Development of Rail Noise Isolating Material

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1. Introduction

Recently, as railway car running speeds have increased and demands for noise abatement in residential areas have intensified, there has also been an increasing need to control the rolling noise generated between wheels and rails, which represents a large proportion of trackside noise. However, conventional countermeasures such as noise-proof walls have a big disadvantage in that their installation is very labor-intensive; it is therefore essential to develop a new, easily installed measure\(^1\). Under these circumstances, the authors have developed a new type of material, named as rail noise isolating material (RNIM), which consists of two laminated layers, one of a foamed ethylene-propylene rubber and another of vibration-damping steel. Impact tests performed in a laboratory and on a commercial line and noise measurements of passing trains verified that RNIM is effective in reducing rolling noise.

Keywords: rolling noise, noise isolating, impact test, vibration, ethylene-propylene rubber

2. Structure of Rail Noise Isolating Material (RNIM)

Figure 1 illustrates the structure of rail noise isolating material (RNIM), which consists of two laminated layers, an inner layer of a soft viscoelastic rubber, and an outer layer of thin, rigid plate. Two pieces of RNIM completely cover a rail’s web and flange and are fixed by means of a bracket over the outer layer. The structure of RNIM is expected to lend itself well to the isolation of rail vibration; RNIM is lightweight and easy to install.

3. Impact test performed in laboratory

This chapter provides an outline of the impact test performed in a laboratory to evaluate RNIM’s basic vibration- and noise-reduction properties.
3.1 Sample and test method

Figure 2 provides a view of this test. A 50kgN-type rail cut to about 800mm in length was used as a sample. Both its ends were supported simply on two PC sleepers, with the distance between two rail fastening devices set at about 600mm. A central point (in both length and width) on the rail tread surface was hit vertically using an impact hammer both with and without an RNIM cover. Then, an exciting force was measured by the hammer, vibration accelerations by piezoelectrical accelerometers, and the noise (sound pressure) radiated from the rail by using standard microphones. Vibration accelerations were integrated once with time into vibration velocities, which were analyzed with frequency and normalized by exciting force into mobility, which corresponded to vibration velocity frequency response functions (FRFs). Noise was also calculated into FRFs by being analyzed with frequency and normalized by the exciting force. In this paper, mobility and noise FRF are expressed in decibels, where 0 dB was equal to 1m/s/N as a reference mobility, with $2 \times 10^{-5}$Pa/N in noise FRF. The frequency range for analysis was from 10Hz to 10kHz.

The measuring points were as shown in Fig. 2. This paper discusses the results from two points that were measured for vibration acceleration, and another that was measured for noise radiated from the rail. One of the vibration acceleration measuring points, marked as V1, was set at the tread surface near the impact point. The other, V2, was set on the rail flange in the case of the rail with no RNIM, and on the outer layer of the RNIM when this was fitted. In both cases, either with or without RNIM, the V2 measuring point was set just beneath the impact point. The noise measuring point was S1, which was positioned 300mm from the surface of the rail web along a section vertical to the rail and passing the central point of it, and at the same level with the center of the rail web in the direction vertical to ground. The impact was repeated eight times per set, and two sets were executed individually for the rail with RNIM and for that without RNIM. Consequently, the data were averaged individually for the test either with or without RNIM.

3.2 Test results

Figure 3 shows the time waveforms for vibration acceleration at point V1, which was set on the rail tread surface near the impact point. From Fig. 3, it is evident that the vibration acceleration for the rail tread with RNIM is slightly less than that without RNIM. From this result, it was revealed that RNIM has no apparent effect on rail tread vibration.

Figure 4 shows the time waveforms for vibration acceleration at point V2, which was set on the rail flange in the case of the rail with no RNIM and on the outer layer of RNIM when this was fitted. From Fig. 4, it can be seen that there was a significant reduction in vibration acceleration on the RNIM’s outer layer when compared with that of the rail flange. Conceivably this is because the RNIM’s inner layer has the ability to absorb vibration, and thus the amount of vibration translated from the rail to the outer layer is significantly reduced.

Figure 5 shows the mobility at point V1, and Fig. 6
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that for point V2. As these figures show, while there was a small change in vibration after attaching RNIM at V1, which was on the rail tread, the vibration of RNIM’s outer layer was significantly lower than that of the rail flange as well as in terms of frequency properties. The decrease in vibration of the outer layer of RNIM was greater at higher frequency ranges.

