DEVELOPMENT OF INSTRUMENTS FOR NDT OF RAIL-TRACKS WITH USE OF CONTACTLESS ELECTROMAGNETIC ACOUSTIC EMISSION TRANSDUCERS (EMATs)

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Abstract：

Currently for examination of railway metals used are ultrasonic and magnetic instruments. It necessary to underline that magnetic testing method provides detection of defects located in subsurface area of railhead (up to 8mm) only, while ultrasonic testing (UT) have wider scope of applications, but to realize those better opportunities it is required to use liquid couplants. The most promising method in this area of application appears to be electromagnetic-acoustic method when use is made of ElectroMagnetic Acoustic transducers (EMAT).

The practical results of EMATs’ preliminary trials showed that this type of transducers become equal to those widely used for contactless UT of various items. At the Scientific-Production Enterprise “VIGOR” developed are methods and design of EMATs to excite and register ultrasonic waves of various types implemented in the processes of rail-tracks examination. The EMATs provide reliable radiation and registration of acoustic signals at angles of 0, 40 and 60 as well as Relay waves. The noise-to-signal ratio for developed transducers is approximately the same as for piezoelectric ones and this make it possible to provide examination sensitivity (in case when EMATs are used) practically the same as achieved for modern contact methods.

The EMA NDT testing method is new and efficient in the field of rail-tracks flaw detection, but at the same time it have wide range of applications, i.e. in the process of: -) output rail-tracks’ quality control conducted by the manufacturers; -) output / input used rail-tracks’ quality control conducted by the rails-welding facilities; -) examination of continuously welded rails after welding works and in the process of rail-tracks’ diagnostics carried out with the help of fast, mobile testing devices. Beside mentioned above, the EMA method can be used in other branches of industry, for example, in oil and gas industry; air, sea and automobile transportation; at heavy duty production, etc.

Keywords: acoustic emission method, EMAT, rail-tracks, output /input quality control, examination, UT, magnetic testing

It is common knowledge that expenses for track works make up a significant part of operation costs applying to servicing and maintaining of the railway equipment. One of the practicable ways of reducing them is to introduce resource-saving technologies for track works, in particular by reusing demounted rails.

It is not reasonable to remelt old rails with defects detected and so withdrawn from the track, in economical terms it seems more profitable to get them back repaired. The used rails removed from railroad tracks are forwarded to specialized enterprises – rail-welding trains (RWT) destined for repairing rails to be subsequently used again.

The purpose of incoming inspection of used rails is to uncover defects therein, to remove defective fragments and then to let weld up joints. The incoming inspection becomes of an especial importance in view of new techniques introduced by several RWT within the few latest years, which includes a mechanical machining of railhead surfaces in order to restore their original profile. To detect faulty rails and to reject them from among those which are to be mechanically processed and welded means a considerable saving of materials and labor resources, that would lead to significant enhance of the manufacture efficiency and reduce the cost price of products in the long run.

Until recently the incoming inspection of used rails arriving to RWT for machining was normally reduced to visual inspections aimed at screening rails with visible external defects and sorting them out. However, the visual inspection methods allow to find out only superficial defects (dents, indents, cracks, defects of corrosive nature, hollows etc.). At the same time, along with superficial defects mentioned above, the rails are exposed to intensive developing of troubles classified among the 2, 3 and 5 defect groups, many of which are not detectable by eye.

The ultrasonic monitoring with the use of contact methods (input and registration of ultrasonic fluctuations – that was applied, for instance, at RWT-29 running at the West-Siberian railroad, station Promyshlennaya, by using an upgraded demountable flaw detector “Poisk-10E”, subsequently “AVI-KON-01”), does not ensure reliable checkup without careful cleaning of the rail top from rust, dust, oil spots and other impurities caused by specific conditions under which the rails are used and subsequently stored in unroofed depots. Each rail undergoes an individual checkup, separately from others. Anyway, the process of the rails’ cleaning and preparation for control inspection, if so applied, requires considerable material and labor costs, and in winter as the rails are iced over, it is absolutely unrealizable at all.

Reasoning from the above, in terms of RWT application, special non-destructive check methods should be applied, which are not crucial for the high-quality preparation of rails for check-and-control procedures. The Scientific production association «VIGOR» has developed and made a special appliance thereto, namely an automated device for incoming non-destructive inspection of rails during the manufacture process and (while recycling) at RWT «UD–EMA–RWT–01M». Its schematic diagram is given in Fig. 1.

