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Investigation of the possibilities of rail base defects detection using the magnetic (MFL) method

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Abstract

This article shows the possibility of detecting defects in the rail base blades by the method of magnetic flux leakage. Theoretical studies were carried out by modeling and the results were verified experimentally on defect models. As a result, a prototype of a magnetic flaw detector was obtained.

Keywords: non-destructive testing, rail inspection, rail base, MFL.

1 Introduction

During the railway tracks operation defects develop in the rails, which can lead to an unexpected rail fracture. Using ultrasonic, magnetic, eddy current and optical methods of non-destructive testing with continuous inspection, defects are successfully detected in all parts of the rails, except for the rail base blades. In the entire Russian railway network up to 85% of officially recorded rail failures occur due to defects in the rail base. This indicates that the known methods and devices do not provide reliable and timely detection of these defects. Attempts to detect such defects by innovative testing methods, such as using ultrasonic waves to test from the rolling surface, including phased array systems or guided waves, have not been successfully applied [1, 2]. Detecting defects from the surface of the rail base blades using ultrasonic methods is limited by the condition of the blades surface, dirt and corrosion presence [3].

The authors propose the idea of detecting defects in rail base blades using the magnetic flux leakage (MFL) method [4]. This work was preceded by many years of experience in designing and operating magnetization systems implementing the MFL method for high-speed flaw detection of rails to search for defects in the rail head, as well as in track structural elements [5, 6]. To implement the proposed idea, it was necessary, through numerical modeling, to investigate the features of the magnetization of the rail metal in the area of the base blades, as well as to propose a system for information retrieving and processing. After manufacturing the magnetization system and the information retrieval system according to the calculated data, experimental work was carried out to assess the detectability of models of defects in rail fragments.

Thus, the aim of the work is a theoretical and practical study of the possibility of detecting cracks in the rail base (including blades) by the magnetic (MFL) method.

2 Methods

In the course of the work the characteristics of the defects of the base blades, which led to the rails fractures were analyzed. It was found that fractures, as a rule, occur along transverse cracks developing from the bottom of the rail base. The cracks are in the form of a segment, with a height of 4 to 20 mm and a width of 8 to 30 mm. Quite often cracks are located outside the projection of the rail web – in the rail base blades. Along the rails length almost all cracks develop in the area of rail tie-plates and track fasteners (clips) [7]. As a rule, cracks are the result of corrosion-fatigue processes.

In order to determine the optimal design of the magnetization system for the rail base blades in the Ansys Maxwell software, mathematical modeling of several design options was performed. Through several iterations, the authors managed to implement a design model of a magnetization system capable of magnetizing the rail base to 1.2 T value.

The second task was simulating magnetic responses from small plane defects in the form of segments located in different regions of the rail base: at the edge, in the middle of base blade and near the center of the rail. In this case, the bases of all defect models coincided with the lower surface of the rail base. Defect responses were calculated both in the area of rail tie-plates and track fasteners, as well as outside these areas. Based on the results of computer modeling, it was possible to obtain positive results, indicating the possibility of using the MFL method to solve the problem.

Based on the calculations a system for the rail base blades magnetization (for a rail of the R65 type) was made, a 10-channel information retrieval system based on Hall sensors was developed (five for each base blade). Signals from the Hall sensors are transmitted to an ADC and then displayed on industrial laptop.

3 Results

The design of the magnetization system was optimized using several iterations of computer modeling. The magnetization system, based on two U-shaped electromagnets, mounted coaxially on both rail base blades, is shown on Fig. 1. The dependence of the magnetization of the rail regions is analyzed at different pole-to-pole distances, with a gap of 1 to 10 mm between the poles and the metal rail base surface.

