Improving the Quality of NDT in the Rail Sector through the Introduction of Advanced Technologies and NDT Means

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Abstract. This presentation gives a survey of topical NDT issues for railway sector and handles a day problems of railroad facilities. Also, there will be presented NDT equipment and latest techniques that are used for testing of railroad bed and rail transport.

One of the key issues of railway traffic safety is to conduct timely diagnostics of the railway. Accordingly, the railway testing can be divided into the following tasks: testing of the solid line rail, testing switches elements and station tracks, testing of welded rail joints. Solving these problems will be considered on the example of NDT equipment applications produced by Promrylad LLC: double rail flaw detector UDS2-73, single rail flaw detector UDS2-77, the ultrasonic flaw detector UD3-71 and non-destructive testing complex “OKO-3” that provides ultrasonic, eddy-current and electromagnetic-acoustic in-line inspection of manufactured rails.

Also, equally important is railway transport parts testing. Most responsible units are carriage’s and locomotive’s wheelsets, as well as bogie frames. For 15 years, Promrylad LLC specializes in the development of techniques and specialized NDT equipment for railway transport wheelsets testing.

This paper will scope features of ultrasonic testing of axles and wheels of wheelsets with the dismantling and without removing the axle-box unit, automated ultrasonic and eddy current speed testing of wheelsets on the carriage-repair enterprises and the depot, and also eddy current testing of the lateral bogie frames.

Introduction

For over 15 years of experience, the scientific industrial company Promrylad operates in the field of non-destructive testing in various industries. During these years, the engineering team of Promrylad LLC has designed and manufactured a large number of instruments and equipment enabling effectively solve the problem of quality control.

The main body

The basic NDT methods implemented in instruments are ultrasonic and eddy current methods the complex application of which allows evaluating the testing object actual state with the high integrity evaluation and taking the right decision concerning the repair and the object service life extension.

Special attention in developments is paid to the solution of non-destructive testing task for the quality of the railway industry. Initially, the problem of railway industry objects state estimation can be divided into the following two parts: the first is the testing of the railway line state, and the second is the direct testing of the rolling stock parts and components.

Accordingly, the railway testing can be conditionally divided into the following tasks: testing of the solid line rail, testing of switch’es and station tracks, testing of welded rail joints. Solving these problems will be considered on the example of NDT equipment applications produced by Promrylad company: double-thread rail flaw detector UDS2-73, single rail flaw detector UDS2-77 and ultrasonic flaw detector UD3-71. At operated rail track quality control it is primarily aimed to detect the generating operational defects.
UDS2-73 rail flaw detector is intended for defects detection in both rails along the running surface and rails cross-section, except the base wings, by means of flaw detection trolley. The following rail types are subjected to the testing: R 49.430, R49.05, R60 and UIC 60.

Since the rail flaw detectors introduction, their development mainly was to increase the reliability of defect detection by the improving of sounding scheme. Therefore the sounding scheme is the most important criteria for the flaw detector capabilities assessment, as the whole electronic part of the multi-channel instrument is developed for its implementation.

By the implemented channels and testing methods number the UDS2-73 flaw detector is currently holds the leading position among analogues, such testing scheme does not even have high-speed testing means installed on locomotives. It includes all the best "conventional" methods of rail testing, as well as innovative testing schemes.

![Fig. 1 - UDS2-73 at operation](image)

Testing schemes, implemented in UDS2-73 flaw detector:

1. “Conventional” testing methods (see Fig. 2):
   - echo and echo images technique of the entire rail section testing in the web projection by the straight double crystal probe for separations and diffuse nature defects detection (bulk type defects);
   - echo technique of the entire section in the web projection testing by two angle beam probes with the probe angle of 45 degr.;
   - echo technique of rails head testing by angle beam probes with the probe angle of 58 deg. and deployed along the longitudinal axis at an angle of 34 deg., however 4 probes used in UDS2-73 flaw detector allow to carry out the testing of working and non-working rail head edge, where the testing area allows testing by straight, single and double reflected beam, significantly improving the testing reliability.

![Fig. 2 – Traditional rail`s sounding schemes](image)

2. Pulse echo techniques that are implemented in UDS2-73 (see Fig. 3).
   - The 1st pulse echo technique is intended for the rail`s head central part testing and allows to detect transverse cracks under slips and surface horizontal separations at a distance of up to 100 mm to the probe.
- The 2nd pulse echo technique is intended for the head side edges testing via 4 channels;
- The 3rd pulse echo technique is implemented only in UDS2-73 and is unique and used for the horizontal separations detection in the head side edges that are not in the web projection.

