# THE APPLICATION OF EDDY CURRENT SECTION IN AUTOMATED SYSTEM FOR COMBINED RAILWAY ROLLING STOCK AXLES INSPECTION

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## Introduction

Two nondestructive methods usually are needed for flaw detection in railway rolling stock axles during production: one for subsurface flaw detection and second for surface breaking flaws detection. For first task the ultrasonic method satisfy all sensitivity and resolution without any competition. For second task the magnetic particle methods usually is applied. But this method has many disadvantages such as hard inspection operation automatization and low productivity. Due these features magnetic particle method is the main reason of limitation of automated system productivity in common. For new inspection system development the main task is the considerable increasing of inspection productivity for synchronizing of inspection procedures with production line productivity. Eddy current (EC) method for surface flaw detection is more perspective for automated inspection systems creation. The possibility to replace the magnetic particle method by application of new EC probes with multi-differential coil connection was determined in our earlier investigation [1].

In view of the aforesaid the task of creating the new automated system with EC method as a partner of ultrasonic method was undertaken.

### Short characteristic of tested object

The liable to inspection RU1 and RU1Sh type railway rolling stock axles are produced from axles steel (GOST 30272-96) according the regulatory document [2]. The common length of RU1 type axle is 2294 mm and RU1Sh type axle - 2216 mm. Diameters of bearing, front hub part, hub and middle axle part are 130, 165, 194 and 172 mm correspondingly. The lengths of axle part along bearing, front hub part and hub are 190 (176 for RU1), 76 and 250 mm correspondingly (fig. 1).

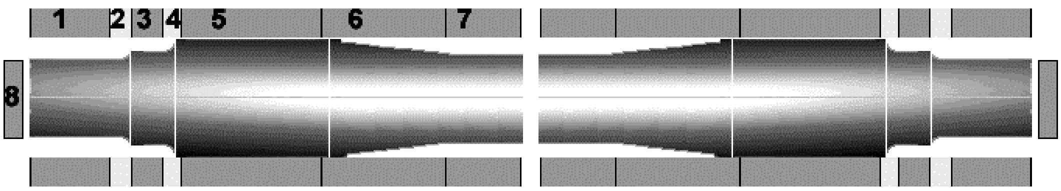



Fig. 1. The railway rolling stock axle form and discrimination of tested surface.

Taking into account the complex axle form, large tested surface and desired high productivity the axle surface is separated on 16 independent zones (marked on fig. 1) that are tested simultaneously in multichannel mode. On fig.1 only half of axle is numbered. For every 1, 3, 5, 6 and 8 zones two EC probes are used, for 7 zone - four EC probes. The round corner 2 and 4 zones have small curvature and must be tested in independent mode (Fig. 1).

That is why these zones are tested by only with one small diameter EC probes. Thus for axle inspection 32 EC probes and 32 channels it is needed to be used.

### The EC probes development and investigation

The preliminary investigations show that the undertaken task can be solved by application of Leotest MDF type multidifferential EC probes. The high sensitivity of these probes during inspection with large clearance was shown in our previous papers [3]. The comparative evaluations in different organizations show that these probes have a number of advantages particularly important for creation of automated inspection systems:

- High sensitivity to different type flaws during inspection with large clearance;
- High level of lift-off suppression and good balance in unflawed zone;
- High spatial resolution in combination with wide inspection zone;
- The possibility to estimate the flaw parameters.

Due these features Leotest MDF type EC probes were successfully used by leading Ukrainian and German firms for creation of automated inspection systems for most difficult task solving [4-5].