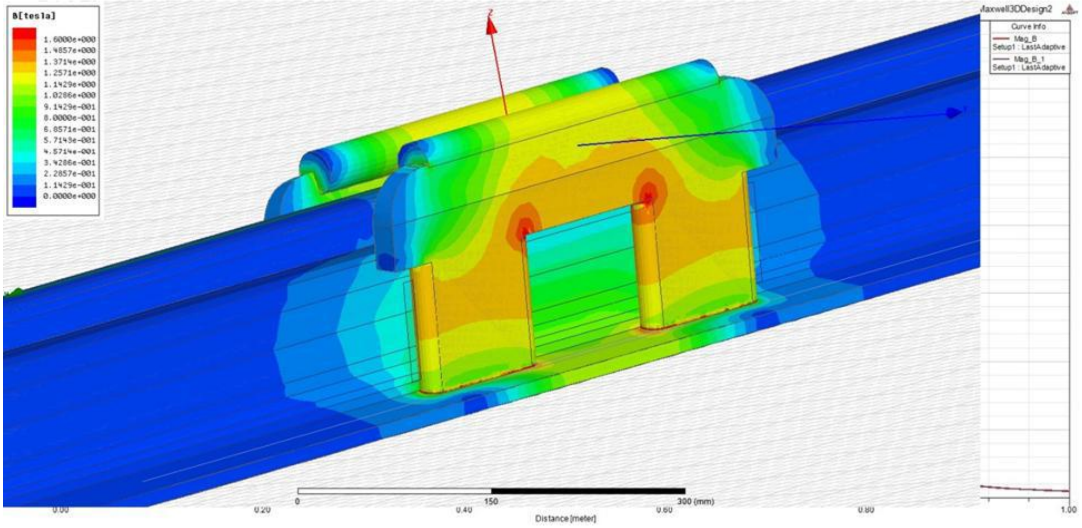

Figure 1: Distribution of magnetic induction on the surfaces of the rail and magnetizing system with vertical coils of electromagnets (Ansys Maxwell software).

Using the same Ansys Maxwell software, responses from defects located in different parts of the rail base were calculated. Fig. 2 shows the distribution of magnetic induction near the defect model, which is a segment with dimensions of 8x10 mm, made on the edge of the base blade.

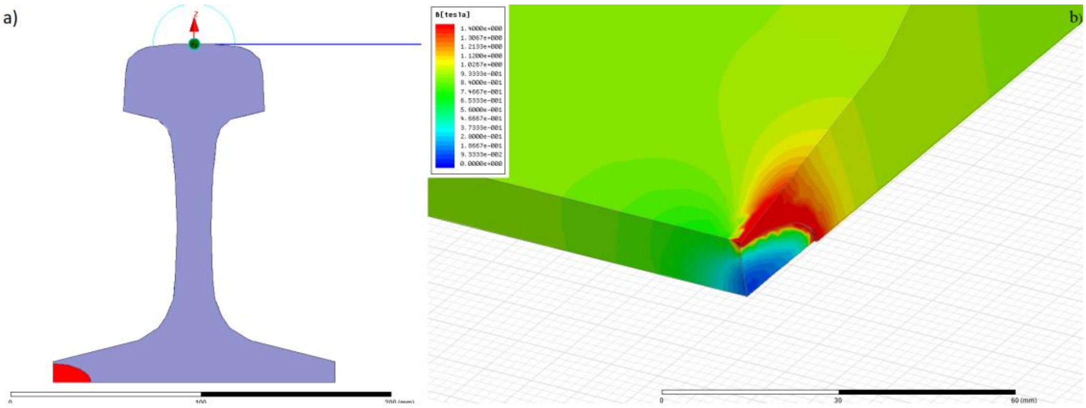

Figure 2: Transverse crack of the base blade (a) and the distribution of magnetic induction on the surface and in the cross-section of the rail in the presence of a transverse crack of base blade (b).

Fig. 3 shows a graph of magnetic induction distribution in the interpolar space (along the rail) on a defect-free section of the rail (blue line) and in the presence of a crack model according to Fig. 2 (red line). The signal burst caused by the defect is clearly distinguishable from the general magnetic background.

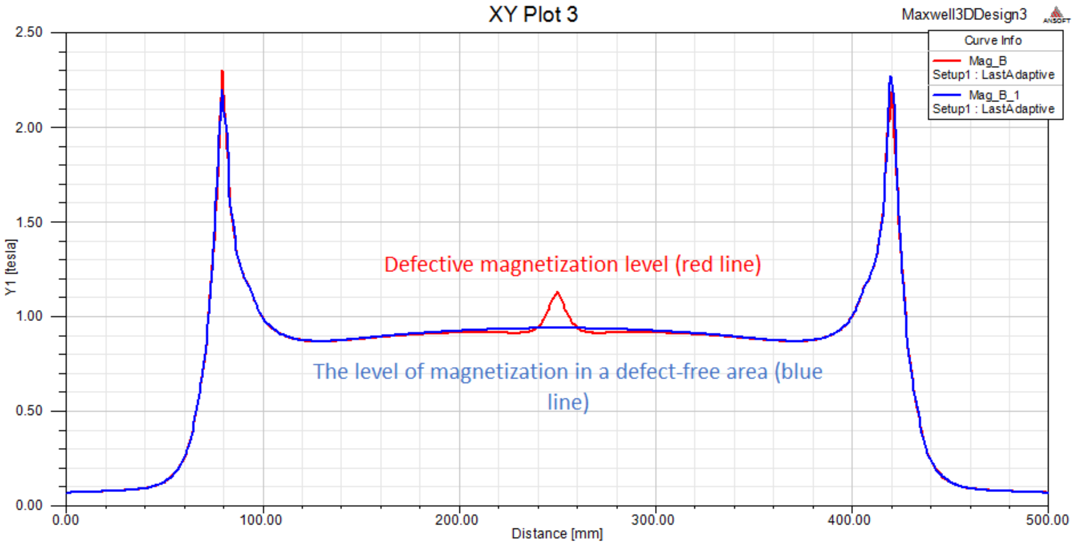

Figure 3: Distribution of magnetic induction on the surface of the base blade along the longitudinal coordinate (along the rail) in the zone of a transverse crack in the base blade.

