 20 dB than the steady part of noise , which is caused mainly from rail/wheel interaction, at the point of 5 meter apart from the center of the track. This difference in A-weighted sound pressure level is considered to become smaller in more distant position from the track.
From the results of hearing experiment, we can see that the increase in loudness of train noise by adding the impact sounds to steady noise shows almost the same value as the increase of sound energy as long as the peak-to-steady ratio lies within about 15 dB. The loudness of train noise in ordinary railways, therefore, may adequately be described in terms of L_{AE} for individual passing of trains from a practical point of view.

REFERENCES

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