TRAINING OF EXPERTS IN THE FIELD OF TECHNICAL DIAGNOSTICS

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Introduction.

Analysis of emergencies at hazardous production objects demonstrates that it is not sufficient to apply only flaw detection methods to prevent unexpected failures of the industrial equipment. The main reason is that conventional flaw detection methods are aimed at detection of macrodefects in the equipment metal. Prevention of unexpected fatigue damages requires, first of all, methods allowing to assess the stress-strain state (SSS) of hazardous objects and to detect the most dangerous areas (zones) of stress concentration. Stress concentration zones[1] (SCZs) formed during the equipment fabrication and operation are the main sources of intensive development of corrosion and fatigue damages and, consequently, the main reason of failure (emergency). For new machine-building products SCZs are determined by structural inhomogeneity and manufacturing technology, and in operational conditions – by the action of working loads. SCZs may vary from fractions of micron (product's micro volume) to sizes comparable to those of the product itself (macro volume). It is practically impossible to detect such SCZs by calculation methods. Currently this is possible only with NDT means. The quality of the equipment metal in a SCZ may be determined using the methods of actual material's characteristics assessment. For example, it may be the metallographic analysis or a quick inspection method like hardness measurement.

Thus, of all the variety of physical methods and technical diagnostics[2] devices for assuring safe operation of hazardous production objects nowadays it is necessary to mark out methods combining fracture mechanics, physical metallurgy and non-destructive testing. For equipment operated for a long time the technical diagnostics is aimed, first of all, at state assessment and lifetime prediction.

Problems of metrology and personnel training at inspection of equipment's stress-strained state

Till date effectiveness of various stress control methods and means remains low at their application directly on equipment.

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[1] According to GOST R 52330-2005 "Non-destructive testing. Stressed-strain state test on industrial objects and transport. General requirements" SCZ – stress concentration zone – is a local product area, in which large strain has occurred as compared to the average strain across the entire product's volume.

[2] According to GOST 20911-89 "Technical diagnostics. Terms and definitions" the term "technical diagnostics" is defined as "the field of knowledge covering theory, methods and devices for objects' technical state determination".

The analysis of capabilities of the known methods of stresses and strains inspection in the base metal and welded joints of equipment and structures allow naming their essential drawbacks [1, 2]:

- unsuitability for inspection of long pipelines and large products, equipment and vessels;
- impossibility to use most of methods in the plastic strain area;
- variation of metal structure is not considered;
- impossibility of deep metal layers assessment for most inspection methods;
- the need to make graduated diagrams based on tests of preliminarily prepared specimens, which, as a rule, do not reflect the actual energy state of equipment;
- the need for inspection surface and Inspection Objects preparation (dressing, active magnetization, sensors adhesion, etc.);
- complexity of testing sensors location determination relative to the direction of the action of maximum stresses and strains determining the structure reliability.

Thus, the above-listed drawbacks of well-known SSS inspection methods are determined by these methods' physics and are regular.

The lack of metrological basis for materials' SSS characteristics measurement means certification and calibration (till date there are no unified standards and specimens in Russian and other countries) leads to ambiguity of requirements and wrong methodical approach towards the developed inspection means.

Besides, at present not a single country of the world has programs and centers for specialists training in equipment's and structures' SSS non-destructive testing. There are no standards specifying general requirements to methods and means of stresses and strains NDT in structures.

The lack of understanding of the physical essence of this or that non-destructive testing (NDT) physical method, used for experimental determination of stress-strained state (SSS) parameters and materials' characteristics, leads to wrong interpretation of measurement results and to common mistake in objects' residual life determination.

Unfortunately, currently the theoretical basis is insufficiently developed as well for objective comparison of SSS inspection methods effectiveness 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 occurring nowadays at practical implementation of various methods and means of materials' SSS inspection.

In practice large difficulties are faced in the course realization of complex technical diagnostics using the methods of SSS inspection, flaw detection and assessment of actual structural and mechanical characteristics of the material. This is associated with the following reasons:

- application of SSS inspection methods independently from other non-destructive testing (NDT) methods [3];
- until recently, the lack of normative documents regulating application of SSS inspection methods in combination with NDT methods at hazardous objects;
- misunderstanding and distrust on the part of equipment owner and very often – on the part of departmental organizations responsible for implementation of technical policy of equipment's SSS assessment necessity in order to prevent the equipment damaging at the stage of defect formation in a SCZ[3];
- increasing of technical diagnostics cost due to extension of scope of works on SSS inspection in addition to flaw detection methods;
- lack of trained experts able to carry out complex technical diagnostics by methods of flaw detection, SSS inspection and assessment of the metal's structural-mechanical properties as well as to perform technical diagnostics using several methods and to make the appropriate conclusions based on its results.

2. Backgrounds for further development of methods of SSS assessment in the course of technical diagnostics.

At present experts working in the field of industrial safety assurance understand more and more the urgency of SSS assessment. Nowadays topic of the stress state control is urgent both for engineering products' quality inspection and during operation in the course of equipment's lifetime assessment.