The basis of the layout of the magnetization and information retrieval system (Fig. 4) are two U-shaped electromagnets fastened to each other, which can move along the rail using rollers, including the rail fastenings without hindrance. In the middle of the pole-to-pole space, on each base blade five Hall sensors are installed, distributed over the surface of the base blades in the cross-section of the rail. Signals from the Hall sensors after pre-amplification are sent to the ADC and then displayed on the screen of a protected laptop synchronously with the movement of the model along the rail, due to the installed displacement sensor.

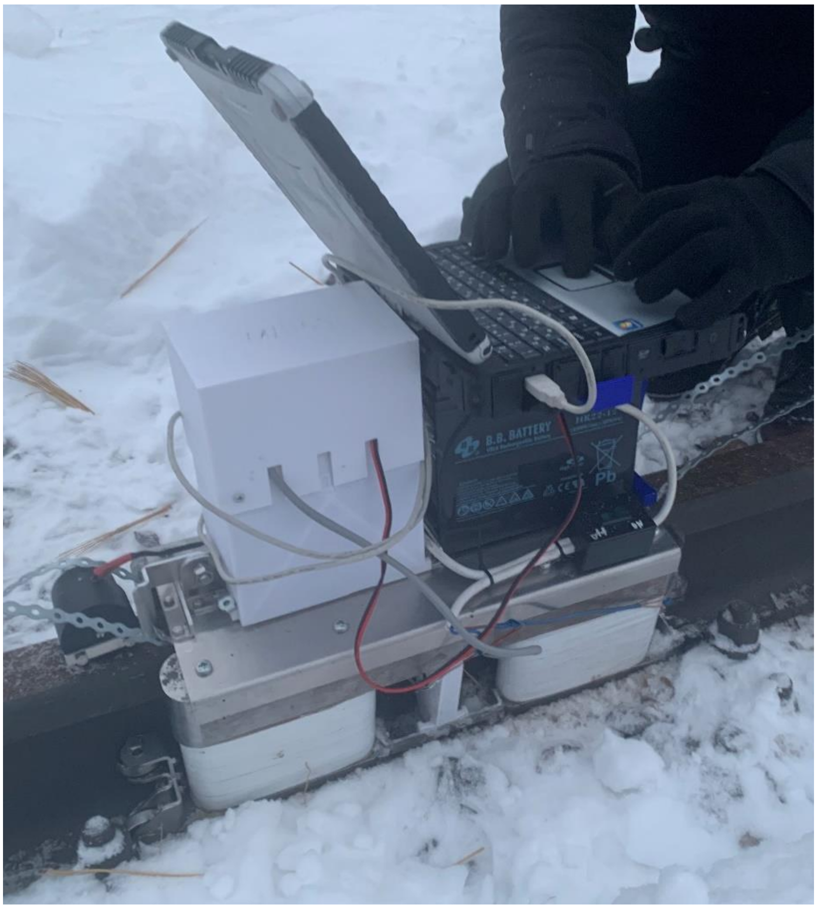

Figure 4: General view of the layout for complete inspection of the rail base by MFL.

For experimental verification, defect models were made in several rail fragments. All models of crack have been detected successfully.

4 Conclusions & Contributions

A drawing of signals of defect models is shown in Fig. 5. The parameters of the defect models were selected based on the factually geometric parameters of real defects that led to rail breaks.

