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Correlation between Barkhausen-noise and corrugation of railway rails

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The magnetic Barkhausen-noise has been investigated on the running surface of a railway rail and a good correlation has been found between the noise and corrugation. The Barkhausen-noise showed minima and maxima at the hill and valley positions, respectively. This correlation can be used to observe or preindicate the corrugation process. © *2002 Kluwer Academic Publishers*

1. Introduction

On high speed railways the knowledge of the state of rail treads is very important. Non-destructive testing methods have become widely used for these investigations because many parameters of the state of the rails can be measured precisely and rapidly by them. The *magnetic Barkhusen-noise (MBN)* measurement is one of the most popular methods, which is mainly applied for examining the stress state of rails [1].

A very relevant problem of the high-speed tracks is corrugation: on the running surface of the rail (the contact surface between the rail and the wheel) a surface modulation of 5–10 cm wavelength and 0.1–1 mm amplitude appears (see Fig. 1). The corrugation is undesirable because it increases the traction resistance, the noise emission and the vibration, which may damage the rail-wheel system.

The origin of the corrugation is not clarified yet, although both our previous measurements [2, 3] and other articles [4–8] on this topic indicates that this is related to mechanical loading and is a specific wear effect. The loading creates a microstructure periodically changing along the axis of the rail treads [4–6]. The different hardness and wear resistance of these differently structured parts leads to the development of corrugation.

One method to eliminate the corrugation is grinding the worn layer of the rail. However, this is a rather expensive and slow process and it is not a simple task to choose the right depth of grinding. If a too small depth is chosen; although the corrugated layer can be removed, one can not be sure that the the periodical changing of the microstructure has been eliminated so that the corrugation can reappear after a short time. (The choice of a too large depth leads to unnecessary costs as well.)

The best method is to grind the surface of the rail before the appearance of the corrugation because in this case only the periodically changing microstructure of the rail has to be removed, which needs a smaller depth of grinding. The key point of this procedure is to find the optimal time and depth. This needs a method which can indicate the periodical changes in microstructure, before any surface modifications would be detected.

As mentioned above Barkhausen-noise is widely used to measure the stress state of rails and generally is sensitive to the microstructure [9, 10]. Therefore, we thought that Barkhausen-noise might be suitable for the examination of the microstructure, and thus for the observation (or even for the pre-indication) of corrugation.

In our previous work [2] we investigated the changes of Barkhausen-noise, measured on the treads, during the use of the rail. After one year of use the noise value decreased to one-third of the value measured at the time of laying. This decrease shows that in the running surface a microstructural change appears, which has an effect on the Barkhausen-noise (e.g., changing of grain size, dissolution of phases, etc.). In this work we present results on the correlation between the profile of corrugation and Barkhausen-noise.

2. Experiments

For our experiment two 1m long UIC54 (C 0.6–0.8%Mn 0.8–1.3%) type rail treads were chosen. One of these was laid on the experimental track of Hungarian State Railways and was investigated *in situ*, and the other was removed from another track and it was investigated in the laboratory. The corrugation profile of the running surface was examined by a special device

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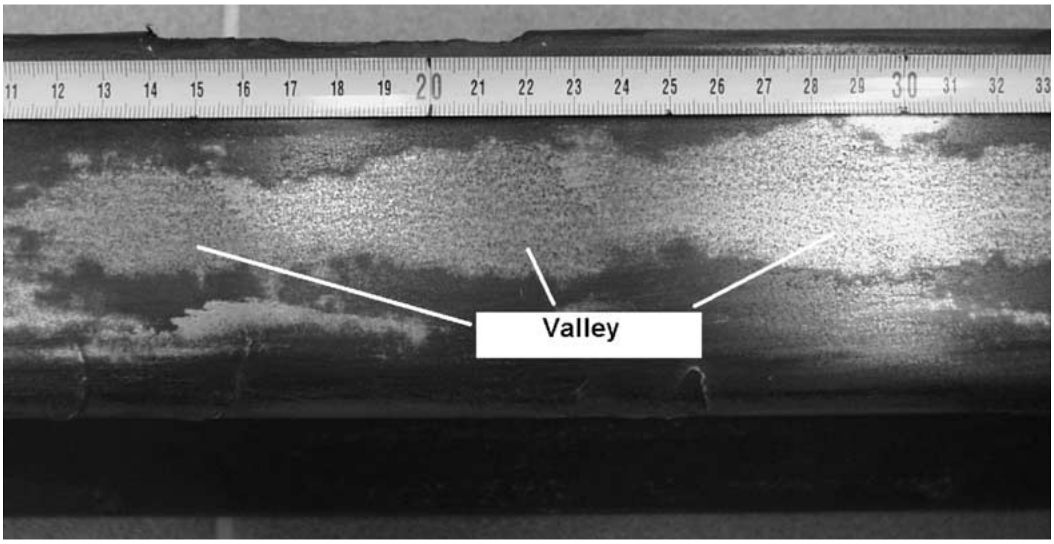

Figure 1 Typical corrugation pattern on the running surface of a rail.

