Experimental Study of the Potential Usage of Acoustic Emission to Railway Track Faults Detection

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Abstract
Estimating of the railway track mechanical integrity is very important for railway transport safety. Non-destructive methods are intensively investigated in order to find faults in railway lines in early stage for the purpose of decreasing the expenses for their elimination and for extending their lifetime. Advantages of acoustic emission point out the benefits of using this method for problem solving. It is partly the fact that it is a passive method which uses loading by train traffic thereby expenses to inspection are significantly smaller than in case of using active methods. Partly, due to this being a non-destructive method, it is possible to use it for repeated monitoring of identified cracks expansion. The activity of acoustic emission increases with the growth of damage extends. The paper shows how the initial investigation demonstrates the acoustic emission method can be used for railway track faults detection.

Keywords: Continuous welded rail, acoustic emission, acoustic signals, rail steel, defects

1. Introduction

Implementation of continuous welded rails has resulted in an improvement of the travelling comfort. Omission of the mechanical rail joints with joint clearances gives rise to a smooth driveway. No bounces on wheels on rail joints are generated on the long-welded rails, so that the dynamic stress of the vehicle undercarriage as well as the rails is reduced. This in turn influences favourably the wear and tear as well as the failure rate of the vehicles and the traffic route. It is shown in practice, however, that welding under unsuitable conditions may result in crack-type faults in the material. Various small cracks and similar defects may arise in hardened material, which are susceptible to propagate easily in the brittle material. Moreover, the yield strength of a high-hardness material is much higher than that of the original material, so that all tensions are adding up. Several cracks of different size may arise in the weld deposit after the welding. Only a few of them can propagate to the surface to be detected and fixed. Hidden cracks may increase in size gradually at a relatively low repeated stressing (at normal traffic) in consequence of material fatigue. Hidden cracks thus constitute a serious problem.

Assessment of the mechanical integrity of railway tracks makes a very important factor of railway transportation safety. Therefore, non-destructive methods are being looked for intensely, which would be able to discover faults and defects in their early stage of development, thus reducing the repair costs and extending the rail service life. As early as the 90s of the past century, research efforts focused on experimental studies of applying the acoustic emission (AE) method to this purpose. They consisted mostly in laboratory experiments which pointed to the advantages of the AE method application to this type of problems [1], [2], [3], [4]. The benefit of this method consists in the fact that it is a passive method, using the train traffic events as a source of the loading forces, thus reducing the application costs in comparison with active non-destructive methods. Another benefit of this method consists in the possibility to monitor the object conditions both in regular intervals and continuously.
2. Experiment set-up

DAKEL-XEDO measuring system was used to carry out the check-up measurements. XEDO-AE acoustic emission parameter evaluation units were used in the measurements. These units make it possible to measure standard parameters of the acoustic emission, to process the acoustic emission events allowing to locate them and to carry out direct digital sampling at a rate of up to 8 MHz (see Fig. 1.) As many as 8 pick-ups can be connected in parallel to this multi-channel measuring device. Three measuring channels differing in frequency filter parameters were used to carry out the check-up measurements. Based on the check-up measurement results, eight measuring channels with high-pass filters over 100 kHz were chosen for subsequent measurements in the railway traffic conditions.

![Figure 1. DAKEL – XEDO acoustic emission measuring system](image)

Magnetically attached MDK 13 sensors proved to be best suited for the rail measurements. Vaseline was used to provide acoustic coupling between the rails and the sensors. The sensors are calibrated up to 600 kHz at least. Impact-echo method was employed to verify the action range of the sensors. A mechanical pulse was applied to the rail surface to generate acoustic waves. The measurement result reproducibility was verified by the exciting pulse realized from two different heights [5], [6]. The frequency spectra were also studied for the occurrence of non-linear effects which serve as a manifestation of structure defects. If the material structure integrity is disturbed, predominant frequencies show a shift at increased intensities of the exciting signal [7]. No predominant frequency shift was observed in the rail segment measured. Based on our measurement results, it has been verified that the AE sources (defects, cracks) in a rail can be identified within a distance of up to 500 m.

