Application of ISO 5725-1-5725-6 for the Validation of Ultrasonic Testing

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Abstract. On the basis of main provisions of ISO 5725-1-5725-6 standards, reproducibility and repeatability in determination of measured characteristics of artificial reflectors and real defects have been evaluated, and suggestions are given for including evaluation of repeatability and reproducibility of measured characteristics in the ultrasonic testing technique (and equipment) validation procedure.

Introduction and statement of problem

During recent decades, the problem of assessment ("validation", "verification", "qualification" …) of non-destructive testing (NDT) techniques attracts close attention of a wide circle of specialists – both developers and "users" of testing techniques. Most researchers estimate quality of techniques by their "trustworthiness" which is characterized by a number of indicators analyzed in detail in [1, 2].

The most complete and accurate assessment of trustworthiness for qualification of an ultrasonic testing technique can be obtained from results of testing a sufficiently large quantity of specimens followed by determining the real defect situation by means of destruction of specimens and analysis of opened cross-sections of the specimens under testing. Naturally, such qualification procedure is practically unacceptable. There exists a possibility of using specimens with artificial reflectors covering the entire range of reflective properties of defects. However, in this case, some uncertainty of the actual defect situation exists since it is characterized by values of measured characteristics of reflectors, determination of which demonstrates significant data spread.

International standards of ISO 5725 series [3, 4] regulate methods for assessment of accuracy in measurements of various physical values in compliance with a standardized procedure (technique) and introduce concepts of reproducibility and repeatability of measurement results.

Main provisions of ISO 5725 standards in terms of NDT

The term "accuracy" when it is related to a series of measurement or test results includes a combination of random components and a general bias [5].

In the process of ultrasonic testing, measured characteristics of defects are determined [6]. A decision on acceptability or unacceptability of defects detected during testing is made by comparing the values of measured characteristics of defects to rejection criteria, values of which are preset also by normative documents for testing. Therefore, the

correct assessment of fitness of the tested object and classification is influenced by the accuracy of defects characteristics measurement.

ISO 5725-1 standard introduces the concept of:

- "correctness" understood as a degree of closeness of a measurement result to the true (actual) value of the quantity being measured, which can be adopted [3] as a mean value of a preset collection of measurement results;
- "precision" which is considered as a degree of closeness between independent measurement results obtained in particular established conditions and depends on random factors only. The measure of precision is usually calculated as standard (root-mean-square) deviation of results of measurements performed in definite conditions.

Also introduced are concepts of "repeatability" and "reproducibility", which are two extreme cases of precision, where the former concept characterizes minimum and the latter maximum variability of results.

In practical interpretation of measurement results, this variability must obligatorily be taken into account. For instance, for assessment of ultrasonic testing results, the obtained value of the measured characteristic of a detected defect (amplitude of the echo signal from the defect, equivalent area, conventional extent, etc.) is compared to the threshold value established by the relevant normative document [6]. However, the actual difference between the obtained result of measurements and the preset value, of course, cannot be established if they both lie in the region of inevitable random errors of the measurement procedure.

In consideration of difficulties in assessment of trustworthiness of non-destructive testing techniques, and taking into account that application of the reproducibility and repeatability concepts is possible even if information about the actual value of the measured quantity is unavailable, an attempt is made in this report to use them for comparative assessment of ultrasonic testing techniques.

Evaluation of precision in determination of measured characteristics of artificial reflectors and real defects

The most important measured characteristics of defects, in accordance with various normative documents, include: defect coordinates, maximum echo signal amplitude (or detectability factor), conventional extent measured by various methods. The detectability factor Kd is the difference, in dB, between amplitude of the echo signal from the defect and amplitude of the echo signal from a certain artificial reflector.

In order to assess precision of determining the depth of artificial reflectors location, results of measurement of lateral cylindrical holes were used. The measurements were carried out by operators of the same level of skills. Flaw detectors of the same type with incidence angles of 50^{o} and 65^{o} were used. The results of precision assessment in determining the depth of artificial reflectors location are presented in Figure 1.

It is known that the error in determination of defect location depth increases with increasing the angle of incidence [6, 7]. Accordingly, worse reproducibility of reflectors location depth measurement shown in Figure 1 can be attributed to an increased direction-finding error when a transducer with a large angle of incidence is used.

