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RAIL CORRUGATION: CONSEQUENCES FOR RAILWAY NOISE

P C Dings

Netherlands Railways, Technical Research, Utrecht, The Netherlands

1. INTRODUCTION

Surface irregularities on railway wheels and rails, with wavelengths between 0.5 and 25 cm and rms amplitudes up to 30 μm, are important parameters determining rolling noise of railway vehicles. Rolling on these irregularities causes vibrations in wheels and rails and subsequently radiation of sound. Research in the last years has shown that for the situation of Netherlands Railways, wheel roughness generally dominates rail roughness, due to the large amount of block braked wheels on Dutch rolling stock [1]. Nevertheless, at some spots on the Dutch network excessive wear occurs with a periodic pattern, called rail corrugation. The sharp peaks in the wavelength spectrum caused by this kind of wear is responsible for noise levels up to 18 dB(A) higher than on normal track. In Netherlands Railways, a criterium of 50 μm peak-to-peak amplitude is used to determine which parts of the network have to be treated in the yearly grinding campaign. This criterium is chosen to avoid dangerous situation and to minimize maintenance cost. A survey was carried out to determine whether the grinding criterium would be different if it would aim at minimizing sound radiation. A second objective of the study was to see how corrugation is removed by grinding and whether it reappears on the same spots.

2. ROUGHNESS AND NOISE MEASUREMENTS

Four sites with rail corrugation were selected, all on lines in full service. The track ages varied between 11 and 15 years. Three tracks had twin-block concrete sleepers, one had timber sleepers, all carried a UIC54 rail. The track sections were selected in such a way that noise measurements could be performed of both disc braked and block braked rolling stock on all four sites.

Description of the measurements
On each site, the rail roughness and the pass-by noise of passenger trains was measured a few days before and a few days after grinding and after that each four months during a year.
Roughness. The rail roughness was measured using the Müller-BBM measurement device RM1200E [2]. This device measures the longitudinal profile of the rail head on a narrow line of 1.2 m length. More than 24 lines were gathered on each site at each measurement session, over a total length of 6 m. During a measurement each 0.5 mm a sample is taken. Each measured profile (consisting of 2400 samples) is turned into a narrow-band wavelength spectrum using FFT. The narrow-band spectrum is summed up to a third-octave spectrum that gives the roughness level distribution in the wavelength range between 0.1 and 10 cm. Roughness is presented as a level L_r in dB re 1 μm. $L_r = 20\log(r_{rms}/r_0)$ with $r_0 = 1\mu$m. The roughness spectra are energetically averaged to get separate averages for the left and right rail and for the site.
Noise. Pass-by noise of service trains was measured each time during half a day on each site. Microphones were positioned at 0.5 m from the rail at rail head height. Trains with speeds around 140 km/h were selected to be analyzed to third-octave spectra of the equivalent pass-by level.

3. MEASUREMENT RESULTS

Roughness
Roughness profile. Two examples of roughness measurements are shown in figure 1. One is a measurement of a corrugated track, the other is the same track section directly after grinding. In the

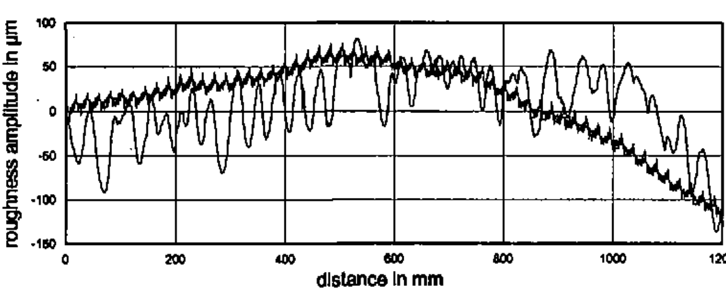

Fig. 1: Rail roughness profiles for a corrugated and a ground rail

corrugated track the sine shaped wave can be recognised, which willl turn up in the spectrum as a peak between 4 and 5 cm. The measurement directly after grinding clearly shows grinding lines, the circular grooves made by the rotating grinding stone. The repetition each 2.5 cm also causes a peak in the spectrum, off course. Both peaks, corrugation and grinding lines, evidently show up in the noise spectra as well. Other authors, e.g. [3], have indicated that the wavelength of the grinding peak is determined by the propagation speed of the grinding train and the number of revolutions per minute of the grinding stones (f_g) by the relation $\lambda_g = v_g/f_g$.