Figure 7 shows FRFs of noise measured at point S1, which was positioned 300mm from the surface of the rail web in a direction vertical to it. From this, it can be said that attaching RNIM reduces the noise radiated from the rail. The decrease in noise became more pronounced at high frequencies.

Table 1 shows complete pass values for mobility and FRFs of radiated noise, calculated by integrating the spectrum data in the 10Hz to 10kHz range. From this it was found out that while mobility decreased when the RNIM was in place at V1 by only 2.2 dB, that at V2 was as much as 12.9 dB. Moreover, noise radiation from the rail (S1) was reduced to 7.8 dB by attaching RNIM. The reason of this noise reduction is thought to be as follows. According to acoustic theory 3), noise radiated from a vibrating body depends on its surface vibration velocity in contact with the atmosphere. Applying this theory to a rail covered with RNIM, the noise radiated from the rail depends on the vibration velocity of the RNIM’s outer layer. Because the vibration velocity of the RNIM’s outer layer is reduced, as mentioned above, the noise radiated from the rail is reduced by attaching RNIM.

4. Tests performed on commercial lines

This chapter describes tests performed on some commercial lines to estimate the practical effects of vibration and noise reduction.

4.1 Installation of RNIM and test contents

Previously, the RNIM installation tests had been mainly carried out on two commercial lines; an electrified double-slab track and an electrified double-ballasted track.
The locations of the two lines, which are almost straight and have little gradient, are illustrated in Fig. 8. RNIM was installed on one side of the track on both lines. The RNIM installation extended approximately 200m on the slab track line and approximately 25m on the ballasted track line. The simplicity of the installation work enabled this to be finished in 5-6 hours in the case of the slab track line, in approximately two hours for the ballasted track line.

To estimate RNIM's effects, an impact test was performed on the slab track line and measurements of the noise generated by trains passing over the ballasted track line.

### 4.2 Impact test performed on commercial line

#### 4.2.1 Test method

The following provides an outline of the impact test performed on the slab track line. The vibration measuring points taking in the rail flange and the RNIM's outer layer were set near the center of the installation area. In the case of the point on the rail flange, an accelerometer was attached directly to the surface of the rail flange at a point where part of the RNIM had been cut away and removed, as illustrated in Fig. 9.

![Fig. 9  Photo of measuring points on slab track](image)

The center of the rail tread surface was hit vertically at points just above each measuring point on the rail flange or outer layer of the RNIM by the impact hammer used in the laboratory test mentioned in Chapter 3. Then, the exciting force and vibration acceleration were measured, and the measured data analyzed into accelerance, which means the vibration acceleration spectrum normalized by the exciting force and mobility by the method described in 3.1.

#### 4.2.2 Test results

First, a comparison was made between the vibration responses of the rail flange measured by the laboratory test and the test performed on the commercial line. Figure 10 shows a comparison of the two rail flange accelerance values, one measured in the laboratory test and the other from the test performed on the commercial line. From Fig. 10, it is apparent that the laboratory data values are much higher at frequencies below 300Hz than those from the test on the commercial line. At frequencies above 300Hz, the two sets of data show one noticeable difference in that the laboratory spectrum has many peaks derived from the proper vibration mode whereas the commercial line test has only a few peaks. These differences are thought to have been caused by the differences of physical properties of rails. The sample rail measured in the laboratory test was regarded as a finite-length beam, while that measured on the commercial line was a semi-infinite length beam. According to vibration theory, it is characteristic of a finite length beam for vibration response values in the low-frequency range to be enhanced and show many peaks derived from the proper vibration mode in the high-frequency range. On the other hand, Fig. 10 also shows that the baseline from the commercial line test data approximately agrees with that from the laboratory test above 300Hz. Considering that in general the averaging values of the vibration response above 500Hz have a significant influence on noise radiation, the laboratory test proved to be effective in providing approximate predictions of RNIM's vibration and noise reduction properties on a commercial line.

Figure 11 shows the mobility of the rail flange and RNIM's outer layer measured by the test on the commercial...
cial line. From Fig. 11, it can be seen that the characteristics of the two mobility values of the rail flange and the RNIM’s outer layer, which were measured by the commercial line test, are very similar to those measured by the laboratory test, that is to say, the magnitudes of mobility for both the rail flange and the RNIM’s outer layer measured by the commercial line test individually closely resemble those measured by the laboratory test. Moreover, the mobility of the RNIM’s outer layer is significantly less than that of the rail flange, the decrease being greater at higher frequency ranges, as shown in the laboratory data.

