About a New Classification of NDT Methods Based on Risks and Component Service Life

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Abstract. In order to have reliable results of residual lifetime assessment of long-lived engineering structures and components the actual mechanical properties and the stress-strain state of the material as a result of operation are the most important inputs. The main function of NDT methods is to provide information in the volume required and sufficient for performing lifetime calculations and risks assessment. This implies that a 100% examination would be required for a guaranteed monitoring of the most dangerous zones, i.e. the stress concentration zones and the degradations initiated in these zones. At present a large arsenal of methods and means for stress-strain state control of objects has been accumulated. In this connection it is imperative to include the “Stress control” into the list of NDT methods.

The current classification of NDT methods is based on the physical principles of the methods. Instead, the authors recommend a new classification of NDT methods based on the type of physical fields. The physical fields utilized can be active (a “forced” physical field with specified orientation is created in the inspected object’s material), and passive (using proper physical fields reflecting the internal energy of the inspection object’s material). Distinction between active and passive fields will be presented which is the precondition for degradation assessment; they can grow (dangerous) and can remain stable (non-dangerous). Also the training, qualification and standardization of “Stress control” will be discussed.

The most important stages of risk and inspection object’s (IO) residual lifetime assessment process should comprise not only defects detection and determination of their parameters (flaw detection measurements) but, which is more essential:
- detection of local zones of developing damages – stress concentration zones (SCZs);
- identification of the most dangerous SCZs, which are the most probable sites of an object’s failure;
- determination of stress-strain (energy) state parameters in the most dangerous SCZs;
- determination of the actual structural-mechanical characteristics of the material in SCZs;
- evaluation of damage development rate and direction based on the identified mechanism of damaging development.

It follows that the main purpose of non-destructive testing methods is obtaining the information in the scope required and sufficient to carry out lifetime calculations and risks assessment. This implies that a 100% object inspection is required for guaranteed detection.
of the most dangerous zones – SCZs and of developing damages. Currently, classification of NDT types and methods in European and International standards, introduced for the field of flaw detection, has a formal character and distinguishes the entire variety of NDT methods and devices rather by the way of identification of the applied effect than by the type of physical fields.

When classifying of the known NDT and diagnostic methods by the type of physical fields, following types can be highlighted:

- electric;
- magnetic;
- electromagnetic;
- thermal;
- mechanical.

At the same time such well-known and widely used methods as optic, radiowave, X-ray, acoustic, holographic, capillary, methods of electrical resistance, strain gage methods as well as moiré, net, photoelasticity and other methods did not disappear. They occupied their places within these five types.

It is principally important that the new developed standards classify NDT methods by: active – with creation in the studied object's material of a "forced" physical field of specified orientation, and passive – using self-physical fields reflecting the internal energy of the inspection object’s material.

The following may be referred to passive NDT methods:

- autoemission method;
- acoustic emission method;
- metal magnetic memory method (contact and non-contact);
- thermal method (contact and non-contact).

All other methods listed in the current standards are referred to active NDT methods.

Classification of NDT methods by active and passive ones forms the background for objective classification of detected defects by dangerous (developing) and non-dangerous (not developing). The proposed classification of NDT methods is critical for inspection objects industrial safety assurance at equipment lifetime assessment, as well as evaluation of reliability and risks during various industrial objects operation.

It is necessary to include "Stress Control" in the list of NDT types. Various methods and means of stress NDT are widely spread in Russia and abroad nowadays. The list of inspection types for personnel training in ISO 9712 "Personnel Qualification and Certification" includes testing with strain gages, which is obviously insufficient, since currently there is a large arsenal of stress-strain state NDT methods and means in Europe and worldwide.

In 2005 the RSNDT TD President V.V. Kluev approved the "System of voluntary personnel certification in the file of non-destructive testing and diagnostics" where "Stress control" is included in the list of NDT methods.

SDOS-05-2010 "Provision on Personnel Certification in the Field of Stress-Strain State NDT" guideline document was adopted in Rostekhnadzor system in 2010. In accordance with this document, training of experts in the field of SSS NDT is performed in Russia.

GOST R 52330-2005 "Non-destructive testing. Stress-strained state tests on industrial objects and transport. General requirements" was put into effect in 2005 in Russia.

This standard specifies general requirements to application of methods and means of industrial and transport objects’ stress-strain state non-destructive testing during assessment of engineering products’, equipment’s and structures’ lifetime. The standard
covers products and equipment manufactured of steel and alloys, cast iron and other structural materials without limitation on size and thickness including welded joints.

The Russian Standard GOST R 52330-2005 was first developed by Energodiagnostika Co. Ltd. experts, and it has no analogues in Russia and abroad. This standard was presented on behalf of Russia as draft International ISO standard at the Annual Assembly of the International Institute of Welding in Quebec (Canada) in September 2006.

It is known that stress concentration zones (SCZs), occurring due to manufacturing process defects, working loads or their combinations, are main sources of equipment and structures damaging.

SCZs may vary from fractions of micron (product’s micro volume) to sizes comparable to those of the product itself (macro volume).

A SCZ – stress concentration zone – is a local zone of a product, in which large strain occurred compared to the average strain across the entire product’s volume.

For new engineering products SCZs occurrence is conditioned by structural inhomogeneity and manufacturing technology.

Presence of SCZs both on new and used products sufficiently reduces their lifetime. Therefore products’ stress-strain state control and SCZ detection using non-destructive testing devices is an important task for ensuring their operational safety.

At present a large arsenal of methods and means for materials’ SSS diagnostics has been accumulated in Russia and abroad. However, objective comparison of these methods and means application efficiency is not possible, since till date there are no standard specimens, programs and centers for experts training in equipment and structures’ SSS non-destructive testing. Unfortunately, currently the theoretical basis is insufficiently developed as well for objective comparison of SSS inspection methods efficiency and determination of boundary conditions and scope of their application. A uniform theoretical basis developed based on modern scientific achievements in the field of fracture mechanics, material engineering, solid-state physics may become a basis for resolution of contradictions that currently occur during practical implementation of various methods and means of materials’ SSS control. An attempt to develop such theoretical basis was made in the book by V.T. Vlasov and A.A. Dubov "Physical Theory of "Strain-Failure" Process", Moscow: ZAO "Tisso", 2007, 517 p.

Nowadays the topic of "Stress Control" is challenging both for engineering products’ quality control and for operated equipment’s lifetime assessment.

To obtain reliable results of residual structural strength calculation for objects operated for a long time, it is necessary to know, first of all, the actual mechanic characteristics of the material, as well as the characteristics of its stress-strain state (SSS) formed to date as a result of the object operation. This task has become the main concern not only in the objects study and static strength assessment; it also becomes crucial in the study and fatigue strength assessment due to the local character of fatigue failure and its strong dependence on the actual material's SSS.

Based on the object material’s actual SSS assessment and early SCZs detection, it is possible to perform more objective risk assessment, as areas of potential damages and the degree of their hazard for emergencies development become known.

Thus, there is a long-felt need to include "Stress Control" in the list of NDT methods. This classification is specific stress control methods based on the type of physical fields used will correspond to the proposed classification of flaw detection methods.