ESTIMATION OF NON-DESTRUCTIVE TESTING AIDS APPLICATION FOR RAILWAY TRANSPORT STOCK ELEMENTS

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Abstract: Role of nondestructive testing (NDT) within the Russian Railroads system and relationship of testing methods, means and methodologies is defined. Necessity of introduction of the unified system of testing results recording in electronic form and cases of part breakdowns in operational conditions is demonstrated. Scheme of performance of comparative tests of new NDT means is proposed.

GENERAL PROVISIONS

Quality of railroad transport services depends on the quality of its facilities, including rolling stock and track. Nondestructive testing (hereinafter referred to as the NDT) is component part of the quality system of railroad transport services. By means of NDT, such quality parameters as traffic safety and economic efficiency of repair and maintenance of rolling stock are provided (Figure 1).

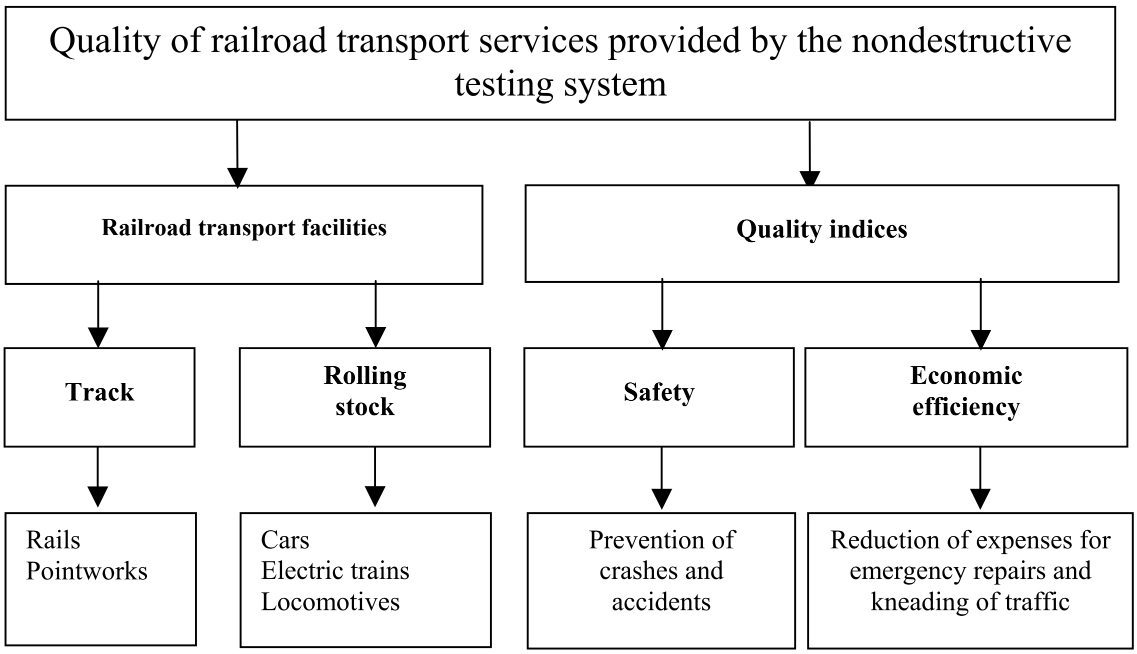

Figure 1

NDT means make it possible:

- to detect in test object defects like metal discontinuities;
- to measure and monitor geometrical parameters of parts and other test objects;
- to monitor physical and chemical properties of parts (test objects) material;
- to measure and monitor thickness and quality of protective coatings of parts (test objects;
- to carry out technical diagnostics of railroad transport assemblies and facilities.

Test objects on a railroad transport are: parts of rolling stock, rails, bridges, stations and other engineering works.

Within frames of the present paper, NDT matters are discussed that provide detection in rolling stock parts defects conditioned by discontinuity in metal, i.e. matters of flaw detection.

ROLLING STOCK

Quality of rolling stock is ensured by quality of its component parts (assemblies, units), which must be monitored and maintained at all "life" stages of an article.

Table 1 presents main NDT processes and parameters monitored at various life stages of rolling stock.