Two types of special EC probes with needed sensitivity and spatial resolution were developed: the Leotest MDF 0701 type EC probe with 7 mm diameter for cylindrical and face surfaces inspection and the Leotest MDF 0601 type EC probe with 6 mm diameter for small radius fillet surfaces inspection. The parameters of these probes permit to provide adequate to magnetic particle method sensitivity level by class B in accordance with regulatory document [2]. The sensitivity was confirmed by application of reference standards made from axle steel. The reference standard with artificial 15 mm length longitudinal and 50 mm length transverse like crack flaws was fabricated. The depth and width of artificial flaws were 0,5 and 0,02 mm correspondently. Such flaws define the sensitivity demands for axle's inspection. Such reference standard type is registered in industry list of inspection means by № MT 039.2001 and is allowed for application in railway transport. The important features of developed EC probes (especially for creation of automated inspection system) are good lift-off suppression and high sensitivity with 0,2-0,4 mm clearance between tested surface and probes.

The Leotest MDF 0701 and MDF 0601 type EC probes have enough sensitivity to threshold flaw on operational frequencies from 100 to 400 kHz. The frequency dependence of EC probes signal response in relative units is presented on fig. 1. The signal maximum is observed on operational frequency 300 kHz.

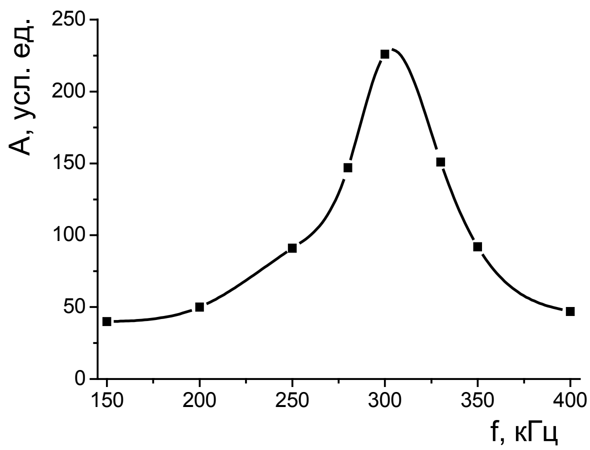
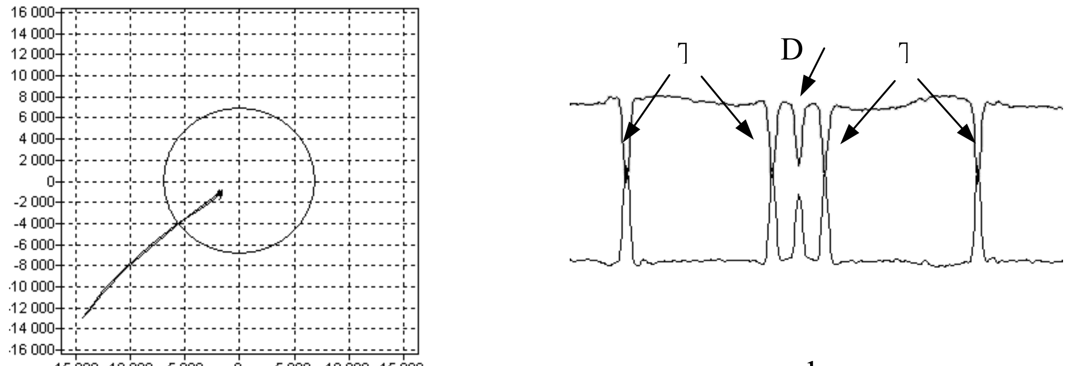



Fig. 2. The frequency dependence of EC probes signal response

The signal responses in impedance plane (a) and real and imaginary signal components in time-base deflection mode (b) obtained from longitudinal flaw in reference standard is presented on fig. 3. Flaw signal response have quasiabsolute behavior. Flaw signal response on time-base deflection mode defectogram (b) is situated in center (D on fig. 3). There are four technological signals (T on fig. 3) on time-base deflection mode defectogram obtained from the reference standard edges. Reference standard axle consists of two inserting pieces with flaw mounted on special axle. On the impedance plane defectogram (fig. 3,a) technological signals are not visible because are intercepted by cursor section choice.




a b

Fig. 3. Flaw signal responses obtained with MDF 0701 type EC probe on optimal operational frequency.