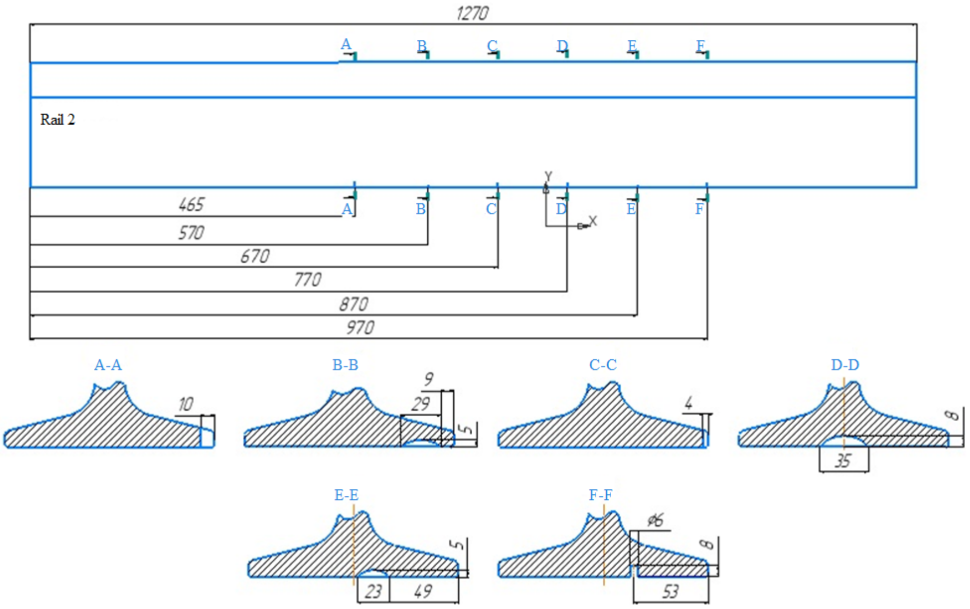

Figure 5: Drawing of six manufactured models of defects in the rail base.

Signals from all 10 testing channels (5 for each base blade) from the defect models in Fig. 5 are shown in Fig. 6. Hall sensor number 1 and 6 are located closer to the rail center. The larger the crack size and the closer it is to the corresponding Hall sensor, the greater the signal amplitude. All defect models are located in one of the blades except for the "D-D" model, which is fixed by the channels of both base blades. It is planned to further improve the visibility of signals from defects by filtering and correlation processing of signals.

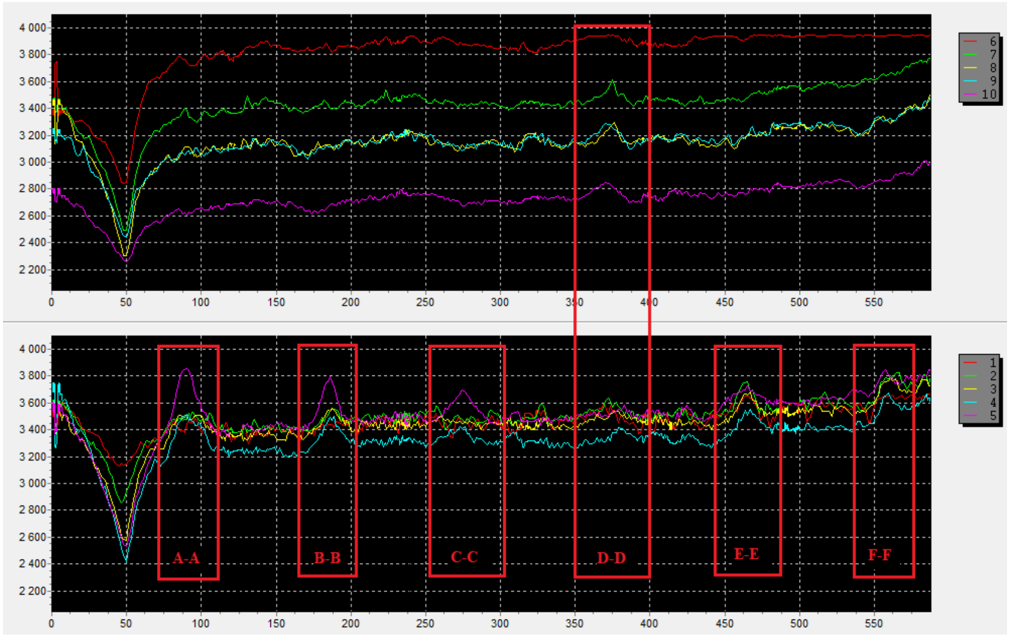

Figure 6: Signals on 10 channels from six manufactured models of defects in the rail base.

During the research, the following results were obtained:

1. Theoretically, the fundamental possibility of defects detection in rail base blades using the MFL method has been established. Based on the results of computer modeling, the design of the magnetization system and the concept of the information retrieval system are proposed.
2. A prototype of the magnetization and information retrieval systems was manufactured for continuous testing of the rail base blades in laboratory conditions. The possibility of detecting defect models in base blades has been confirmed.
3. It has been theoretically and practically established that the minimum height of a detected defect is 4 mm, provided it is located outside the rail fastening area (from 8 mm in the rail fastening).

Thus, the research carried out makes it possible to start developing a magnetic flaw detector for continuous testing of rail base blades.

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