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COMPREHENSIVE ANALYSIS OF SIGNALS IN THE PROCESS OF ULTRASONIC FLAW DETECTION

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This article describes the main stages of the complex analysis of the signals received by the ultrasonic flaw detector in the monitoring process. In practice the flaw of the head of the rail was detected and the defectogram of the defective section was analyzed.

The introduction of the state of the art equipment, designed for a non-destructive control of rails, and the complex analysis of signals, formed by sensors included in a scanning pattern require timely and advanced training of the personnel involved in control. Correct and qualitative interpretation of the information received from the rail and processed by an electronic flaw detector unit increases monitoring efficiency and allows determining the parameters and the position of the flaw with respect to the cross-section of the rail with a high degree of accuracy.

To date, non-destructive inspection system is a multi-stage structure, the main feature of which is a variety of measuring devices, instruments and apparatus used according to the control objectives. The list of non-destructive testing methods used is quite wide. These include:

-electrical;
-magnetic;
-acoustic;
-visual;
-thermal;
-etc.

One of the most difficult for automatization, but effective methods is an echo-method of ultrasonic flaw detection. Great difficulty in the automatization process for this method is the need for incorporation of a number of factors (the cutoff of false actuations, the selection of a useful signal on their background; inability to accurately determine the cause of various emergency situations that arise during the process of ultrasonic testing, etc.), that can not only complicate the receiving signals from an object under control, but also significantly distort the results of the control, which in its turn can lead to the skipping of dangerous flaws. Thus, the question of further improving of already used control methods, implemented on the basis of portable flaw detectors, study of features of signals recording and methods of their comparison for presenting the overall state of section defectiveness as well as upgrading the skills of the staff carrying out control come to the fore.

The analysis of suspect cross sections is impossible without the knowledge of the monitoring circuit of the device. In general, a group of piezoelectric transducers (PET), implemented on the basis of a specific device (flaw detector), that provide the most efficient detection of flaws in accordance with the goals and objectives can be referred to as a monitoring circuit (sonic test).

Today, there is a wide variety of circuits used to control the rail head. Each of them has its advantages and disadvantages. Circuits, that use more than one method, demonstrate the highest efficiency (for example, a circuit named "ROMB" which realizes both EHO- and mirror- methods, each of which is active at specific time points so that they don't work simultaneously). These circuits allow detecting flaws with different types of reflective surface along with the detection of differently directed flaws.

In flaw detection devices (RDM-22) used in the experiment for the control of the whole railhead there are the following PETs:

Channel #1 – the channel is realized by using pitch-and-catch PET with the acceptance angle of an ultrasonic wave in the controlled object of 0º. In practice, the channel shows high efficiency in detecting various types of horizontal bundles and cracks. The inspection area depending on a rail type is between 0 and 190 mm.

Channel #2 – PET with the acceptance angle of 70º along the longitudinal rail axis in the direction of ultrasonic flaw detector movement (channel 7 - in the opposite direction).The practical utility of this channel is in its ability to detect cracks developing under the extended horizontal bundles which are impossible to detect by PET with other acceptance angles due to the peculiarities of the reflection of ultrasonic waves from different types of reflective surfaces. It surely detects cracks developing at an angle of 18-20˚ from the normal. The inspection area depending on the type of a rail is between 3 and 45 mm.

The main drawback of this transducer is the greatest dependence of the size, measured from the defective cross-section, on the temperature among all transducers used in RDM-22. So, in the range of temperatures from minus 40ºC to plus 50ºC a nominal acceptance angle of this transducer changes from 60º to 74º. Changing the acceptance angle to 74º leads to the formation of a surface wave which is sensitive to the smallest surface flaws.

Channel # 3;6;8 – PETs with the acceptance angle of 55º, unfolded at 34º relative to the longitudinal rail axis and directed to the working face of the rail against the direction of the ultrasonic flaw detector, to the non-working face of the rail against the direction of the ultrasonic flaw detector, to the working face of the rail in the direction of the movement of the ultrasonic flaw detector respectively. The turn of inserts by 34˚ allows controlling the whole volume of the rail head. The only drawback of those PETs is high sensitivity to surface flaws. In some cases, even with small and shallow bundles, due to multiple reflections of ultrasonic waves (RAS) between the bundle and the surface, the operator may give a false conclusion about a flaw in the rail. The inspection area of this channel is 144 mm.

PETs with the acceptance angle of 55º, unfolded at 34º relative to longitudinal rail axis, represent the circuit named "SNAKE". This circuit is the most complex one in terms of both the process of reflection of ultrasound beams from different faces of the rail head and understanding of the principle of signals display on B-scan. This is due to the fact that for the detection of flaws in the head of the rail one-, two- and three-fold reflected from its edges beams are mainly used.

Figure 1 illustrates the path of the ultrasonic beam propagation in the rail head using the circuit "snake" and a fragment of the defectogram where there are signals of a standard reflector (for example, the end of the rail).