Presented results show the reliable detection of threshold flaw (class B) in reference standard with very high signal to noise ratio. When real axles are detected the noise is higher but the signal to ratio can be improved by additional signal processing. For this purpose the differential summation of signal samplings was proposed to be applied. To demonstrate the differential signal processing effectiveness the noise in impedance plane (a) and on time-base deflection mode defectogram (b) before (fig. 4) and after (fig. 5) the signal processing are presented. The noise signals were obtained with MDF 0701 type EC probe during the real axle surface scanning. The sensitivity during these scanning was adjusted the same as on fig. 3 with flaw signal response.

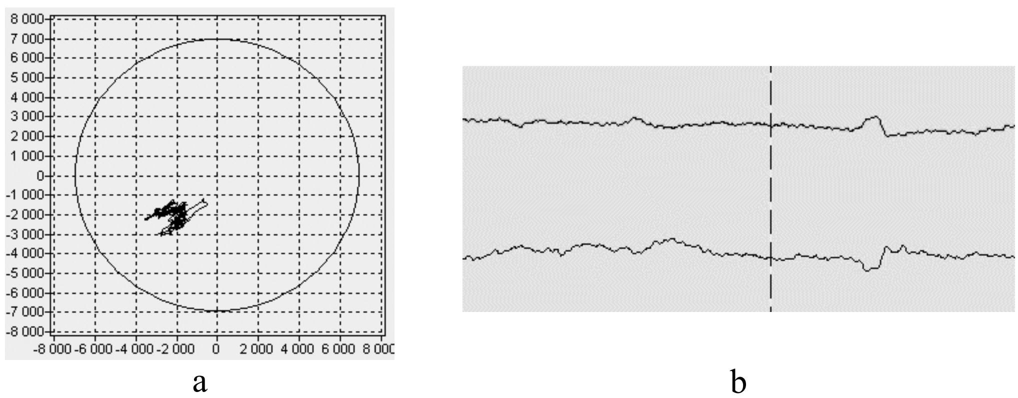



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Fig. 4. Unprocessed noise obtained during axle surface unflawed zone scanning.

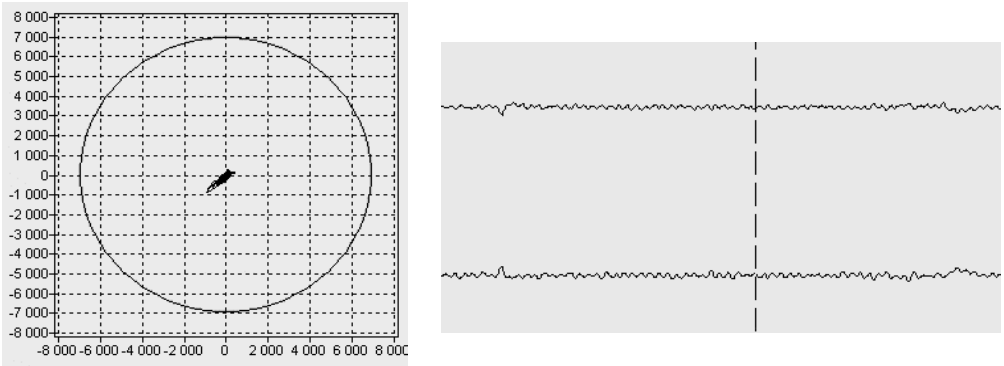


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Fig. 5. Noise obtained during axle surface unflawed zone scanning after differential signal processing.

The comparison of noise level on figure 4 and 5 confirm the differential signal processing effectiveness. It is possible to notice that observed noise can’t reduce the inspection detectability due high signal to noise ratio (more 12 dB). Though for additional noise suppression it was proposed to use the differential signal processing that demonstrate high effectiveness and implementation simplicity during rough surface inspection [6].

