Actual metrological and legal issues of non-destructive testing

K V Gogolinskii and V A Syasko

Saint-Petersburg Mining University, 2, 21st Line, St Petersburg 199106, Russia

e-mail: nanoscan@yandex.ru

Abstract. The article is devoted to the analysis of the problems of metrological support and regulation in the field of non-destructive testing. Analyzed the differences between measurement and testing procedures. The approach to non-destructive measurements as a multi-parameter measurements is proposed. The example of the multipurpose primary standard for the complex calibrations of metallic coatings on metallic bases reference standards for the calibration of eddy-current coating thickness gauges is given.

1. Introduction

The modern development of the tools and techniques of non-destructive testing (NDT) is inextricably linked with the trends and challenges of the current 4th industrial revolution. It is based on the principles of digitalization - the transition to digital methods of collecting, transmitting and processing all the data received, as well as the automation of processes in all industries, including the design, development, manufacture and operation of products. In this regard, the role of non-destructive testing and condition monitoring at all stages of the life cycle significantly increases.

2. Problems of metrological support and legal regulation of NDT

The difficulties of metrological and regulatory (legislative) support for NDT are related to the fact that NDT includes several complementary concepts: **testing** itself - the study of the behavior of an object under certain external effects; **inspection** - verification of the object's compliance with established technical requirements; **evaluation** - a quantitative assessment of the characteristics of an object that is closest to the concept of measurement from the point of view of metrology, as the process of experimentally obtaining quantity values, ensuring their traceability to the standards. Such a combination leads to significant problems both in the methodical and in the legislative field. The established requirements for materials and products in the manufacturing process critically depend on the specifics of the materials themselves, technological processes in the manufacture of products and the conditions for their further operation. In this regard, the criteria for the suitability of a material or final product depend on many factors and can only be established in the process of scientific and engineering research and trial operation. In the case of applying NDT techniques for inspection or control, the responsibility for their use lies solely with the manufacturer. However, if NDT is used for inspection of the technical condition of potentially hazardous facilities, for example, in railway transport or nuclear energy, etc., then the procedures and equipment used should be subject to state attestation and certification. On the other hand, if the NDT tools are considered as test equipment, the legislation in the field of ensuring the uniformity of measurements is applied to it to a substantially limited extent. In the case of using NDT tools for measurement, they are subject to all types of metrological certification as a measuring instrument ensuring traceability to state standards. The consequence of the complexity and versatility of NDT is that, unlike other types of measurements, tests and controls, there is a multi-stage system of certification of specialists in NDT [1].

Non-destructive testing can be divided into flaw detection (defectoscopy) and NDT measurement methods. In the case of defectoscopy, some objects (flaw) are detected as material inhomogeneity or discontinuities (pores, cavities, delamination, cracks, foreign inclusions, etc.), which are often problematic to characterized by some dimensional value. In the case of measurements by NDT methods, a certain physical quantity (for example, the thickness of the coating or the pipe wall) can be determined objectively in dimensional units. For the characterization of NDT instruments as measuring ones, their sensitivity and resolution are important. However, there is no clear boundary between defectoscopy and measurements. For example, the same pulse echo technique in ultrasonic testing and the corresponding equipment can be used for detect flaw in the part volume and to measure its linear dimensions. In the first case, the indicator of the flaw is the fact of the appearance of a reflected acoustic wave, in the other, the reflection time is measured, and to measure the thickness, it is necessary to know the sound velocity in the material. However, in the above example, the problem of detecting a flaw is easily transformed into a measuring one, namely, determining the flaw depth and its sizing. For defectoscopy, the key problem is the definition of the defect itself. From the point of view of process control, not any detected flaw (discontinuity) is a defect (terms according to [2]), i.e. the reason for rejection or the need to replace parts. Often there is a need to rank the detected defects by their effect on the suitability of the product or the risk of its operation. It is precisely these procedures of tests and technical diagnostics that are critically different from the procedures of measurement. For the latter, the main parameters are their metrological characteristics.