Table 1 - Main NDT parameters monitored at various life stages of an article (rolling stock)

Manufacturing of blanks (Manufacturing plants)	**Manufacturing of parts** (Plants manufacturing rolling stock units, workshops for production of parts and assemblies)	**Rolling stock operation** (check stations)	**Rolling stock repair** (engine houses, plants, workshops)
Testing of chemical composition of blanks	Measurement and testing of physical and mechanical properties of articles	Testing of mechanical state of critical assemblies and parts	Measurement and testing of physical and mechanical properties
Measurement and testing of physical and mechanical properties of blanks	Measurement and testing of geometrical dimensions of articles	Diagnostics of critical assemblies	Measurement and testing of geometrical dimensions
Detection of inadmissible internal and surface flaws (pores, weakness, cavities, hairlines, etc.) in blanks at various production stages	**Detection of surface flaws of production origin (heat-treatment and grinding cracks, hairlines) in articles at various production stages**	**Detection of dangerous surface flaws in parts and assemblies accessible for inspection and testing**	**Detection of fatigue surface and internal cracks in parts following dismantling of assemblies**

In addition to main problems resolved by means of NDT (safety and economic affect), conditions of NDT performance or industrial standards, in other words, are of great importance. Let's call them conventionally as NDT means servicing. It includes automation, large- and small-scale mechanization, arrangement of working place taking into account ergonomics standards, computerization, design, etc.

Thus, it is necessary to determine the NDT development level in three main directions: **safety, economic effect and servicing** (Figure 1).

Currently, there is a park of NDT means applied in the network of railroad tracks and providing some basic level of safety, efficiency and servicing. In order to determine degree it does not satisfy us, it is necessary to mark out by every direction test objects (parts) requiring closest attention.

All range of the rolling stock parts can be divided into three large groups of parts that, when are broken, result in the following:

1) crashes and accidents;
2) expensive emergency repairs;
3) detentions and minor unscheduled repairs.

In [1], three levels of quality are established:

«First one – for critical components, i.e. for structural elements resulting through their breakage to the failure of a whole system or even an accident.

Second one – for non-critical components, i.e. for structural elements that do not result through their breakdown in an accident, but are able to violate normal operation of a system or facility.

Third one – for non-critical structural elements that can result through their breakdown in some unhandinesses».

First group of objects requiring close attention in all three directions is defined relatively easy. Boundary between second and third groups is provisional. Third group constitutes the main massive of parts, which due to low-quality testing can result in large losses for the network in general, but do not cause noticeable damage to every specific enterprise. On other part, this group can include parts or objects requiring no NDT; for example, in the event when their replacement costs much lesser than performance of testing or when no breakdown of such parts was observed for several years and no crack was detected in it during performance of NDT.

All NDT objects can be presented in the form of pyramid with objects of first group in its top and objects of third group in its base (Figure 2).

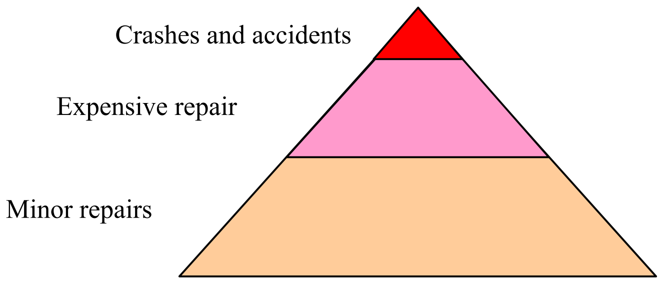

Figure 2

First group includes small range of assemblies and parts representing mainly elements of wheel pair, axle equipment, freight-car truck and rails.

PROVISION OF SAFETY

Traffic safety is ensured due detection and withdrawal from operation of first group parts with cracks presented in them with dimensions exceeding some level. This level depends on many parameters, including crack growth rate, which, in its turn, depends on the intensity of load on a part and interval between two operations of this part testing.

The following is necessary:

1. To define degree, in which NDT means currently applied for testing first group parts provides required level of sensitivity.
2. To select parts requiring replacement or improvement NDT means in order to increase sensitivity.
3. To define possible options and most prospective directions of improvement and development of NDT means.

Testing sensitivity matters for rolling stock parts are related closely with rejection standards established for every part. In normative documentation on repair of rolling stock assemblies and parts, it is possible to meet often statement: “Cracks are not permitted”. Herewith, testing method is indicated at the best case. However, what can be considered as a crack? In some cases, scratch is also considered as a crack. It seems that only two NDT means were available at the moment these instructions were written; therefore, it was meant that cracks “are not permitted” that are detected by NDT equipment applied in this purpose. Currently, every part is tested by one or more methods and means having different threshold (or limit [1]) sensitivity.