4.3 Measurement of noise as trains pass

4.3.1 Test method

The following provides an outline of the test performed on the ballasted track to measure the noise as trains pass. Figure 12 illustrates the measuring points, which were set along the section near the center of the installation area. This paper discusses the results of the test cars, that were run to estimate RNIM’s effect properly, measured at point S7 which was 6.25m from the track center and 1.2m over the ground level. Noise level was measured by a standard or directional microphone, under the condition that the frequency characteristic was A-weighted and the time constant fast. Moreover, a one-third-octave band analysis of the measured data was performed.

4.3.2 Test results

Figure 13 shows time waveforms for noise levels measured by a directional microphone at point S7 during one set of test cars passage. This figure reveals that the peaks and bottoms of the train passing were repeated in the noise-level time waveforms both before and after the installation of RNIM. The peaks of the waveform corresponded to noise generated by the passage of each of the test car’s axles and the bottoms the noise generated between them. Figure 13 also shows that installing RNIM reduced the noise level for the full duration of the train’s passage; however, the decrease was more pronounced at the bottoms of the waveform and comparatively less at the peaks. The presumed reason for this is as follows. At the peaks of noise level, which are primarily caused by the passing car’s axles, the contribution of noise radiated from the rail to the total trackside noise drops because the noise radiating from the wheels and parts of the car body, such as the drive unit gears, becomes superimposed. On the other hand, at the bottoms of noise level, which are generated between the passing of an axle, the strength of noise sources other than the rails becomes
studies into railway vibration and noise 5), the contribu-
tion being especially apparent. According to previous
range, with the decrease in the 500Hz to 2kHz frequency
installation of RNIM reduces noise levels over a wide
noise level value. It can be seen from Fig. 14 that the
analysis of the data shown in Fig. 13 at the maximum
was reduced at the moment an axle passed.

Figure 14 shows the results of a one-third-octave band
analysis of the data shown in Fig. 13 at a peak noise level value (test
motor car, point S7)

slight, and thus the noise radiated from the rail predominates in the trackside noise. Because RNIM has a noise
reduction effect only on noise radiated from the rail and
has little effect on any other noise sources, noise reduction
was enhanced between the passing of the axles and
was reduced at the moment an axle passed.

Figure 14 shows the results of a one-third-octave band
analysis of the data shown in Fig. 13 at the maximum
noise level value. It can be seen from Fig. 14 that the
installation of RNIM reduces noise levels over a wide
range, with the decrease in the 500Hz to 2kHz frequency
range being especially apparent. According to previous
studies into railway vibration and noise 5), the contribu-
tion of noise radiated from the rails surpasses that of
trackside noise around 1kHz. Taking this into consider-
ation, this result confirms that RNIM has an effect in
reducing the noise radiated from rails.

Figure 15 shows the peak noise level values when the
axles of test motor cars passed, measured by a standard
microphone. In general, when one of the motor car’s ax-
les passes, the noise level often shows the maximum value
throughout the passage of the train car set because the
noise radiated from the motor is added at that moment.
Therefore, to assess the noise environment it is vital
to estimate the noise level at the moment of motor car’s axle
passage. In addition, considering that RNIM’s effect at
the moment of car’s axle passage is relatively weak, as
shown in Fig. 13, it becomes even more important to esti-
mate the noise level at the moment of motor car’s axle
passage. From Fig. 15, it is apparent that the 2 dB–3 dB
decline in noise level achieved by installing RNIM was
measured in a wide speed range (60km/h–105km/h), and
verified that RNIM is effective in improving the noise
environment.

5. Conclusions

To realize an effective, easily installed countermea-
sure, the authors have developed a new type material,
named as rail noise isolating material (RNIM). To evalu-
ate RNIM’s vibration- and noise-reduction properties,
impact tests were performed in a laboratory and on a com-
mercial line, and the noise of passing trains measured on
a commercial line. As a result of these tests, the follow-
ing conclusions were obtained:

1) As the results of impact tests, it was revealed that the
vibration of RNIM’s outer layer was significantly re-
duced because RNIM has a vibration isolating prop-
erty.

2) As the result of the impact tests conducted in a labora-
tory, it is apparent that noise radiated from the rail is
reduced with RNIM because the vibration of RNIM’s outer layer is reduced.

3) The results of installation tests performed on commer-
cial lines proved that RNIM is easy to install.

4) As a result of measuring the noise of a passing train
on a commercial line, a 2 dB–3 dB reduction in noise
level was measured after RNIM had been installed, verifying that RNIM is effective in reducing noise ra-
diated from a rail.

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