Evaluation of the Reliability of Ultrasonic Testing Russian Railway Transport

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Abstract. Algorithms to estimate ultrasonic testing method based on the integrated use of indicators of reliability and accuracy, and built according to the nature of techniques, features of their application and evaluation purposes (comparison techniques, the introduction of new methods, containing test procedures, etc.). On the basis of the main provisions of ISO 5725-1, 5725-2 the estimate reproducibility and repeatability of measured characteristics determine the design of reflectors and real defects and reliability of non-destructive, including ultrasonic inspection of railways

One of the main problems of ultrasonic testing techniques reliability evaluation is obtaining of information about a real defect situation of the test object, used for experimental determination of confidence index. To collect information about a real test object defect condition it is necessary to conduct special studies with following cutting of sections marked as “defective”.

In studies conducted by the Institute for bridges & NDT to identify moulded pieces defects of car trucks using two methods (M1, M2) side frames and bolsters of car trucks 18-9810, 18-9841, 18-100 №№ 577, 679, 742, 1033, 8764, 8410, 8607, 8488, 7745, 8451, 608339 were tested before and after heat treatment. Defected and unfailing pieces were chosen randomly. Sequential inspection of pieces using two methods in accordance with current technological documentation was carried out by two – four inspector teams independently. Results of inspection are shown in table 1.

Table 1. Inspection results using two methods

M1	**Conjunction**	**M2**
144	3	96

Thus, using two inspection methods, there were found totally 240 “defected” sections, of which for both methods coincided only 3. For confirmation were chosen 51 “defected” sections, including: 15 “defected” sections found using method M2, 39 “defected” sections found using method M1. For inspection results confirmation were performed cutting and metallographic analysis (Pic.1).

Metallographic analysis results of 49 “defected” sections proved the presence of defects only in 36 sections. Thus, the relative frequency of defects detection using inspection method M1 is 0,94, and using inspection method M2 - 0,06. The relative frequency of false detection is 0,08 and 0,92 respectively. With the small amount of specimens and large and small values of detection relative frequency and false detection, it is possible to find the probability of detection P_{11} and probability of false detection P_{01}

using found relative frequency values. Considering the number of test object specimens the values of corresponding probabilities are found for confidence probability 0,95, which ere also shown in table 2; they differs from the relative frequencies of defect detection and false detection, and the minimum value is taken for defect detection probability while for false detection probability - maximum.

Pic. 1. Cutting of side frame №742; in zones, marked by results of testing by method M2 internal flaws were not detected

Table 2. Estimation of inspection data using results of visual inspection and cutting

Method	**Relative frequencies (38 defected, 13 fault-free)**		P_{11}	P_{01}
M1	38/38	3/38	0,86	0,017
M2	1/13	12/13	0,36	0,988

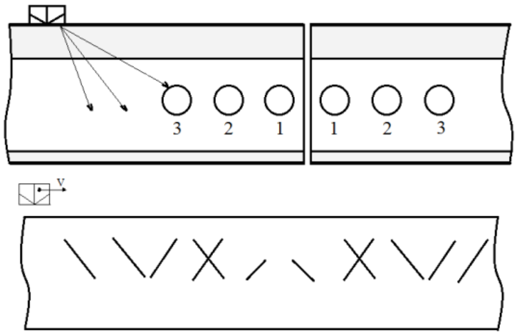
Thereby, the correct definition of confidence index is impossible without cutting of “defected” sections found, that is complicated and expensive way.

Considering that in most ultrasonic testing techniques the decision about test object quality is made by comparing of main defect test feature or defect test feature complex with specified rejection criteria, there is a problem of evaluation of the measurement accuracy of defect test features. Evaluation of the measurement accuracy according to ISO 5725 involves an analysis of measurement repeatability and reproducibility. The purpose of repeatability and reproducibility analysis is to define which part of measurement results variability is caused by the difference of defect parameters, inspectors or inspection apparatus (reproducibility) and by the measurement errors, when the same operators inspect several times the same objects using the same apparatus (repeatability).