In order to assess precision of determining the conventional extent and detectability factors of artificial reflectors, we used results of tests on specimens that had models of

defects on their surfaces made in the form of vertical cylindrical holes from 2 to 4 mm in diameter. The weld itself was simulated by a bar that, at the same time, hid existing reflectors from the operator. Testing was carried out by two groups of operators. The first group included operators without practical experience while operators of the second group had working experience longer than 10 years. In the process of testing, the operators performed scanning and determined measured characteristics of reflectors.

Each point in Figure 2 corresponds to results of conventional extent measurement of a definite diameter hole averaged for a group of five operators. First of all, Figure 2 confirms that the average value of an undirected reflector conventional extent measured by a relative method does not depend on the reflector diameter. Reproducibility of conventional extent measurement results is, naturally, higher for experienced operators than for those without work experience.

Accordingly, depending on the minimum conventional size of the defect preset by the testing technique, and taking the precision evaluation data into account, a conclusion can be made that it is possible to fulfill the technique requirements during testing, in the given case, by operators having different skills. It follows from Figure 2 that, if minimum conventional extent of an unacceptable defect is 15 mm, then the requirements of such technique will be fulfilled even by low-skilled operators, and if it is 10 mm, then such technique can be realized only by operators having experience in the work.

For studying reproducibility and repeatability of determining measured characteristics of actual defects, three skilled operators measured detectability factors and conventional extents of real defects of lack-of-fusion type (5 mm and 10 mm long) in butt-welded joints with a direct beam (m = 0) and a singly reflected beam (m = 1) using transducers with incidence angles of 65^{o} and 50^{o}, respectively.

Thus, determination of measured characteristics of defects can be quantitatively characterized by reproducibility of results, which depends primarily on the operators' skills and, in some cases, on testing parameters. It should be noted that the purpose of experiments in reproducibility and repeatability determination is to find the limits within which results may vary in practice, which is rather important information for establishing rejection criteria by which the operator makes a conclusion about acceptability or unacceptability of a detected defect.

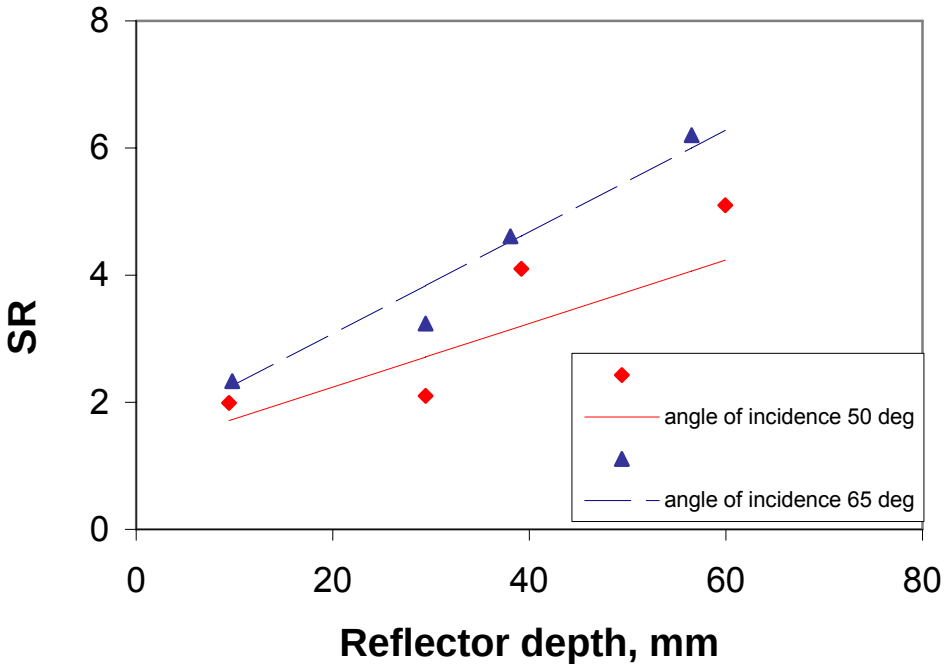

Figure 1: Reproducibility of reflector depth measurements (11 operators 10 measurements each)

