WAYS OF MODERNIZATION OF THE LVIV RAILWAY MAGNETIC NON-DESTRUCTIVE TESTING CARRIAGE USING MAGNETIC FLUX LEAKAGE RAIL INSPECTION

Summary: Modernization ways of the information-diagnostic system on the Lviv magnetic testing carriage #442 are considered. For testing railway this carriage uses Magnetic Flux Leakage (MFL) method which has several advantages over widely used ultrasonic method. MFL is used in the UK, Iran, the US and former Soviet Union. According to the report, magnetic system of the carriage (which is highly cumbersome and energy consuming) should be completely replaced with powerful permanent magnets. One-component receiving system (based on integrated induction sensors) should be replaced with a three-component system which is based on Hall's sensors. New hardware and software parts of the diagnostic system also should be developed for collection, transmission and analysis of testing information.

Keywords: MFL, rail, defect

1. INTRODUCTION

Nowadays, magnetic flaw detection carriages (based on MFL) are widely used for speed inspection of the railway tracks. They allow us to control state of the rail head on a depth until 7-8 mm at velocities from 20 to 80 km/h during different weather conditions.

MFL is also widely used for diagnosis of the technical state of pipelines, tanks and steel ropes [1, 2].

According to [3] in countries of the former Soviet Union are exploited about 100 magnetic flaw detection carriages (wagon-defectoscopes) of various modifications and configuration.
The first production carriages appeared in the early 50s of the previous century. Although they were improved all the time, principle of their work remained unchanged. Over the rolling surface of the rail is located strong U-shaped electromagnet (distance between poles is 0.8-1 m) for magnetizing track in the longitudinal direction. Inductive sensor is placed directly above the rail head between the poles of electromagnet. Its axis of sensitivity is directed along the rails. The electromagnets and sensors (by one for each rail) are placed on the special cart (so-called "induction cart" or "induction carriage") which is moved along the rails. Inspected rail area is magnetized/demagnetized during the checking of rails.

Fig. 1 shows overall view of the magnetic flaw detection carriage #442 which is used on the Lviv Railway. Fig. 2 represents process of signals registration at the hardware-software complex "Defectoscop", which is equipped inside the carriage. Fig. 3 shows induction cart of the wagon-defectoscope of Lviv Railway.

Fig. 1. Overall view of the magnetic flaw detection carriage #442 which is used on the Lviv Railway

Fig. 2. Process of signals registration during the checking rails

Fig. 3. Magnetizing system of the wagon-defectoscope of Lviv Railway
When magnetic structure of the rail is uniform, field of scattering in the sensor location varies slightly, mainly due to the impact of steel substrates between the rails and sleepers. If there are some violations of magnetic structure homogeneity in the top of rail (e.g., crack or other type of defect) the field of scattering in place of the heterogeneity changes significantly. While the sensor passes over this heterogeneity, inside of it appears pulse of electromotive force (EMF). An approximate conclusion about the nature of heterogeneity can be done by the shape of EMF.

Fig. 4 represents the separate piece of rail inspection signal (defectogram) with the signal from defect.

Fig. 4. Defectogram (signal, obtained during the checking railway) with a signal from transverse crack in the rail head

2. PECULIARITIES OF MFL DIAGNOSTICS OF RAILWAY TRACKS

MFL stands out from the other methods of non-destructive testing of rails due to its peculiarities of decoding defectogram. Among these features are:
1. High reproducibility and repeatability of defect signals.
2. Signal patterns from the structural and non-structural elements of railway tracks are independent from weather conditions and mainly related with the state of the rails.
3. The character of signals that are generated by MFL in a range of working speeds of a wagon-defectoscope varies slightly and basically only the amplitude of the signal is affected.
4. During repeated inspections of identical track sections can be observed dynamics of changing signal from defect.
5. MFL defectogram represents signals from regular (structural) elements of railway tracks (bolt connections, rail and welding joints, sleeper substrates, crosses, etc.) and irregular (non-structural) elements (such as defects of different types) very well.

6. As a result of rails inspection is formed topogram using which it is possible to find particular railway element position.

Nowadays the main work on defectogram decoding is performed by operators of wagon-defectoscope. They use own experience to give expert evaluations about the nature of detected irregularities. Received and recorded inspection signals very often have not evident and ambiguous patterns that requires additional checking and surveys of suspicious rails directly on the place. Incorrect interpretation of the rail inspection signals sometimes brings to naught all benefits of MFL, since the results often depend on subjective factors, i.e. operator's qualification or experience.