All leading world diagnostic centers are now occupied with the problem of mechanical stress measurement in operated structures for the purpose of their state assessment.

At present in addition to the well-known stress control methods (the method of stress measurement using strain gages, X-ray diffraction) works are carried out on development and standardization of magnetic NDT methods (Barkhausen noise, the metal magnetic memory (MMM) method, coercive force measurement).

Such active development of this direction of non-destructive testing and engineering diagnostics was taken into account in the latest edition (2005) of the International Standard ISO 9712 "Non-Destructive Testing. Qualification and Certification of Personnel", which introduced the new type of inspection – "Strain Testing" along with conventional methods.

The tendency of technical diagnostics development towards complex application of SSS methods was taken into accounts in Russia as well. GOST R 52330-2005 "Non-destructive testing. Stressed-

[3] It should be noted that the Industrial Safety Review system in the course of experts training considers the topics of SSS assessment. But finally the engineering examination programs formation is carried out on the bases of technical regulations and normative documents that often disregard the topics of SSS assessment.

strain state test on industrial objects and transport. General requirements" was put into effect in 2005. The standard was developed by experts of Energodiagnostika Co. Ltd. and passed the expert review according to the established procedure in the Technical Committee TC-132 "Technical diagnostics" of the Federal Agency on Technical Regulation and Metrology. This standard was published for the first time and it has no analogues in Russia and abroad.

GOST R 52330-2005 specifies general requirements to application of methods and means of industrial and transport objects' stress-strained state (SSS) non-destructive testing at life assessment of machine-building products, equipment and structures. The standard covers products and equipment made of steel and alloys, cast iron and other structural materials without limitation by size and thickness, including welded joints. The principal requirement of this standard to the applied methods and means of products' stress-strained state NDT consists in determination of SCZs – the main sources of damages development – in them.

In 2005 the Russian Society for Non-Destructive Testing and Technical Diagnostics (RSNDTD) approved the "System of Voluntary Personnel Certification in the field of Non-Destructive Testing and Diagnostics (SVPCNDT) where the stress state control is included in the list of NDT methods as a separate type.

Three parts of the new ISO standard on the metal magnetic memory (MMM) method (ISO 24497-1:2007 (E) Non-Destructive testing – Metal magnetic memory – Part 1: Vocabulary, ISO 24497-2:2007 (E) Non-Destructive testing – Metal magnetic memory – Part 2: General Requirements, ISO 24497-3:2007 (E) Non-Destructive testing – Metal magnetic memory – Part 3: Inspection of welded joints) were published based on the National Russian Standards (GOST R 52005-2003 Non-destructive testing. Metal magnetic memory method. General requirements, GOST R 52081-2003 Non-destructive testing. Metal magnetic memory method. Terms and definitions) and the Standard of the Russian Welding Society (ST RWS 004-03 "Non-destructive testing. Welded joints of equipment and constructions. Method of metal magnetic memory).

Harmonized Standards GOST R ISO 24497-1-2009, GOST R ISO 24497-2-2009 and GOST R ISO 24497-3-2009 identical to the corresponding parts of the International Standard will be put into effect in 2010. The main purpose of the MMM method during the inspection is to detect SCZs on the material's structure inhomogeneities and on developing defects.

National Russian Standard GOST R 53006-2008 "Engineering diagnostics. Estimation of potential dangerous objects lifetime on the basic of express methods. General requirements" was published in 2008. GOST R 53006-2008 publication was a result of the many years' activity of the Federal Agency on Technical Regulation and Metrology TC-132 "Technical Diagnostics" Working Group, in which experts of Energodiagnostika Co. Ltd. took an active part.

GOST R 53006-2008 offers to use actual energy characteristics of the MMM, AE and Thermal Control methods as basic criteria of the metal's limiting state. This GOST takes into account the results of many years' experimental and theoretical investigations presented in paper [4].

Introduction of the new NDT type – "Stress Control" – in the new edition of the ISO Standard 9712 gave the grounds for purposeful training of NDT experts in this type of inspection.

3. Experience in NDT experts training for carrying out technical diagnostics of hazardous objects.

Since 1998 the Independent Body for Personnel Certification in the field of NDT ("Energodiagnostika" Certification Body) carries out personnel training and certification in the field of NDT by the MMM method based on National and International Standards, normative documents and programs and examination digests approved by the Russian Technical Supervision Body (Rostechnadzor) departments authorized corresponding to the field of certification.

Formally the MMM method refers to the magnetic testing (MT) methods. However by its physical bases the MMM method principally differs from other magnetic methods because it uses natural magnetization (the magnetic memory of metal) formed in the course of the product fabrication or under exposure to strain energy due to working loads [4, 5].

Nowadays there are more than 40 guidance documents and inspection techniques relating in full or partially to MMM method application in various industries. Specialized instruments for inspection by the MMM method are duly certified at the Federal Agency on Technical Regulation and Metrology and are included in the List of Inspection Devices.