Pulse echo techniques allow detecting developed transverse defects with the reflecting surface and allow carrying out a reliable testing of so-called "noisy" rails.

Thus, sounding scheme consists of 20 data channels, and it is in two times more than in similar devices and provides detection of internal defects (transverse cracks, longitudinal cracks, cracks in bolt holes, defects in the welded joint) during their development and already developed, in accordance with the defects classifier TES 02 Rail Defect Standard. One-of-a-kind special – purpose composite probes were produced for such complex testing scheme implementation, and the scheme is implemented using only four resonators for one rail thread. Increase of the flaw detector channels number significantly increases an information load on the operator and therefore requires the upgrading of his qualification level. New modes of information presentation, additional modes of operation and other service functions were implemented to simplify the operator work. Besides the standard "A-scan" presentation, the flaw detector has the "B-Scan" mode. Moreover, the "B-Scan" is simultaneously displayed in real time via 2, 4 or 8 channels;
- Possibility to save the testing results for all channels;
- Possibility to create separate reports;
- Possibility of position coordinates affixment and correction;
- The rail ensounding and saving of testing results is performed with a step of 1mm.

For welds manual ultrasonic testing for the presence of defects an ultrasonic flaw detector UD3-71 was used by our company in a set with special-purpose scanning device (see Fig. 4). The flaw detector was supplemented with specialty application-dependent software, due to which operators got the ability to a quick and qualified testing of rails welded joints.
The following areas are tested by means of this equipment:
- Rail head from the roll surface;
- Rail head from the side edge;
- Rail web and base from the roll surface;
- Rail web from the side edge;
- Rail base wings from the base wing surface.

Figure 5 - Appearance of the UD3-71 flaw detector software.

To improve the rail in-service testing quality the complex of rails non-destructive testing OKO-3 was developed by the Customer request. OKO-3 complex can be supplied in the form of a complex consisting of 3 modules: eddy current, ultrasonic and EMA, or by separate modules depending on the requirements on implementations of non-destructive testing at the enterprise. The Complex ensures meeting requirements of rails testing according to GOST P 51685-20XX, TU 0921-231-01124323-2009, EN13674:1-2011, “Manual for ultrasonic testing of rails and welds” Research Designs & Standards Organisation Lucknow-22601.

This Complex implements the mechanized in-service testing of rails with possibility to transfer the data from each module to the workstation via Wi-Fi, and store the database and to protocol the testing results with the affixment to the internal recording system of the production line.

The Complex allows carrying out ultrasonic testing of the rolling surface, rail head side edges and the web and base of the rail. To different modules are used for the testing. Also, additionally by the Customer`s request ensures the testing from the rail base wings (Fig.6).

Fig.6- OKO-3 complex ultrasonic modules testing schemes.

To ensure the rail surface quality control according to EN13674:1-2011 the eddy current module provides the testing of the rolling surface and rail head side surfaces (including the radial transition), ensuring the microcrack detection of longitudinal and transverse orientation. This testing prevents the
further development of dangerous defects during rails operation. As well, this module is used for the rail base surface testing (Fig. 7).

Fig.7 - OKO-3 complex eddy current module testing schemes.

During carrying out the EMA testing the “dry” ultrasonic testing of the rail head central part, base and web of the rail as well as the rail head side edge is implemented on the basis of the EMA module due to the through ensounding. This technique allows examining the metal properties during the rails output from the production (Fig. 8).

Fig.8 – OKO-3 complex EMA module testing schemes.

Also, it is equally important to test railway transport parts and units. The most critical units are car wheel sets and locomotives, as well as trolley frames.

Over 15 years Promprylad company was specialized in the development of techniques and special-purpose equipment for the railway transport wheelsets testing that include the following critical elements: wheelset axle, solid-rolled wheel or wheel center, racers of axlebox unit, roller bearings of axlebox units.

Figure 9 - The appearance of UD4-76 flaw detector and specialty application-depended software.
An ultrasonic flaw detector UD4-76 was adapted to carry out the testing of car wheelset parts (see Fig. 9), and in a set with special-purpose scanning devices and software provides the testing of wheelset axle, solid-rolled wheel, racers of axlebox unit for the presence of operational defects.

This type of testing is carried out with the full dismantling of the wheel set when providing an access from the axle surface butt ends, removing the axlebox units.