Fig. 1. Flow chart of UD–EMA–RWT–01M unit

The UD–EMA–RWT–01M devices are distinguished with electromagnetic-acoustic transformers (EMAP) applied therein as primary sensing devices. The said type of sensors allows to check a rail with 0,5 through 1 mm clearances between the EMAP and the rail top surface, to transmit longitudinal and transverse ultrasonic waves within the frequency range from 0,2 up to 2,0 Mhz inside the rail.

The EMA–method has the following typical peculiarities:

- excitation and registration of USF (ultrasonic fluctuations) without using contact fluids;
- ability of regenerating and recording ultrasonic fluctuations of various polarization (longitudinal, transverse, surface waves);
- ability of exciting and registering ultrasonic fluctuations within a wide range of changing frequencies, temperatures and movement velocities of objects checked;
- air clearance that considerably increases the reliability and service life of ultrasonic transformers, mechanical equipment and the whole integrity of inspection tools in general.

Such advanced property as an operating clearance without any ultrasounds inside it allows the UD–EMA–RWT–01M to inspect rails covered with ice, rust etc. One more advantage of using the EMAP is that it is equipped with permanent magnets with a high magnetic induction which ensures a stable acoustic contact between the EMAP and the rail surface. This effect combined with the special construction of the device's mechanisms provides not only a controllable clearance between EMAP and rails, but also enables an exact tracing of longitudinal and transversal curvatures of the rail. At the same time, absence of contact liquid improves the ecological compatibility, moreover it makes the operation easier and the milling of used rails more economically efficacious.

The UD–EMA–RWT–01 device allows to monitor rails at a control speed of 0.1 – 1 m/s, the irradiation discrecity being 1 mm. The integrity of hardware and software facilities of UD–EMA–RWT–01 comprises tools to diagnose the state of measuring channels in the real-time operation mode that ensures a reliable authenticity verification of data arriving from EMAP and from automation sensors during checkup procedures.

Recently an updated version of the UD–EMA–RWT–01M unit has been developed for non-contact inspection of rails to be used under normal operation and RWT conditions, in which a 10-channels rail-sounding scheme is applied that ensures an overall control of the rail all over its crosscut profile. The sounding scheme is shown in Fig. 2.

Fig. 2. Rail-Sounding Scheme implemented in the UD–EMA–RWT–01M unit

The EMAPs are mounted on 4 carriages (see Fig. 3), four whereof run over the railhead rolling surface (1), two on the carriage installed at the railhead's side edge (2) and 4 EMAP – on carriages under the rail foot (3).

Parameters of the sounding scheme:

Types of waves emitted .... transversal, Rayleigh
Number of EMAP units 10
Number of irradiation channels 8
Number of receive channels 8
Nominal frequencies EMAP, Mhz 1,8; 1,0; 0,5; 0,25
Nominal angles of incident EMAP, Grad. 0, 40, 90
Dead space of control inspection, mm..................... 0
Clearance between EMAP and rail, mm, ... 0,5÷1,0

Fig. 3. Scheme of carriages arrangement with EMAP

The shadow and mirror-shadow control methods applied in the echo-sounding scheme, including those using the Rayleigh and Lamb waves, enable not only to inspect the entire profile of a rail's head, neck and neck projection into the rail foot, but also make possible the control of rail foot points which could be checked by the RWT only visually up till nowadays. As a result, the EMAP-assisted nondestructive check-and-control technique factually reduces the dead space (out-of-control shadow range) width to zero. Moreover, EMAP guarantees a good external monitoring for rails having superficial damages which can not be checked with a contact ultrasonic flaw detector.

In addition, the hardware complex encompasses tools of acoustic and light indication / signaling, able to register the times of the inside-rail flaws detection. It is possible to use defect controllers which mark defect profiles of rails by painting in an automatic mode and fix the fact of control with an approximately 300 m long colored stripe at the rail's end. The decoding procedure provides measurement of the distance between the rail's beginning and the profile where a flaw was detected. The parameters of measuring channels are automatically tuned up to defect patterns modeled therein at the beginning of each work shift with the use of a 12.5 – 25 m long control string.