Threshold sensitivity is defined by minimal dimensions of a flaw detected by specific NDT equipment. Sometimes, two NDT means (as interchangeable) based on different methods like UST (ultrasonic testing) and MPT (magnetic particle testing) or MPT and ECT (eddy-current testing) are allowed for testing just the same part. However, UST and ECT allows detection of cracks with depth of more than 3 mm, while MPT – of more than 0.5 mm. Then, what cracks are not permitted? Moreover, during elaboration of new NDT methods and means, “cracks are not permitted” requirement allows virtually designers to establish by themselves rejection criteria basing on capabilities of their equipment.

This very important problem can be resolved by means of performance of complex and expensive tests of parts of every type or by means of analysis of previous experience of NDT means application for most critical parts. Second method or methodology of its performance can be implemented by introduction of the unified recording system for testing results.

From the point of view of the danger of structure destruction in the process of operation, depth of surface crack is the most important flaw parameter. All NDT method and means can be arranged provisionally by the descent of their threshold sensitivity to this parameter of a crack. Figure 3 demonstrates exemplary sensitivity of the main NDT methods to the depth of surface crack depending on tested part surface roughness. Sensitivity dispersion within every method is conditioned by capabilities of specific means, methodologies and peculiarities of test objects like part shape and dimensions, structure, mechanical and electromagnetic properties of tested article metal.

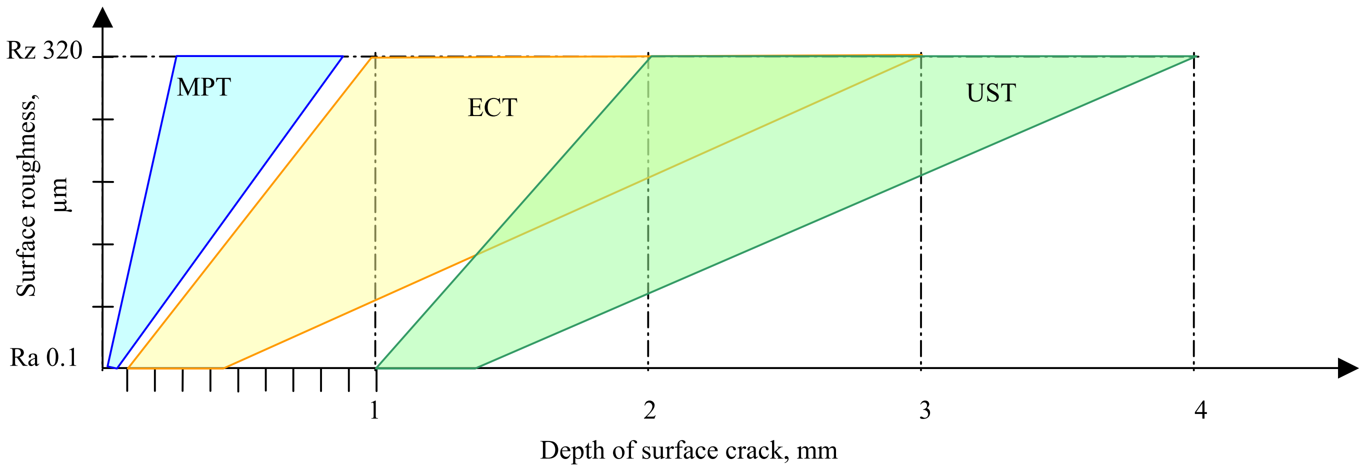

Figure 3 – Exemplary sensitivity of magnet particle (MTP), eddy-current (ECT) and ultrasonic (UST) NDT methods on tested part surface roughness

As is seen from Figure 3, sensitivity of magnet particle method is higher considerable than one of eddy-current and ultrasonic methods. Ferroprobe method is referred to magnetic NDT methods, but there is no sufficient data on its actual threshold sensitivity in order to determine at this stage more or less accurately its position on a diagram.

It is necessary to take into account that threshold sensitivity of NDT equipment to crack depth can be restricted by other crack parameters, including width of its opening. For eddy-current and ultrasonic methods, noticeable reduction of sensitivity occurs at opening width of less than 0.5 µm, especially when crack walls are joining partially. For magnet particle and ferroprobe NDT methods, crack opening width is of special importance. This fact is reflected in GOST on magnetic (MPT and FPT) NDT methods in the form of provisional levels of sensitivity. With crack opening width of less than 20 µm, sensitivity of magnetic methods decreases; and, under certain conditions, even through-the-thickness crack can be omitted. In practice, it is possible, for example, when part with surface crack is subjected to hardening by knurling. Moreover, it should be considered that with opening width of more than 20 µm, crack can be detected visually.