If required to carry out the fast and efficient testing without axlebox unit disassembling Promplylad LLC has created a technique and a set of mechanized equipment on the basis of ultrasonic multi-channel "UD4-94 DSO-01" flaw detector. An ultrasonic testing according to this technical instruction is carried out by the pulse-echo technique using seven sounding schemes from the wheel rim and by pulse-echo and echo-images techniques using 5 sounding schemes from the wheel seat axle area. Two scanning devices are included to the testing set: USK-01 and USO-01 (see Fig. 10).

This type of testing provides the following benefits:
- High productivity due to the "UD4-94 DSO-01" flaw detector multi-channeling;
- The simultaneous presentation of testing results on all channels on the flaw detector screen;
- Reduce of the human factor influence through the testing mechanization.

An important criterion for the car wheelsets safe operation is the integrity of roller bearings of axlebox units. In practice it is established that even the smallest defects on the rollers surface with the crack edge opening size of 2 µm and a depth of 0.05 mm, lead to the roller destruction and as a result to accidents. In order to ensure qualitative and high-performance testing at production of automated flaw detector the eddy current was used that allows detecting small surface defects.

Special-purpose eddy current flaw detector VD-131 ND (see Figure 11) is intended to detect surface defects in steel cylindrical rollers with a diameter of ø 32 mm and a length of 52 mm from the rolling contact bearings used axlebox units of freight and passenger rail cars, as well as for the testing of other rotation figures such as: ball and piston pins, sleeves, cylinders, piston rods, cartridge casing, etc.

The main VD-131 ND advantages are:
- testing of rollers surfaces butt ends;
- detection of defects with the crack edges opening from 2 µm;
✓ presence of demagnetizing device;
✓ productivity of testing is at least of 120 rolls per hour (in a full mode cycle);
✓ automatic sorting of serviceable defective rollers by take-up spool;
✓ connection to PC;
✓ small dimensions and weight.

For many railway enterprises and depots to carry out the manual testing of car wheelsets parts is unacceptable due to low productivity and the need for the full testing process registration. For such enterprises needs an automated system of non-destructive testing SNK KP-8 was manufactured on the basis of Promprylad LLC (see Fig. 12), that fully meets the requirements of international standards and provides 100% testing of wheelset without dismantling of wheel centres from the axle using ultrasonic, eddy current and EMA techniques. The system provides the testing of up to 12 wheelsets per hour considering the time of wheel sets loading and uploading.

The system provides the testing by means of ultrasonic channels for the:
- solid – rolled wheel testing-21;
- wheel set axle testing -13
- testing of the solid-rolled wheel roll surface (using EMAP) – 4.

and eddy current channels for the:
- wheel rim side surfaces testing -16;
- roll surface testing - 8;
- fillet transition testing from the disk to the rim- 20;
- web axle testing – 8.

![Fig. 12 – Appearance of SNK KP 8.3 system](image)

Also, NDT means are developed on the basis of our company and that allows carrying out the testing for the bogies parts integrity. Among them an eddy current VD3-81 flaw detector can be distinguished (see Fig. 13). VD3-81 eddy current flaw detector with a set of special-purpose eddy current probes is intended for surface cracks detection in cars items and parts (trolley, automatic coupler and etc.).

If consider more in detail, than it can be noted the flaw detector application for the trolley side rim and bolster testing for the presence of surface defects. When testing the rough surface parts (casting) the eddy current method is more informative and demonstrative than the magnetic particle and penetrant methods.

![Fig. 13 – Appearance of VD3-81 flaw detector](image)
One of the most promising directions of our company development is the engineering of the acoustic emission system. Due to the critical need of trolley rim bars condition monitoring, the testing technique was developed by the Promprylad LLC experts on the basis of GALS 1 system and is intended to carry out the non-destructive testing and evaluation of critical objects technical state without their removal from operation; for detection, position determination, hazard evaluation and monitoring of the sources of acoustic emission signals (defects) of testing objects – tanks and pressurized vessels, side rims and bogies bolsters, lifting devices and other engineering and industrial structures and parts.

AE diagnostics using GALS-1 allows testing of the whole object integrally or even of several objects. At the same time, it enables detection of the most dangerous defects (disposed to development) and their classification by the risk level. AE testing by means of GALS-1 does not require preparation of the testing object surface (except small areas where the probes will be placed); makes it possible to perform the testing of objects which are partially inaccessible (underground parts of pipelines, tanks, etc.).

Conclusions
Necessary to consider that the timely implementation of non-destructive testing (ultrasonic, eddy current, magnetic particle testing) and repair of car items (wheel pairs, bogies, automatic couplings, etc.) will improve the moving traffic safety, extension of service life of cars parts and mechanisms and reduce the cost of buying of cars parts.

References