Flaw signal response after differential signal processing reverses the sign during the flaw zone scanning (fig. 6). The digital filtration by differential signal processing permit to eliminate the low frequency signal trend caused by surface irregularities and material magnetic characteristics changes.

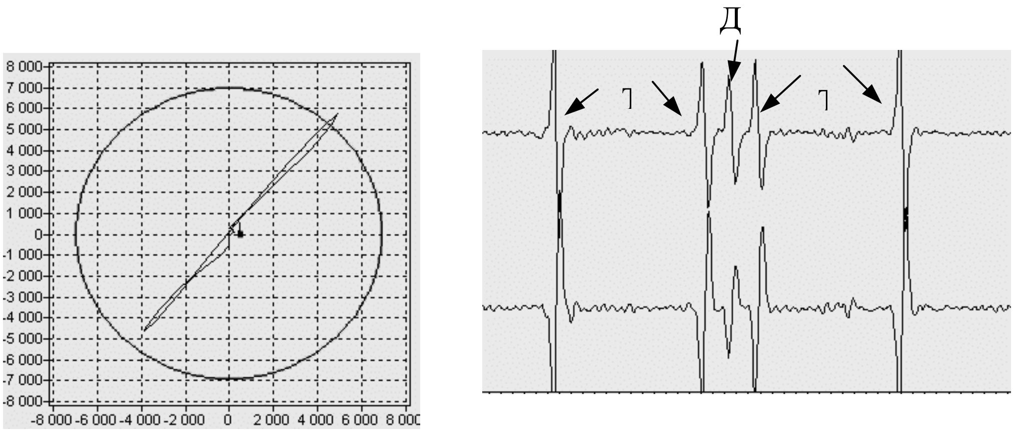


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Fig. 6. Flaw signal responses after differential signal processing.

Presented investigations allow improving the technology of EC railway rolling stock axle inspection. The achieved sensitivity level permits to replace magnetic particle method.

## Eddy current section of automated system for axles inspection

Obtained results were used for the development of the EC section for automated system «SANK-3» intended for combined axle inspection (fig. 7).

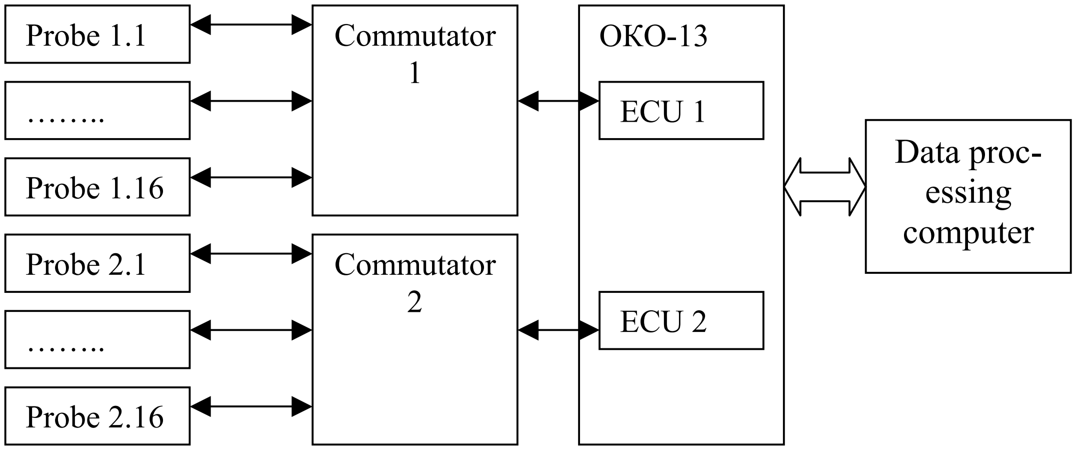


Fig. 7. Functional scheme of automated system «SANK-3» for combined axle inspection.

