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SPATIAL-FREQUENCY DOMAIN ANALYSIS OF DEFECT SIGNALS IN RAIL MAGNETIC-DYNAMIC NON-DESTRUCTIVE TESTING

Abstract

The aim of the investigation is search of possible methods of automatic processing of defect signals from a magnetic testing carriage that realizes magnetic-dynamic non-destructive testing. The wavelet-like transform with a fragment of the recorded signal as a mother function was used to analyze the transversal crack signal. The signal pattern was resampled (rescaled) in such way that a file of signals, that were stretched or compressed relatively to the original length, was created. The described methods can be used for detection of dangerous defects in rails. The programme realization does not require large amount of calculation that enables to carry out real-time signal processing.

INTRODUCTION

Diagnostics of technical state of objects guarantees their safety exploitation and opportune detection of defects. It is especially actually in diagnostics of the objects which defects can be reasons of great material losses or human victims. Rails are among such objects. Opportune detection of the defected rail enables to take measures for preventing rail breaks under trains that improve safety and economical effectiveness of the railway transport as a whole. Now ultrasonic and magnetic defectoscopes, which supplement each other, are used for high-speed rail diagnostics. Magnetic defectoscopes, in particular, can better detect transversal cracks in the rail head, which are especially dangerous because they can lead to rail breaks under the moving train [2].

Investigations, that are carried out to create systems and algorithms for automatic detection of defects [3,5,7], can be effective only in the case when the maximally possible number of defect signal variants is used. Some data about shapes of signals caused by the longitudinal component of the magnetic field H_y of the defect are described in [1,5,6]. At the same time information about the shapes of signals from two other field orthogonal components H_x, H_z, and about characteristics of signals from multi-channel sensors is insufficient.

Obtaining many of signals by experimental way needs a considerable amount of time and costs. Because of that creating the mathematical model of a defect, that could enable calculation of all components of signal magnetic field (H_x, H_y, H_z) as a function of defect geometrical parameters and location in the rail head, and taking into account the used sensor type is a very actual problem.

1. STATEMENT OF THE PROBLEM

The aim of the investigation is search of possible methods of automatic processing of signals from a magnetic testing carriage that realizes magnetic-dynamic non-destructive testing [6].

In [4,8] investigation of possibility of use of the transversal crack signal recorded by magnetic testing carriage as a pattern were carried out. The wavelet-like transform with a fragment of the recorded signal as a mother function was used to analyze that signal. This fragment was detected at the Lviv – Sianki – Chop section on 11/06/2009 and is the signal from the transversal crack without rail surface break. The signal pattern was resampled (rescaled) in such way that a file of signals, that were stretched or compressed relatively to the original length, was created. The ratio of the new length to the original one varies from 0.5 to 2. Then correlation of the defectogram fragment with all these signals was carried out. Correlation maximums of the obtained two-dimensional file were fined as functions of the defectogram length and pattern signal scale change. It was shown that maximum take place at the scale 1:1 both for cracks and truck joints because joints and cracks have identical influence on the rail magnetic field. Also it was shown that for signals from extraneous objects, such as steel wire unriveted on a rail, maximum is at other scales.

But the real signal contains noise and other interferences caused by surface defects near the crack and it is also a unique case with its own peculiarities. So its use as a basis is not sufficiently effective. High-quality records of transversal cracks occur very rarely. So it was decided to create a model on the base of which it is possible to obtain the shape of signal at the sensor output. Two ways were considered for solving the formulated problem.

The model on the basis of fictive magnetic charges at the break interior surfaces is used in the first method [1]. The model was extended from one-dimensional to three-dimensional that enabled modeling field of the crack with arbitrary form in the space over the rail.

The second method uses creating adapted mother function on the basis of the real recorded signal by approximation with means of the Matlab Wavelet toolbox.

The shape of the field above the rail was obtained on the basis of the model. This pattern corresponds to the static distribution. The Hilbert transform which supplements the signal with imaginary component was used to the obtained signal with the aim to take into account the fact that the inductive sensor measures the field changes when the testing carriage moves (Fig.1).