Consistent with the work tasks there were treated the previously obtained by Bridge Research Institute results of ultrasonic testing of rails with artificial defects. Studies were carried out on test section of track Mytischi-Pirogovo of Moscow Railway, designed to test functionality of ultrasonic inspection trains and removable rail flaw detectors. Defectograms were interpreted (conditional dimensions of rail bolt holes were measured) for each of five passes (forward and reverse directions, Pic.2) over the test section of track (15 rails) of two removable rail flaw detectors, which are marked by convention as:

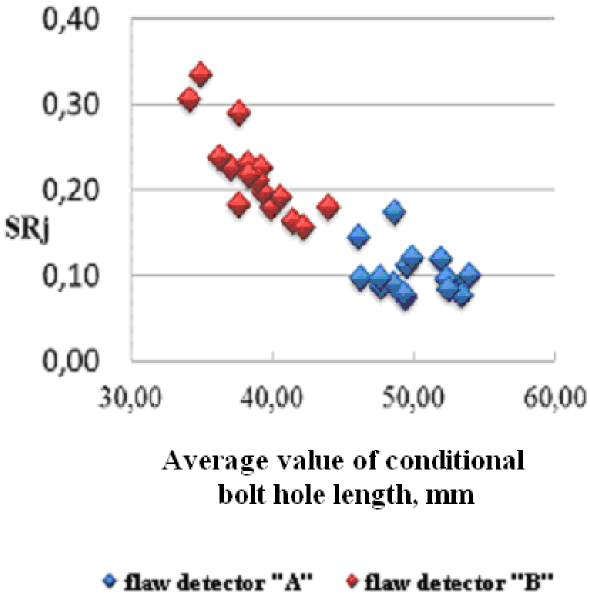
- removable rail flaw detector «A»;
- removable rail flaw detector «B».

Main parameters of ultrasonic testing: frequency of ultrasound 2,5 MHz, refraction angle $\alpha=42^0$, conditional sensitivity 14 dB.



Pic.2 – B-scan for bolted rail joint

Results of defectograms interpretation gave 1800 values of conditional bolt hole dimensions for each rail flaw detector. Standard deviations of repeatability and reproducibility of conditional bolt hole length measurement results were calculated according to ISO 5725 [1] (Pic.3). Number of defected artificial defectes flaw defector A – 44,5; flaw defector B – 40,8.



Pic.3 - Reproducibility of conditional bolt hole length measurement

For rail flaw detectors “A” and “B” there is a difference in mean values of conditional bolt hole length, i.e. measurement results of conditional bolt hole length by different rail flaw detectors, with the same main parameters, differ from each other, which leads to the difference of inspection results in case of detection and parameter measurement of real defects by means of different rail flaw detectors. This difference can be attributed to the partial loss of coupling, which leads to the reduction of conditional length value and increase of reproducibility standard deviation, i.e. to the reduction of measurement accuracy. There is a correlation between the reduction of reproducibility of measurement results of conditional bolt hole length and the reduction of detected defects number (Figure 8) for different types of rail flaw detectors.

Studies of the impact of loss of coupling on the measurement results of conditional bolt hole length were continued by the results of track sections inspection on North Railway: sections with high traffic volume (less then 800 MGT and more then 800 MGT), with small radius curves (450 m and 500 m) and with low traffic volume. 30 passes are analyzed for different flaw detectors: testing vehicles – ultrasonic testing trains and removable rail flaw detector (rail flaw detector C), 60 km of track totally, for loss of back wall echo.

As measurement results length of back wall echo loss zone was used in mm per one km of track. The resulting data confirmed the effect of the curvature of the way and missed tonnage, that is wear by the amount of loss of bottom signal.

Thus, for validation of techniques it is usable to assess also reproducibility of evaluation of defects measurable parameters or coupling condition, which show both inspection conditions and inspection techniques specialties.

Conclusions

The most complete non-destructive testing technique is characterized by eliability, the determination of which is complex and expensive procedure. One of the stages of technique validation can be assessment of reproducibility and repeatability of results of the determination of the measured characteristics in accordance with ISO 5725, for example, conditional extension, and the length of back wall echo loss zone.

References

[1] ISO 5725: 1994 Accuracy (trueness and precision) of measurements methods and results