The developed eddy current section provides computerized 32-channel inspection with 32 EC probes simultaneously. All EC probe are separated to 2 groups (from probes 1.1 to 1.16 and from probe 2.1 to 2.16). Each group of 16 probes is operated by one commutator which carries out all probe interrogation by-turn. All probes are mounted in holder with possibility to scan the axle surface with 0,2 mm separation (fig. 8).

Fig. 8. Automated system «SANK-3» for combined axle inspection.

Electronic module for preliminary signal processing OKO-13 consists of 2 EC units ECU1 and ECU2 (fig. 8). Each unit operates with one commutator. The electronic module OKO-13 is developed on the base of transformed universal multichannel EC device OKO-1 (without display and control elements). Module OKO-13 and EC units are mounted in common case. Module OKO-13 is equipped with network unit for connection with PC. The driving sinusoidal signal and code relevant with current EC unit arrive from ECU to commutator. When commutator activate the channel in accordance with incoming code the EC signal arrive from selected EC probes to selected EC unit for preliminary processing and accumulation. After the inspection finishing these data are transferred to central computer for derived processing and storage. Pieces with threshold flaws are mounted as a part of special tuning axle (fig. 9) for availability verification and automated system calibration.

Fig. 9. Reference standards mounted on the tuning axle.

Operator can analyze the inspection results with special software. The external interface of the automated system “SANK-3”is presented on fig. 10.

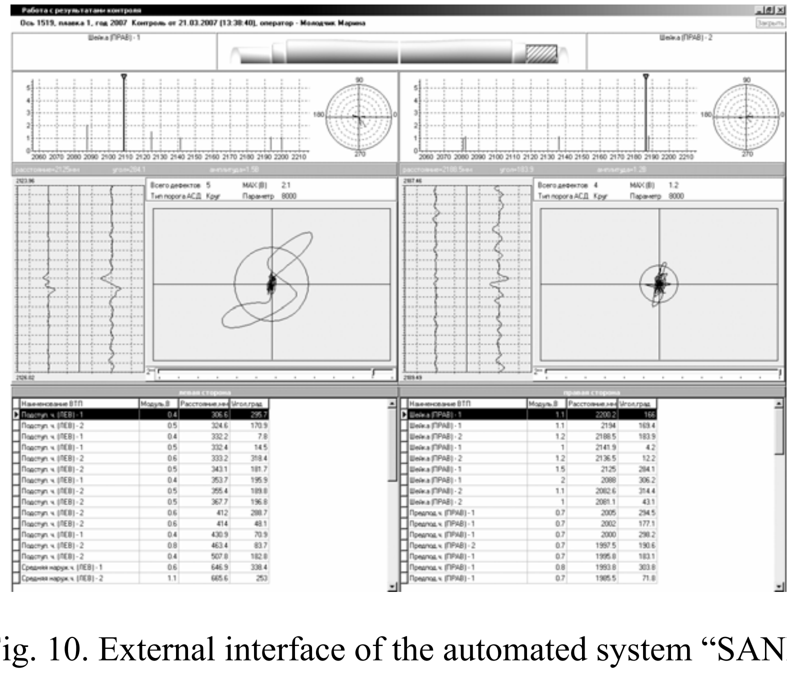

Fig. 10. External interface of the automated system “SANK-3”.

Automated system software provides each channel tuning. For example the next parameters can be installed: operational frequency, the amplitude of EC probe driving voltage, sensitivity, and threshold or filtration mode. All parameters settings are reserved in database.

## Conclusion

1. Eddy current method with high resolution EC probes application have enough sensitivity to replace the magnetic particle method. Eddy current method optimally complements the ultrasonic method during the automated axle inspection.

2. For better noise suppression and simplifying the EC signal interpretation the additional filtering signal processing by differential summation of signal samplings is effective.

3. The developed eddy current section provides computerized 32-channel inspection with 32 EC probes simultaneously.

4. New automated system with EC section provides the considerable increasing of inspection productivity and permit to synchronize the productivity of inspection procedures with production line productivity.

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