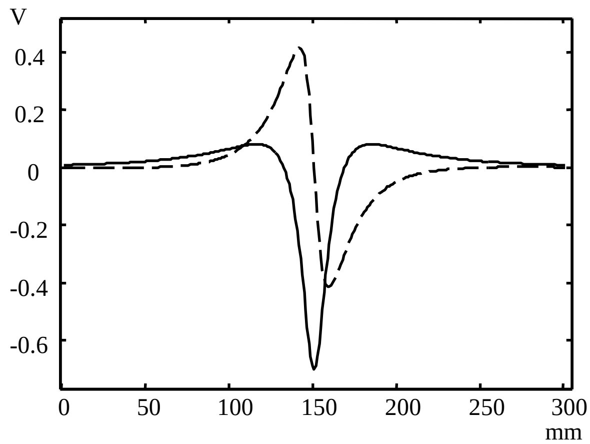


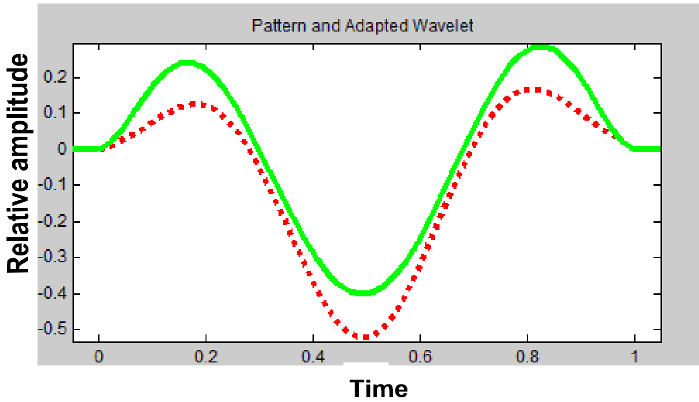
Fig.1. The modeled signal from the crack and its orthogonal complement (the dotted line).

This form was resampled to create some scales both with stretching and compressing. The patterns were normalized according to the scale changes (inversely proportional to the square root of the stretching coefficient). And then the correlation of the defectogram with every rescaled pattern was conducted. It was formulated the condition that the maximum of correlation coefficient must be at the 1:1 scale and must not exceed the level of correlation with the truck joint.

2. USE OF THE ADAPTED WAVELET

Interpolation of the considered signal (for shape smoothness) were done and adapted model of the transversal crack signal, that corresponds to the mentioned peculiarities of the considered defect (Fig.2b, the dotted line) were created to obtain the adapted wavelet.

a)



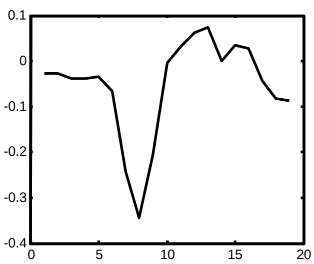
b)

Fig.2. The real signal from the rail transversal crack (*a*), the model of the signal from the considered defect (*b*, the dotted line) and its approximate value (*b*, the full line).

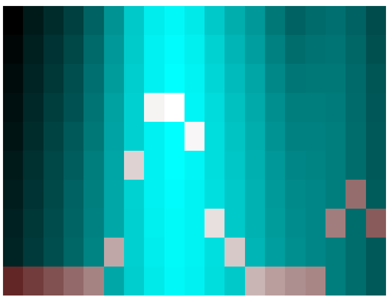
3. USE OF THE MODELED AND ADAPTED SIGNALS

With the aim to check practical use of the proposed magnetic field model the defectogram of the Lviv-Sianky-Chop railway section with the 78 km length was analyzed and there were 97 suspicious impulses detected. Majority of them corresponds to welded joints. Besides this the elaborated programme detected the transversal crack without surface break at 36 km of this section. It was detected earlier by operators of the testing carriage (Fig.3a,b).

The experiment was repeated with the adopted wavelet. At the same pickup conditions there were detected 38 impulses among which the signal from the crack was detected (Fig.3a,c). Such improvement of false detection characteristics can be explained by the fact that the adapted wavelet was created on the basis of the same crack signal.



a)



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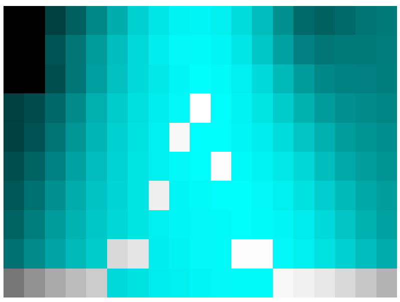

c)

Fig.3. The results of the defectogram (*a*) analysis by the modeled signal (*b*) and by the adapted wavelet (*c*)

CONCLUSION

The described method can be used for detection of dangerous defects in rails. The programme realization does not require large amount of calculation that enables to carry out real-time signal processing.

ANALIZA SYGNAŁÓW W OBSZARZE PRZESTRZENNO-CZĘSTOTLIWOŚCIOWYM W NIENISZCZĄCEJ MAGNETYCZNEJ-DYNAMICZNEJ DEFEKTOSKOPII SZYN

Streszczenie

Wciąż prowadzone są poszukiwania metod automatyzacji procesu obróbki dynamicznych sygnałów pochodzących z defektoskopu magnetycznego umieszczonego w wagonie pomiarowym. Dla analizy sygnałów od poprzecznego pęknięcia zostały wprowadzone przekształcenia, w których w roli funkcji macierzystej występuje fragment zapisanego sygnału. Wycinek sygnału poddano dyskretyzacji i przeskalowaniu tak, że otrzymano przebiegi sygnałów, które są rozciągnięte lub ściśnięte w odniesieniu do pierwotnej długości. Opisane metody mogą być używane dla wykrywania niebezpiecznych wad w szynach. Realizacja nie wymaga dużych mocy obliczeniowych i umożliwia prowadzenie i przetwarzanie sygnałów w czasie rzeczywistym.

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All illustrations are original in the report.

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