Taking into account the capabilities of the MMM method, the NDT personnel training program (Table 1) is made so as to highlight both the issues of hazardous objects' SSS assessment with detection of SCZs using the MMM method and the procedures of additional use of NDT devices and those for assessment of actual structural and mechanical properties of the materials during the complex technical diagnostics.

Keeping in mind that the accuracy and descriptiveness of the technical diagnostics data influence the industrial safety review conclusions and the residual lifetime assessment, the appropriate issue was included in the program. At the same time it is stressed that the official conclusion on the residual lifetime assessment is within the competence of industrial safety experts.

Table 1.

Program for NDT personnel certification by the MMM method (Qualification Levels I and II).

No.	Subject name	Hours
1.	General questions of non-destructive testing.	4
2.	Physical bases of magnetic testing methods.	4
3.	Physical bases of the metal magnetic memory (MMM) method. Basic provisions of fracture mechanics. Energy criteria.	8
4.	Basic provisions of standards on the MMM method, technical diagnostics and reliability in engineering: - GOST R ISO 24497-1-2009 "Non-destructive testing. Metal magnetic memory method. Part 1. Terms and definitions"; - GOST R ISO 24497-1-2009 "Non-destructive testing. Metal magnetic memory method. Part 2. General requirements"; - GOST R ISO 24497-1-2009 "Non-destructive testing. Metal magnetic memory method. Part 2. Inspection of welded joints"; - GOST R 52330-2005 "Non-destructive testing. Stressed-strained state test on industrial objects and transport. General requirements"; - GOST R 53006-2008 "Methodical guideline on potentially hazardous objects' lifetime assessment based on quick methods of technical diagnostics"; - GOST 20911-89 "Technical diagnostics. Terms and definitions"; - GOST 27.004-85 "Reliability in engineering. Process systems. Terms and definitions"; - GOST 27.002-89 "Reliability in engineering. Process systems. Terms and definitions";	4
5.	Magnetic parameters of inspection by the MMM method. Metrological bases of the MMM method. Operating principle of transducers for measurement of weak magnetic field characteristics. Inspection data recording and conversion principle.	4
6.	Devices for inspection by the MMM method. Modifications of instruments and scanning devices. Instrumentation running procedures.	8
7.	Program software: - Program for MMM-inspection data transfer from the instrument to PC; - Program for MMM-inspection data processing – "MMM-System"; - Program for vector representation of multi-component data obtained during the inspection by the MMM method – "MMM-ED-3".	8
8.	Technique for inspection of potentially hazardous objects of industrial equipment using the MMM method. Normative documents and techniques for inspection of potentially hazardous objects of industrial equipment.	8
9.	Methodical and practical techniques of complex technical diagnostics by the MMM method and conventional NDT methods (VT, RT, UT) and by the methods of the equipment material's actual mechanical characteristics (hardness measurement, metallography). Application procedure for methods of metal's SSS and mechanical properties control and flaw detection methods during the lifetime assessment.	4

Table 1 (continued).

Program for NDT personnel certification by the MMM method (Qualification Levels I and II).

No.	Subject name	Hours
10.	Bases of residual lifetime assessment for potentially hazardous objects: - Problems of ageing equipment's residual lifetime assessment; - GD 03-484-02 "Provision on the procedure of safe operation period prolongation for technical devices, equipment and constructions at hazardous production facilities"; - GD 09-102-95 "Methodical guideline on residual lifetime estimation of potentially hazardous objects under supervision of Rostechnadzor"; - Branch normative documents on residual lifetime estimation of potentially hazardous objects. - Program for residual lifetime assessment of the metal in SCZs based on the results of inspection by the MMM method – "MMM-Resource".	4
11.	Laboratory classes. Training in inspection by the MMM method on specimens.	8
12.	Qualification exams.	16
	TOTAL:	80

In 2009 "Energodiagnostika" Certification Body extended the field of experts certification in the field of NDT to Level 3 in magnetic NDT methods, including the MMM method. The program of experts training for Level 3 differs from the program presented in Table 1 as it considers in more detail the issues on the physical bases of the MMM method and development of specialized inspection techniques.

4. Conclusions.

4.1. It is possible to improve the level of industrial safety of hazardous objects by application of complex technical diagnostics using SSS control methods in addition to flaw detection methods applied in industry.

4.2. Application of up-to-date physical methods of SSS control and experts training in technical diagnostics is restrained due to the following factors:

- lack of normative documents in the field of industrial safety regulating application of technical diagnostic methods;
- deficiency of suitable for practice efficient devices for non-destructive stress control;
- distrust and misunderstanding of stress control and technical diagnostic methods on the part of equipment owners;
- increasing of the cost of diagnostic works compared to flaw detection.

4.3. For further effective implementation of SSS assessment methods it is necessary to introduce an independent type of “stress state” control into the “Uniform system of conformity assessment in the field of industrial and ecological safety as well as safety in the field of power engineering and construction” using the SVPCNDT RSNDTD and ISO 9712 recommendations.

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