3. Objective of the experiment

The measurements were carried out on two railway tracks, denoted rail No. 1 and rail No. 2. The train passage induced acoustic emission signals were picked up by eight AE sensors simultaneously on both of the mentioned rails. The sensors were fitted to the outer webs of the rails and their output was fed into the AE analyser channels (the channel numbering was identical with that of the sensors). The location of Nos. 1 through 4 sensors on the first rail is...
shown in Fig. 2. The location of Nos. 5 through 8 sensors on the second rail is shown in Fig. 3.

![Figure 2. Sensor location on the first rail](image)

![Figure 3. Sensor location on the second rail](image)

4. Measurement results

We evaluated the counting rates of the AE signals and the frequency spectra of the particular signals [8]. The results are presented in the form of AE activity vs. time plots and event frequency dependence diagrams. The diagram of Fig. 4 shows the AE signal count increase, which is due to the passage of an express train. In this particular case, channels No. 1 though 4 correspond to the loaded rail (Fig. 2), channels No. 5 through 8 to the rail, which was not loaded (Fig. 3). The curves of Fig. 4 show the AE signal count increase, as recorded by all channels.
As is seen in the diagram, only isolated AE signals were recorded in channels No. 5 through 8 (rail, which was not loaded). Fig. 5 shows frequency spectra of the signals which were recorded in channel No. 6 (the rail which is near the loaded rail track) in the time interval from 13 to 15 seconds, where the signal count grew up. It is seen that the frequency components of the signal recorded in the 15th second are in the vicinity of 100 kHz and in the range from 200 to 700 kHz. In view of the fact that these values are several orders of magnitude lower than those of the run-over rail, this is a kind of "noise", e.g., transfer via the subbase, etc. No elevated amplitudes of the above-mentioned frequencies were recorded by S7 and S8 sensors, which were fitted to the farthest rail.

The frequency spectra of the AE signal (Fig. 6) correspond to the signal recorded by channel No. 1 on the loaded rail in the time interval from 6 to 20 seconds. The amplitude peaks occur
within the vicinity of 200 kHz. Starting from this value, an almost linear amplitude decrease is observed. The maximum attained amplitude at 200 kHz exceeds the noise background by 80 dB.

The time distribution of the AE event predominant frequencies for channel No. 1 in 3D linear coordinates is shown in Fig. 7. The diagram also shows that the predominant frequencies emerged during the time interval from 6 to 20 seconds.
4. Conclusions

The measurements were carried out in two different locations with a view to verify the measurement result reproducibility and find out a correlation between the AE parameters evaluated and the condition of the rails under test.

Following correlations have been established on the basis of our experiments and experiment result analyses:

- Frequency components in the vicinity of 200 kHz were predominant in the frequency spectrum if the rails were loaded by an express train running over them. They can be regarded as the consequence of the wheel-to-rail interaction.
- Elevated amplitude values in the frequency range from 10 kHz to 100 kHz result obviously from mechanical sources, as was confirmed in the case of fitting the sensors to the rail points.
- In the case of a passenger train running over the rails, the AE method proved to be able to identify different modes of the train movement (slowing down, stopping and subsequent drive away).

The measurement results did not prove any existence of cracks in the rails tested, which was verified by means of the nonlinear ultrasonic spectroscopy tests of rail No. 1. This confirms our assumption that the initiation of a crack in a steel rail brings about a high-frequency signal of sufficiently high intensity. A certain shortcoming consists in the fact that we were not in a position to apply the method to a damaged rail.

It has been verified by our experiments that the AE parameters, such as the signal counts and frequency spectra make it possible to assess the internal structure of the object under investigation. Continuous or periodic tracking of the changes of selected parameters provides us with important information of the changes taking place in the material structure. If any changes in the structure are detected it is advisable to verify the measurement results by another NDT method, such as the nonlinear ultrasonic spectroscopy (NEWS). The two above-mentioned methods can complement each other to advantage. The AE method makes it possible to perform real-time location of emerging defects under service condition stimulation, whereas the NEWS method is applicable to locating the defects zones without exciting loads. Simultaneous application of the both methods is very advantageous from the economic point of view. Once developed and verified in practice, acoustic emission apparatuses and procedures can be - in conjunction with the nonlinear ultrasonic spectroscopy - employed to build up a rail condition monitoring system. Such systems are being denoted as SHM (Structural Health Monitoring systems). At present, they are used in aviation and efforts are made to modify them with a view to monitor building object condition.

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References