All aforesaid peculiarities of hardware and software units allowed to achieve the required reliability and quality of the incoming and acceptance-related external inspection of used rails under RWT conditions, as well as at manufacturing sites. Proven is the system's capability of reliably detecting defects pertaining to 69-code along the entire profile of 4 – 5 mm-sized (and bigger) foots, as well as that of sounding the rails' heads and necks all along their profiles.

The hardware/software complex UD-EMA-RWT-01 developed by us ensures a high probability of flaw-detection and a reliable automated operation of every piece and module of the device described here, its automation and receiving system as well as its data-processing, saving and analysis systems. Fig. 4 shows photos of rail defects found out by the device together with their defectograms (such defects are displayed on the integrated screen).

Fig. 4. Internal rails' defects and their defectograms

The creation of an automated EMAP-assisted device designed for the incoming inspection of used rails under RWT conditions guarantees an enhanced level of production standards and a great number of new economic indices:

- The project excludes such costly and environmentally unsafe elements as specialized systems of treatment, supply and disposal of water necessary for providing the acoustic contact;

- No more need in removing the rust and corrosion-caused damages from the rail surfaces; the procedure of rails preparation for check-and-control under winter conditions becomes more simplified, the same relates to the storage requirements owing to the possibility of inspecting rails at temperatures -50 through +50°C;

- It gets impossible any longer for used defective rails to be laid by omission on the track.

As analyses show, the EMA transformers – on having passed the preliminary processing stage in appropriate units for incoming checkup of rails at RWT – may be regarded as full-fledged means of non-contact ultrasonic control applicable for the widest variety of products.

EMA method of control, being a modern and effective external inspection technique, has all opportunities to be adopted by manufacturing companies in the flaw detection procedure during the outgoing control of the rails' quality, as well as for incoming and outgoing checkup of used rails at rail-welding enterprises, while inspecting rail strings after welding, while performing diagnosis of rails by using mobile means of speed control. Besides, the EMA method may also be applied to other branches of economy, e. g., oil-and-gas production, the sphere of aerial / marine transport and automotive conveyances, in the heavy engineering / machinery industries and in other domains.