From the safety point of view, method and equipment is optimal, if they provide fail-free operation of an assembly or part for the interval between repairs, during which NDT is performed under methods and by means having similar threshold sensitivity.

Let’s consider model of development and detection of the surface “ideal” crack from the moment of first testing of part applying specific NDT-1 means to second testing with the same means taking into account operation and intermediate inspections in technical servicing center or current repairs without application of NDT means or with application of less sensitive means.

Let’s assume the following:

– crack in the process of part operation grows in depth linearly and provisionally from 0 to 8 mm;
– 7 mm is critical size of a crack; when it is exceeded, probability of part breakage grows drastically;
– qualification of all flaw detector operators and inspectors is similar;
– threshold sensitivity of NDT-1 means is 3 mm.

Let’s break down conventionally the whole operation period between two repairs of a part applying NDT means into four intervals separated uniformly by points I-1, I-2, I-3, where scheduled visual inspection of a part or its testing under method being less sensitive than one of NDT-1 is performed.

Following performance of NDT-1, parts with cracks having depth that does not exceed sensitivity threshold of NDT-1 means (Table 2; Figure 4) are admitted for operation.

Table 2 – Scenario of the development of cracks omitted during performance of NDT-1

Type of maintenance	Testing method	Conventional depth of surface crack not detected by NDT1 means, mm								
		less than “threshold”				higher than “threshold”				
NDT1	NDT1 means	0	0	1	2	3	4	5	6	**7**
I1	Visual	0	1	2	3	4	5	6	7	
I2	Visual	1	2	3	4	5	6	7		
I3	Visual	2	3	4	5	6	7			
NDT2	NDT1 means	3	4	5	6	**7**				

Legend:

0 – there is no crack; however, structural variations have occurred in a metal that precede appearance of a crack.

1, 2 – crack depth detected neither visually nor using NDT1 means.

3, 4 – crack depth that can be detected using NDT1 means.

5, 6 - crack depth that can be detected visually.

7 – critical crack depth, when part breakage is possible.

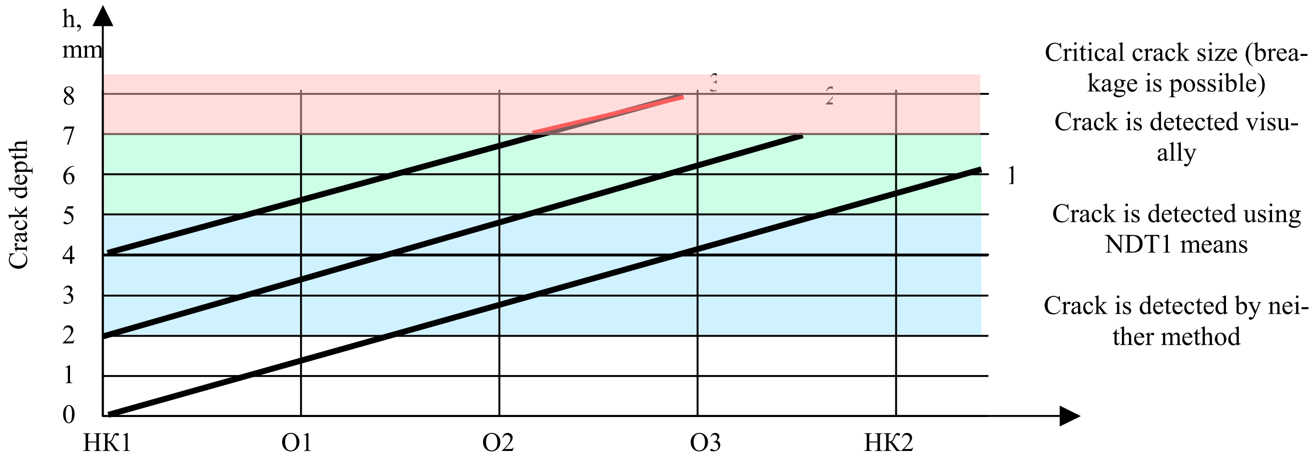

Figure 4 – Dynamics of development and detection of cracks omitted during performance of NDT-1

As is seen from Figure 4, if crack with depth exceeding threshold value is omitted during NDT1, it must be detected during I1 (3); however, if under some reasons, it is omitted during I1 and I2, breakage can occur by the time of I3 performance. Thus, system of intermediate inspections or testing with less sensitive means ensures safety in general. In this case, NDT1 means that do not guarantee detection of such cracks require replacement for more sensitive ones.