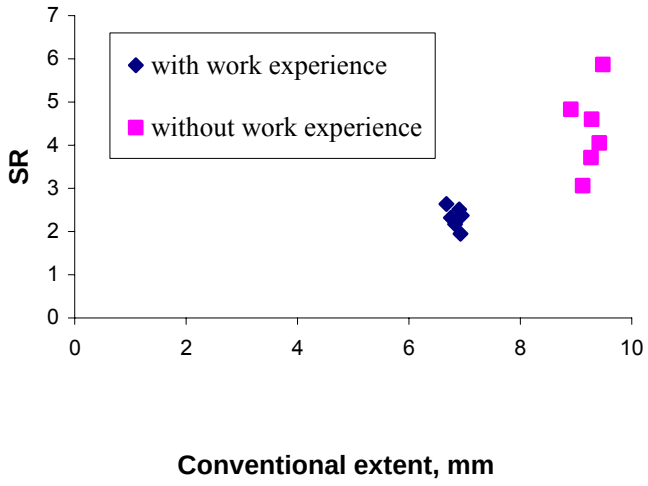

Figure 2: Reproducibility of conventional extent measurements for vertical cylindrical holes (10 operators, from 5 to 8 measurements)

Assessment of reproducibility as a tool for qualification of ultrasonic testing techniques (equipment)

Thus, it has been shown that quantitative assessment of an ultrasonic testing technique during its experimental study can be performed by determining reproducibility and/or

repeatability of determination of measured characteristics of defects to be detected in compliance with requirements of NDT technique.

For experimental determining reproducibility and/or repeatability of determination of measured characteristics of defects in compliance with requirements of NDT technique:

- specimens are prepared having real or artificial defects whose size correspond to minimum characteristic sizes of defects to be detected;
- characteristics of defects in prepared specimens are measured; reproducibility and repeatability of determination of measured characteristics of real defects or reflector models are evaluated

The same procedure can be used for qualification of ultrasonic testing equipment.

Experimental check of the possibility to evaluate reproducibility of measurement results for qualification of ultrasonic testing equipment has been carried out for ultrasonic thickness gauges.

Determination of thickness of metal structures was performed by four operators of the same skills using three types of thickness gauges. All measurements were performed 10 times on specimens of different thickness.

Figure 3 shows the difference in reproducibility of thickness measurements by various instruments, which allows the justification of the selection of a particular thickness gauge for inspection of elements having thickness in a definite range.

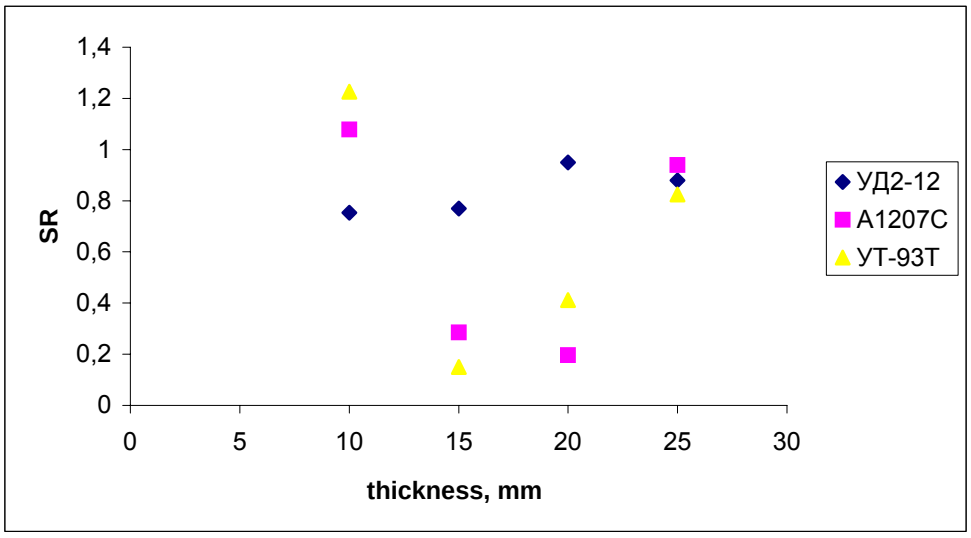

Figure 3: Reproducibility of thickness measurements of metal structure components by thickness gauges of various types

Conclusions

1. Determination of measured characteristics of defects can be characterized quantitatively by reproducibility of results which is in compliance with the procedures described in standards of ISO 5725 series.
2. The possibility of quantitative assessment of a technique (equipment) has been demonstrated. The quantitative assessment of an ultrasonic testing technique during its experimental study or during application can be carried out by determining the reproducibility or repeatability of the determination of measured characteristics of

defects to be detected with a particular NDT procedure or particular ultrasonic testing equipment with affordable effort.

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