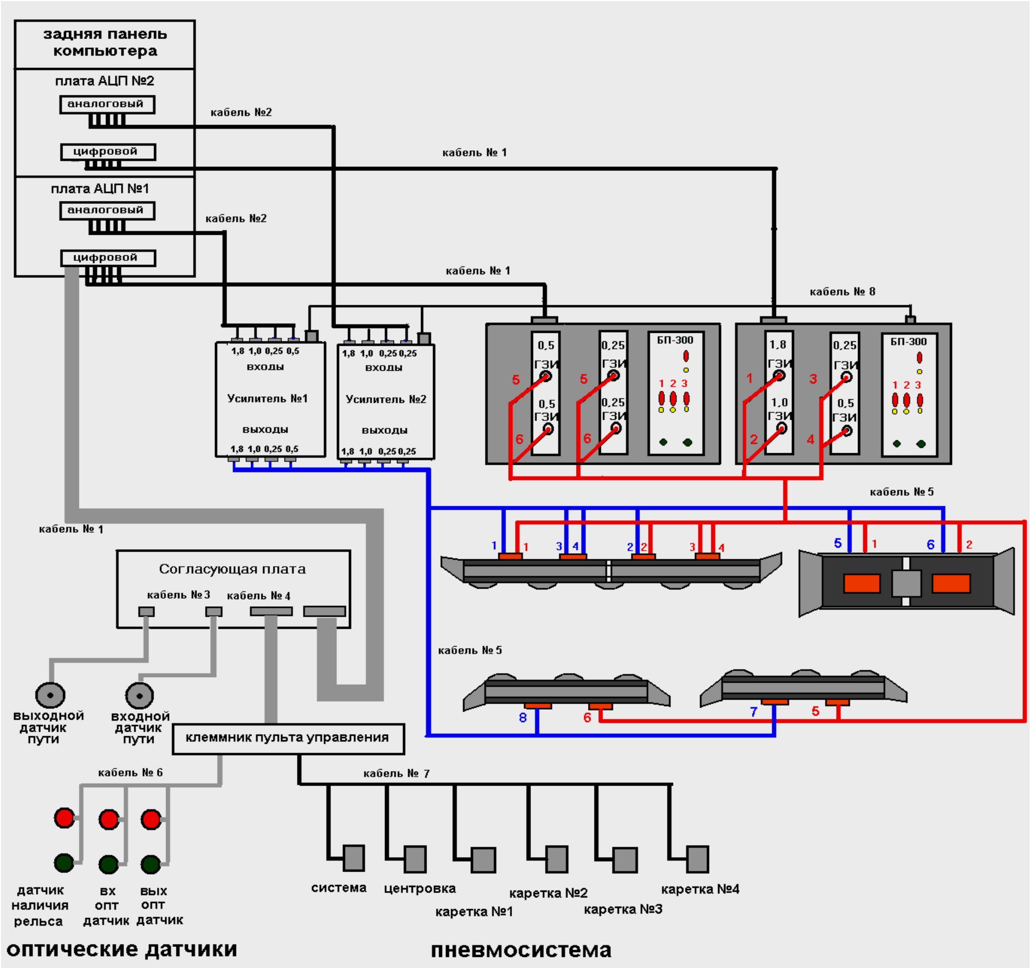
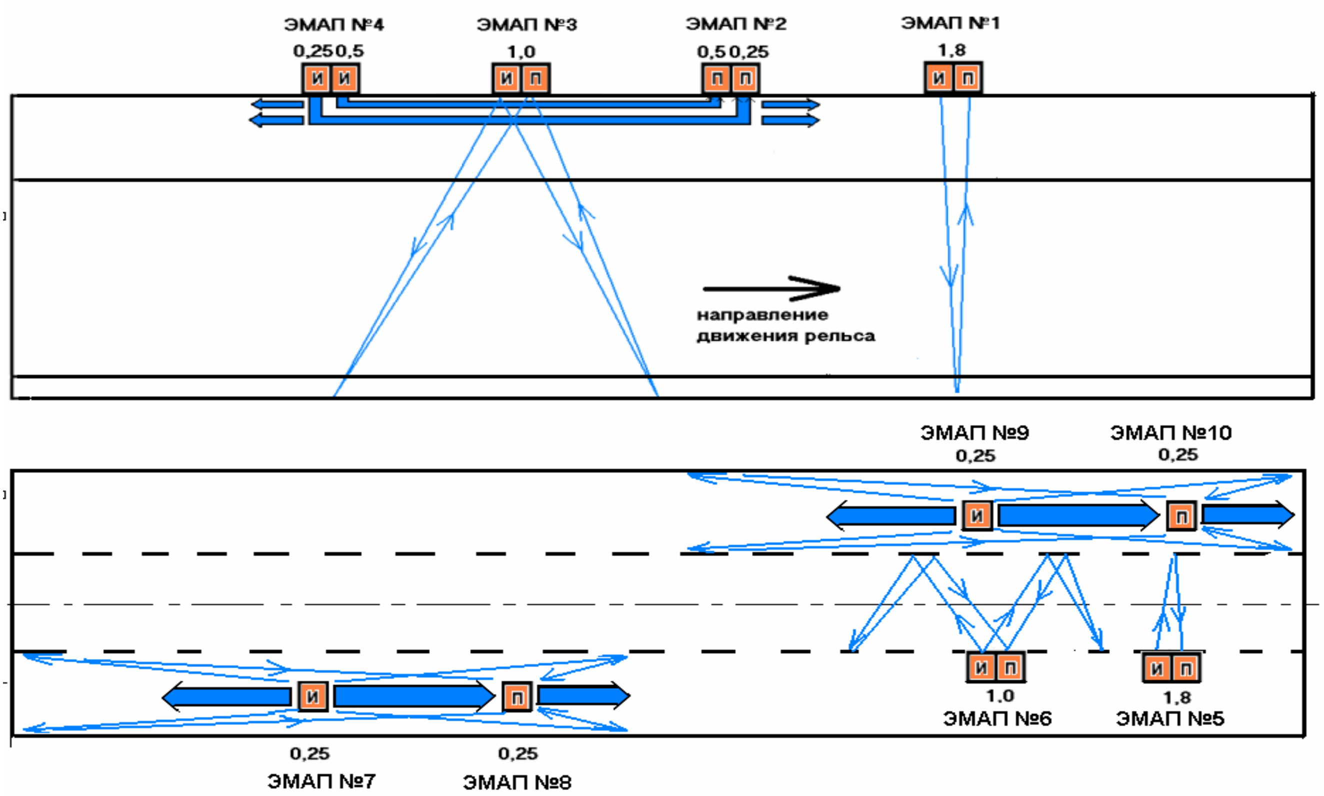