Following analysis for certain period (for example, 1 year) of cases of emergency and scheduled intermediate repairs with replacement of some single part due to a crack presented in it and plotting of a distribution diagram for cases of replacement within the interval between if repairs of similar type, it is possible to determine efficiency of NDT1 means applied for testing the given part (Figure 5).

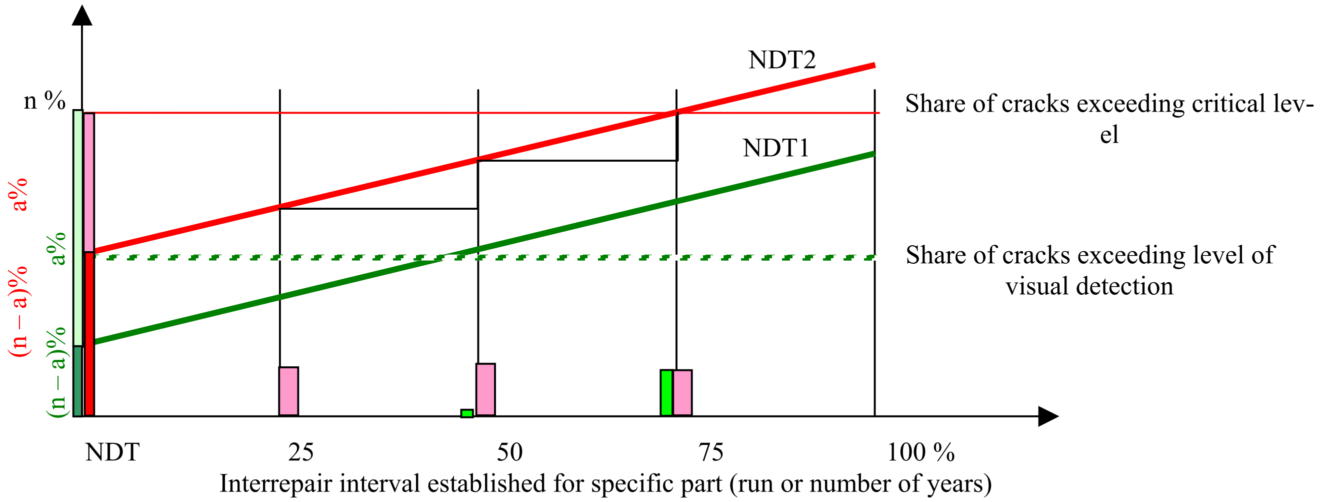

Figure 4 – Scenario of detection of cracks omitted during NDT-1 performed within interrepair interval

At the moment of NDT performance, there are n % parts with flaws of various size in the total number of tested parts.

Depending on threshold sensitivity of applied NDT1 means, a % of them will be rejected; herewith, (n – a) % defective parts will be admitted for operation and can be detected through some interval within interrepair period. In the process of operation, cracks grow and, hence, the number of crack increases that can be detected during inspection or repair of intermediate type, as well as number of uncouplings, coming-offs and other emergencies can increase. From diagram on Figure 4, it is evident that NDT1 means provide safety operation of a part, while NDT2 - no. In this case, safety is ensured by quality of intermediate scheduled preventive measures, rather than by NDT quality.

Actually, of course, dynamics of crack development does not bear linear character and cases of accelerated crack growth under impact of some extreme conditions are always possible. The whole set of scheduled preventive measures is required for this purpose namely. Besides, testing quality depends not only on the sensitivity of NDT means, but on many other factors like equipment of shop, illumination, qualification of flaw detector operator, etc., as well. Reduction of the influence of these factors can be ensured by implementation of mechanized and automated installations and benches, as well as flaw detectors with automatic recording of testing results.

Nevertheless, analysis logbooks of emergency repair cases, results of inspections and flaw detection of parts and assemblies of rolling stock at intermediate stages in the process of operation can reveal certain regularity, especially when it manifests itself for all railroads across the country.

Efficiency of NDT means application from the point of view of economic efficiency and reasonability of their application for testing parts of second and third groups can be considered in similar manner.

Flaw detectors available at the market of testing means and close by destination and sensitivity put customer in a predicament from the point of view of choice. Customer requires independent data on consumer properties of offered means. On this point, body being independent from manufacturing companies, allowing testing of these means and providing comparative estimation is required.