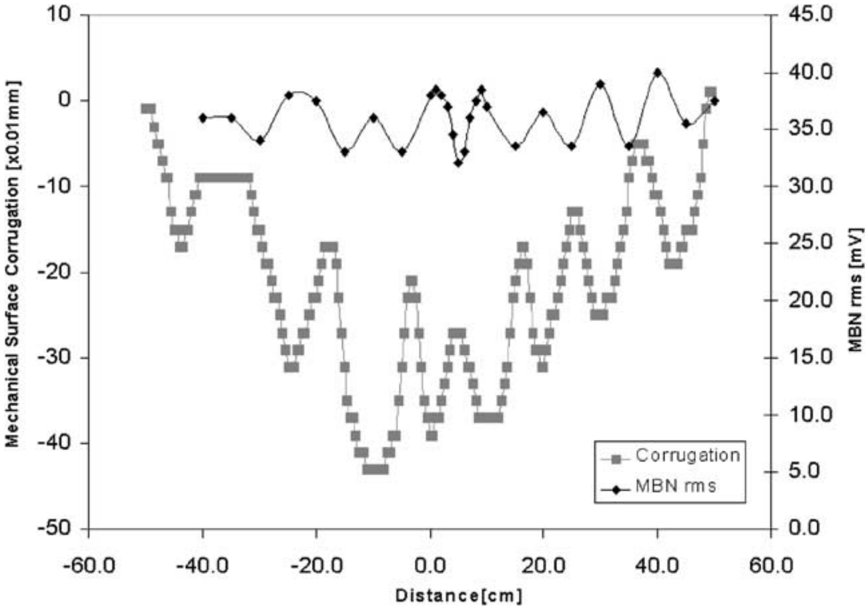

Figure 2 The *rms* value of Barkhausen-noise and the mechanical corrugation along the axes of rail tread, measured on site.

(provided by *Metalelektro Ltd.*, Hungary) which can record the vertical profile along the rail axes without contacting the surface. A fully computer-controlled and portable device was developed to perform the Barkhausen-noise measurement on site [3]. The applied Barkhausen head was fitted to the top of the surface and it was movable along the rail axes. The applied magnetic excitation field was 100 Hz sinusoidal and about 20 W power signal. From the induced Barkhausen signal a *rms* (root mean square) value has been calculated by a *rms* maker circuit. This circuit integrates the noise over a certain time, T:

$$\langle f \rangle_{rms} = \sqrt{\frac{1}{T}\int_0^T f(t)^2 \mathrm{d}t}, \tag{1}$$

where the integral stands between 0 and T. T is chosen in such a way that in this time interval there are several tens of noise packets on average. The *rms* value presents an average characteristic of the complex noise packets.

On the excitation channel there is a special flux stabilizer circuit. This circuit—with the help of a coil placed in the measuring head—can compensate the variable gap between the rail surface and the head, caused by the surface roughness.

3. Results and discussion

Figs 2 and 3 show the corrugation measured on the running surface and the Barkhausen *rms* values of the same positions. The corrugation has about 8 cm wave-length and 0.1 mm amplitude, which are typical values. In Fig. 2 a long wavelength (about 2 m) half wave can be seen on the ”corrugation” curve. This type of rail unevenness originates from the manufacturing process, and it is less harmful than the short wavelength corrugation. It can be seen that the Barkhausen-noise is not sensitive to the long wavelength wear, because the long periodical waves probably do not contain microstructural or stress variations.

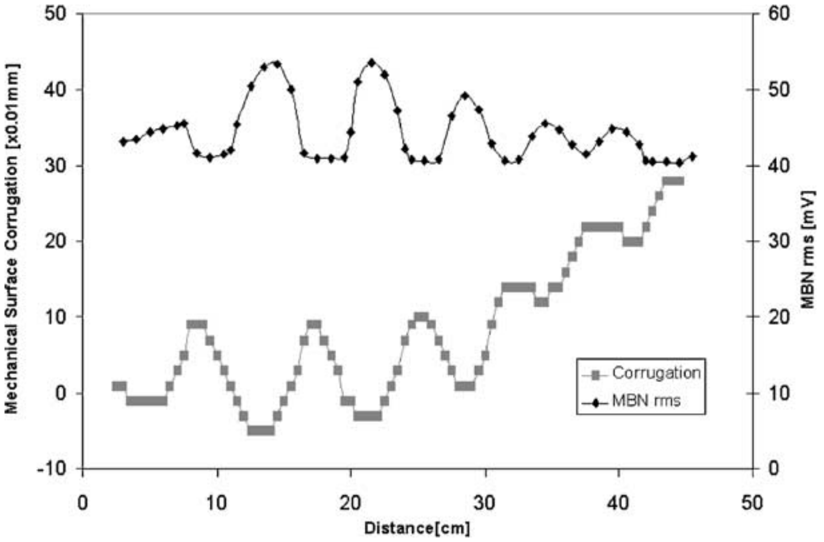

Figure 3 The *rms* value of Barkhausen-noise and the mechanical corrugation along the axes of rail tread, measured in laboratory.

On the other hand the correlation between the corrugation and Barkhausen-noise can be clearly seen on both figures. The Barkhausen-noise shows minima on the hill positions and maxima on the valley positions.

This results can be correlated to our previous work [2], where a decrease of the Barkhausen-noise during the mechanical loading was observed. The loading can reduce the grain size and/or can dissolve and break into fragments the perlit particles of the steel. Both effects decrease the *rms* value of the Barkhausen-noise.

Usually the structural change is not homogeneous along the rail axis [4], [5] and therefore different hardness and wear resistant parts appear during the load. The part of smaller hardness and wear resistance will wear stronger than the part of higher hardness. Thus valleys and hills will be formed. Therefore a definite correlation between the Barkhausen-noise and the corrugation profile—as it is observed—can be expected; the lower noise values at the hills indicate a more drastically changed microstructure (and a higher wear resistance).

As the method of Barkhausen-noise is already used in the field of rail diagnostics, after some modifications it can be suitable for the examination of the origin of corrugation as well. It may also be a great help in tracing or preindicating the development of corrugation.

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