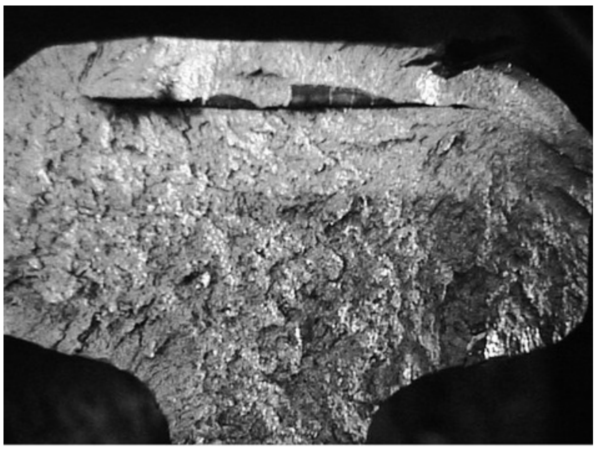
Fig. 1. Flow chart of UD–EMA–RWT–01M unit



Направление движения рельса	Direction of rail motion	Where И – transmitter; П – receiver; EMAP – electromagnetic acoustic transducer
Оптические датчики	Opto (light detectors)	
Пневмосистема	Pneumatic system	
Согласующая плата	Matching plate	
Клеммник пульта управления	Terminal block of the control panel	
Задняя панель компьютера	Computer back	
Входной / выходной датчик пути	Input / output track sensor	
Усилитель №... Выходы	Amplifier №. … Outputs	
Плата АЦП № ...	A-to-D card	
Аналоговый / цифровой	Analog / digital	
Система – центровка	System – centering	
Каретка	Carriage	
Датчик наличия рельса	Rail presence sensor	
Кабель №	Cable №.	

Fig. 2. Rail-Sounding Scheme implemented in the UD–EMA–RWT–01M unit

Fig. 3. Scheme of carriages arrangement with EMAP



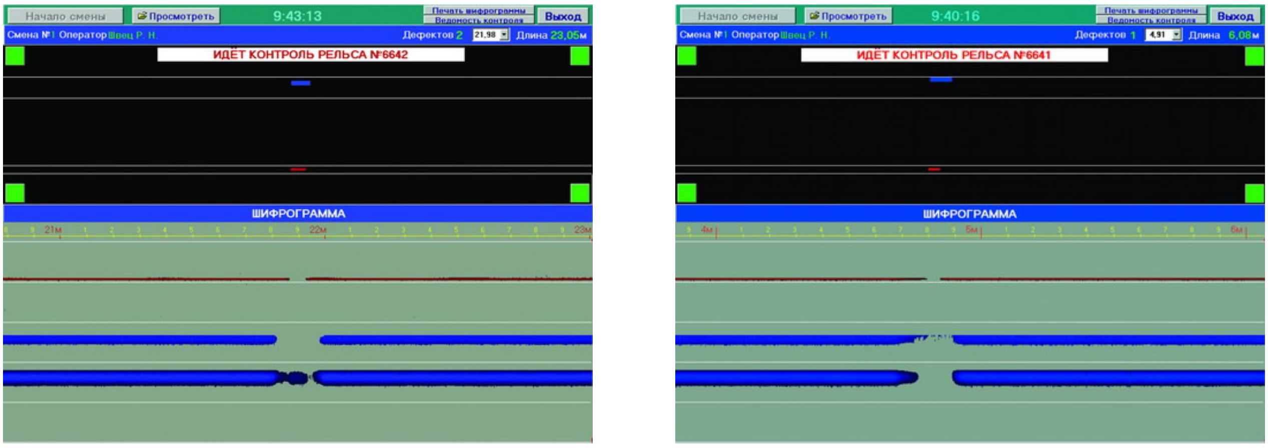


Fig. 4. Internal rails' defects and their defectograms