Roughness spectra. Figure 2 presents the roughness spectra of one of the sites. Before grinding, a broad corrugation peak between 4 and 8 cm can be seen. This peak is removed after grinding. The grinding process induces the sharp 2.5 cm peak and a broad-band roughness increase at very small wavelengths (up to 1 cm). After one year, this small wavelength roughness is removed by the rolling action of the wheels. For unknown reason, the corrugation peak at 4 cm reappears. It is growing steadily and it can be expected that the initial corrugation level will be reached again within a few years.

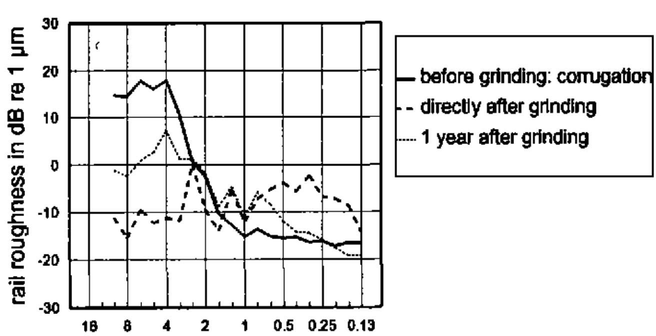

Fig. 2: Development of rail corrugation

Roughness and noise

Figure 3 gives the relation between rail roughness and pass-by noise for a disc braked double decker train and a block braked commuter train. The dB(A) was taken as a one-figure quantity for roughness, as for the time being it appears to be the quantity that correlates best with pass-by noise. The A-correction is taken from the frequency third-octave band corresponding to the train speed v divided by the wavelength λ ($f = v/\lambda$). A study for a quantity giving better correlation is going on at present.

It can be seen in figure 3 that for this type rolling stock no noise levels under 100 dB(A) will be measured, no matter how smooth the rail will get. It is concluded that the wheel roughness is predominant in this region. We also see that the value of 100 dB(A) is not exceeded by more than 5 dB's when the rail becomes smoother than 10 dB(A).

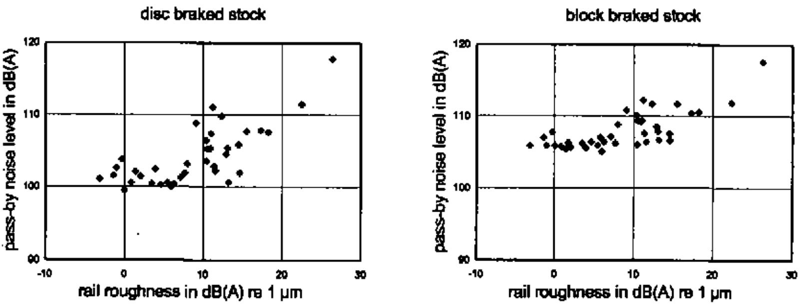

Fig. 3: Pass-by noise levels and rail roughness for two stock types

4. CONCLUSIONS

It can be concluded from figure 3 that noise reductions of 10 dB(A) for block braked stock to 15 dB(A) for disc braked stock can be reached if the grinding criterium of 50 μm peak-to-peak amplitude (corresponding to about 25 dB(A) roughness level) is reduced to 15 of 10 dB(A) respectively. Minimum noise levels will then be determined by the wheel roughness, which in turn depend on the braking system. The peak-to-peak amplitudes that correspond to roughness levels of 15 and 10 dB(A) are about 16 μm and 9 μm. Netherlands Railways will now start an investigation into the possibilities for noise minimisation by rail grinding.

It was also concluded from the survey that corrugation can reappear within one year after grinding. A study to clarify which parameters determine roughness growth is planned as well. Stiffness of the track, rail head quality and initial roughness are among the parameters that will be studied.

References

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[2] G. Hölzl, M. Redmann and P. Holm, *Eisenbahntechnische* Rundschau 39, (1990)
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