There are numerous attempts to automate the process of defektogram decoding (for eliminating aforementioned subjective factors) [2, 3, 7, 10, 14, 17, 22] since computing power of modern personal computers allows processing of obtained defectoscopic signals by different complex algorithms. But at present this problem is waiting for its solution and requires applying new techniques and methods of digital signal processing.

During expert evaluations of signals (Fig. 4 and Fig. 5) should be done the following:
- detection of possible signals from rail damages;
- determining the nature of damages according to specific waveforms features;
- determining the location coordinates of detected defects.

Fig. 5. Elements of railway tracks and the main signal waveforms from the regular track objects

In this case during consideration pulse signals should be mentioned the next:
- width of the signals from sleeper substrates - a and b (Fig. 5);
- average signal level from the sleeper substrates is 2a (Fig. 5) which determines the sensitivity of magnetic channel;
all pulse signals, whose amplitude is 3a_0, i.e., higher than 3 times from the sleeper substrates amplitude - a_0 (Fig. 5);
- initial trend of pulse from zero line (positive pulse starts up from zero line);
- amplitude of pulses (relation to the 2a_0) (Fig.5);
- first of all into account should be taken the most positive or negative pulse deviation (from zero line);
- pulse symmetry, i.e., the ratio between the negative and positive pulse parts;
- pulse width, i.e., the distance between the start and end of the pulse (along zero line).
The final evaluation of the detected signals (like signals from defects) is given after full-scale review of suspicious areas of track.

Such approach for defectogram decoding is very slow. Based on the fact that alternative for storing inspection signals (in digital form) is absent and accumulated materials can be reviewed and analyzed later, the main focus of further development of railway flaws detection is to increase the speed of defectogram decoding (ultimately to the online decoding).

The main advantages of mobile MFL method are indispensable due to the following benefits (over the ultrasonic flaw detection method):
1. The ability to contactless rails control with a gap (to the surface of the rail) up to 8-10 mm.
2. Reliability of control in a wide range of air temperatures and on high working speeds of wagon-defectoscope;
3. Clear representation of the regular track elements on the defectogram, which provides precise detection of the defect location.
4. Proven methods of decoding inspection results by the defect types.
Although magnetic flaw detection carriages were the first high-speed rails fault detection means, they gradually, with the development of information and computational technology, have been modernized.

### 3. WAYS OF MODERNIZATION

From our point of view [3-8] such modernization should be continued in the following areas:
1. Improving of the system for magnetizing rails.
2. Enhancing of the magnetic sensor parameters.
3. Transition to the component and multi channel measurements of the magnetic fields caused by defects in the rail.
4. Application of the new modern information technologies for the detection, analysis, processing and classification signals from defects.

### References


**KIERUNKI W MODERNIZACJI LWOWSKIEGO WAGONU-DEFEKTOSKOPU MAGNETYCZNEGO PRZY ZASTOSOWANIU MAGNETO-DYNAMICZNEJ METODY DIAGNOSTYKI SZYNY TORÓW KOLEJOWYCH**

**Streszczenie:** W materiale zasymplifikowane zostały kierunki modernizacji systemu informatyczno-diagnostycznego, jaki jest stosowany w Lwowskim magnetycznym wagonie-defektoskopowym Nr 442. Dla diagnostyki kolejowej zastosowano tutaj magnetodynamiczną metodę, jaka w obecnej chwili bardzo szeroko jest wykorzystywana. Magneto-dynamiczna metoda (MDM) znana także, jako Magnetic Flux Leakage (MFL) wykorzystywana jest także w Wielkiej Brytanii, Iranie, USA a także byłych republikach Związku radzieckiego. Do przeanalizowania przez autorów referatu o wagonie z defektoskopem powinna być szczególnie zmieniona namagnesowujący system, czyli zamiast masywnego i energostratnego systemu elektronamagnesowującego należy rozpatrzyć system namagnesowujący na osnowie nowoczesnych potężnych stałych magnesów. Jednokierunkowy system służący do przyjmowania na osnowie integralno indukcyjnych sensorów powinien być zmieniony na zmienioną o trzech składowych wielokątałowego systemu pochodzących od punktowych czujników Halla. Powinna być opracowana nowa aparatura i oprogramowanie w obszarze nowej diagnostyki systemu poboru sygnałów, przekazywanych dalej do analizowania informacji defektoskopowych.

**Słowa kluczowe:** MDM, szyna kolejowa, wada