The above problems of metrological support and legislative regulation in the field of NDT industry are sharpen due to the main trends of the 4th industrial revolution. The necessity of NDT procedures automatization requires a reduction of the human involvement in measurement, testing and control. As a result, the initial setup of the NDT tools for the object, the measurement or testing procedure, consideration of the influencing parameters, and the processing of measurement results should be automated. At the same time, the necessity to create means for objective quality control of the measurements and to ensure traceability of the results is increasing.

3. The introduction of non-destructive testing procedure as a separate concept in the legislation on ensuring the uniformity of measurements

The specificity of non-destructive testing and measurement procedures is such that when performing them, it is necessary to simultaneously monitor and take into account many factors. In addition to the standard parameters taken into account in conventional measurements, such as the metrological characteristics of measuring equipment and environmental conditions, these include the properties of the object being controlled, the material from which it is made, the nature of possible defects, the parameters of the probing signal, and many others. A striking example of the influence of material properties on non-destructive testing procedure is the specificity of control of spatial fiber reinforced carbon-carbon composite materials (CCCM), which are actively replacing metal in aircraft and space industry [3]. Ultrasonic NDT techniques are most common for such products. Spatial-reinforced carbon fiber materials are fundamentally different from the metallic by spatial anisotropy of the structure and mechanical properties and, as a result, the velocity of propagation of ultrasonic waves. The nature of the scattering and attenuation of ultrasonic waves in the CCCM is also fundamentally different from metals and alloys, therefore, it is necessary to use transducer of a different frequency and power. The characteristic defects in these materials are no less different: the main type of defects in metals are cracks, and in CCCM, as a rule, stratification and disturbances in the regularity of the structure are observed. Thus, the certified NDT procedure should take into account the specifics of the test object, the material from which it is made, the defects characteristic of this material and product. As a solution to this problem at the legislative level, the authors propose to introduce the concept of the non-destructive **testing procedure**, which is different from the **measurement procedure**. As the main characteristic of the testing procedure, it is proposed to consider the probability of detecting defects in a given range of geometric shapes and sizes. In this regard, it is necessary to note the problem of the development, manufacture and certification of calibration and reference blocks. The authors consider as precarious the attempting to certify reference blocks of defects (terms according to [2]) as reference standard reproducing linear dimensions of defect, since these blocks do not transfer linear dimensions to NDT tools (flaw detectors). Such block can be considered as reference block of the defect only taking into account the geometry of the entire sample, and not only the defect itself, as well as the properties of the material from which it is made.

4. Non-destructive testing as multi-parameter measurements

The above also applies to measurements performed by NDT techniques. These include measurements of wall thickness or coatings by ultrasonic and electromagnetic techniques. The specificity of such measurements is that it is impossible to unambiguously separate informative and influence parameters for the corresponding primary transducers. In particular, eddy current thickness gauges that implement amplitude, phase and amplitude-phase measurement techniques based on the analysis of the electromagnetic field of eddy currents induced in the test object are widely used to measure the thickness of metal coatings [4]. The measurement results of these devices depend on several groups of parameters: electrophysical (specific electrical conductivity of coating and base materials, as well as relative magnetic permeability of base material) and geometric (coating thickness, roughness, curvature radius of the surface, etc.). To ensure the uniformity of thickness measurements by the described method, it is necessary to use reference standard assigned (certified) with over all specified parameters [5]. To solve this problem, a primary standard is being developed that provides measurement of the specific electrical conductivity of the base according to the van der Pauw method; measurement of the complex relative magnetic permeability of metal on annular samples using a permeameter; transferring the value of this parameter to the base of an arbitrary shape with a flat surface; the conductivity of the coating material measurement with the use of an eddy current transducer with a wave-like excitation winding [6].

5. Conclusion

Legislative approval and validation of non-destructive testing techniques, as well as the approach to NDT measurements as to multi-parameter measurements with the creation of appropriate means of metrological support, according to the authors, should contribute to the development of NDT in compliance with modern requirements.

6. References

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