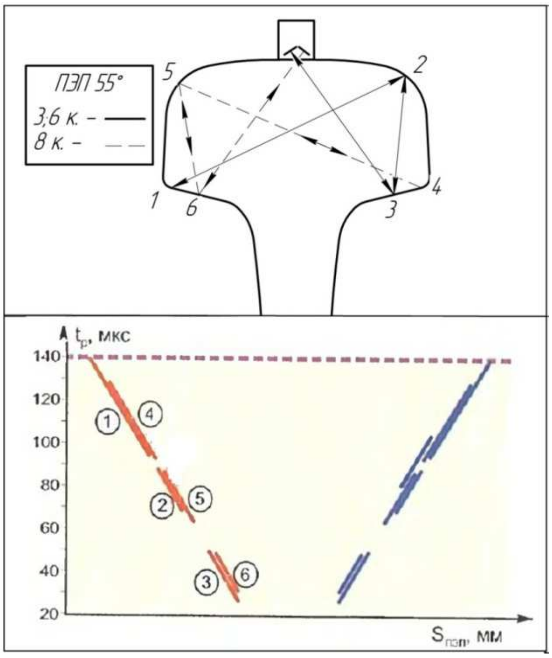

Fig. 1. The path of ultrasonic beam propagation using "SNAKE" circuit
and fragment of defectogram with a standard reflector

When using such a circuit, the whole inspection area can be divided into: near (3; 6), medium (2; 5) and far (1; 4) areas. Due to this, by analyzing the signals received by the sensors, the location of the flaw with respect to the cross-section of the rail can be highly likely defined. Thus, if the signals are identified in the near and middle areas of channels 3 and 6 we can talk about the flaw located in the gauge corner. If these channels recorded signals in the far area then it is a flaw located in the non-working face of the rail. These statements are valid for channel 8 adjusted to its turn with respect to the longitudinal axis of the rail.

In order to improve non-destructive control methods used in the railroad industry, and to develop skills of complex signal analysis of operators involved in its implementation, selective inspection of defective sections was carried out. Control break was carried out to confirm the presence of the rail head flaw.

The inspection of the rail specimen with the size of 110 mm (the minimum length of a specimen for destructive tests) was carried out by an ultrasonic flaw detector UDS2-RDM-22 with manual PETs with acceptance angles of 0º, 55º and 70º realized on a compatible circuit. The inclusion of transducers based on a compatible circuit using echo method is aimed at the detection of flaws with a diffuse surface, i.e. those flaws, the average grain size of which is comparable or larger than the wavelength. It should be noted that in practice such flaws are expanding flaws, whose planes, in the process of the growth of a flaw, has not acquired a mirror-like surface. If the surface is mirror-like, the use of echo method is impractical as an ultrasonic wave is totally reflected from a flaw encountering on its way. In this case it is expedient to use a mirror method, for example K-method.

Figure 2 illustrates the fragment of defectogram of the specimen.

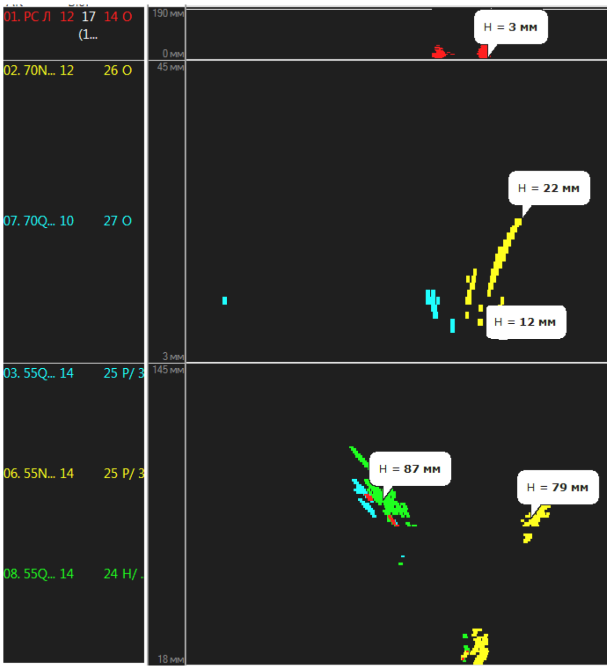

Fig. 2. The fragment of the defectogram of a specimen

The first priority during defectograms analysis is to identify valid signals against noisy ones. The implementation of this stage of the analysis requires the following:

– The mapping of defectograms of previous runs of ultrasonic flaw detectors with registrars with defectograms of the final run. The purpose of this phase is to identify individual signals within the section of interest (defective), which are present in all defectograms.

– By using the function of multithreshold registration and displaying signals on a defectogram, in the case of large amounts of these signals it is necessary to cut off noise and interference. The main feature of noises is that they represent a random process, and often of the same level. So, the threshold shift of a display allows you to get rid of noise and leave only useful signals on the flaw detector display.

As a result of this phase we identified the main signals which position is shown in Figure 2.

The second stage of the complex analysis is to determine the parameters of the recorded signals. So, from the fragment of the defectogram (Figure 2) it follows that:

– there is a damage 65 mm long on the tread surface;

– the damage on the tread surface is 2 to 3 mm deep, which is registered by channel #1 (the angle of entering of ultrasonic vibrations into the rail is 0º);

– channels # 3,6 and 8 (55º) has recorded signals in the depth range of 80 to 90 mm;

– the signal, recorded in the near zone of channel #6 can't be regarded as a clear signal from the flaw, as its presence may be due to the presence of surface damage;

– channel #2 (70º) registered a signal with length from 12 to 22 mm;

– the signal in channel #7 (70º) is a stray and it has been expelled from the signals requiring analysis at the first stage.

The third stage of the complex analysis is to assess the defective section and to make a complete picture of its defectiveness on the basis of the obtained data.

Based on the functionality of the 2nd and 7th channels of ultrasonic flaw detector RDM-22 (70º channels designed to monitor the central part of a railhead), we can conclude that there is a reflector in the central part of a railhead. The signal recorded by channel #2 at a depth of 78 mm indicates the presence of a flaw in the central part of the rail head. Signals located in the 3rd and 6th channels at a depth of 85 mm indicate a flaw, dislocated in the gauge corner.

Having analyzed the defective section, it was concluded that the flaw is located in the central part of the rail head with the development in the gauge corner.

As shown in Figure 3, as a result of the destructive test the complex analysis data have been confirmed.

Fig. 3. Result of the destructive test

So, we can safely say that as a result of complex analysis data confirmed by the destructive test the flaw of the rail head was identified and is described as accurately as possible.

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