Rejection of Welded Connections According to EN ISO 10675: a New Approach to Increasing Objectivity

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Abstract. The currently applied criteria of identification of imperfections based on results of Radiographic Testing have no unambiguous description in regulatory documents. Therefore, there is a lack of coherence between opinions of the experts who are interpreting images on radiographic films. Authors suggest dividing images of imperfections into classes, each of which includes imperfections with similar projections on radiographs. This allows to simplify the identification procedure and to increase repeatability of results of the interpretation which is carried out by different experts independently.

1. Introduction
The purpose of Radiographic Testing (RT) is to obtain images on a radiograph [1]. After comparing characteristics of the shadow image of a imperfection with the admissible values established by regulatory documents, the experts decide whether the welded connection complies or not with requirements provided by regulatory documents.

Characteristics of the image of imperfections on radiographs, determined by results of the analysis, are: imperfection type, length and width of the imperfection, summary length of imperfections within \( L \) (\( L \)- any 100 mm testing length, in millimetres), etc.

As a rule, there are area and shape distortions in images of imperfections on radiographs. Considering that, as well the absence of practical recommendations about the analysis of discontinuity images, it is impossible in most cases to define unambiguously the type of defect which created a specific projection on a radiograph [2, 3].

For example, projections of such imperfections as porosity and gas pores (201 according to EN ISO 6520-1) and slag inclusions (301) are extremely difficult to be distinguished. There are strong similarities between projections of lack of fusion (401), cracks (100), elongated slag inclusions (301), shrinkage groove (5013), lack of penetration (402) [4].

Absence of accurate and clear criteria of sorting imperfections leads to essential differences in results of interpretation [5].
Study [5] contains statistical analysis of results of interpretation of 10 radiographs of welded connections. The interpretation was independently carried out by 9 experts, all of them RT-certified for 2nd or 3rd skill level and having a practical work experience from 3 to 30 years. The purpose of the study was to assess the influence of a subjective factor on results of interpretation. The assessment of the degree of coherence between opinions of experts on identification of the revealed imperfections was carried out gradually:

- Taking into account the results of the interpretation carried out by the experts, the authors determined all statistically significant events (imperfections identified by more than 50% of experts).
- The authors then counted the coincident (and not coincident) decisions made by the experts on identification of the same imperfection projection. For each couple of experts and each discontinuity type, a contingency table (binary matrix) was composed as follows (see Table 1):

| Experts | no | yes | total |
|---------|----|-----|-------|
| no      | 1  | 3   | 4     |
| 1       | (a)| (b) |       |
| yes     | 2  | 2   | 4     |
| total   | 3  | 5   | 8     |

- The contingency coefficient (four-point –\(\phi\)-correlation), a quantitative measure of coincidence in sorting a discontinuity projection within each couple of experts (e.g. categorizing it as porosity and gas pores, including the extended ones, slag inclusions, including the extended ones, lack of penetration, lack of fusion, cracks, root concavity, shrinkage groove), was determined for each contingency table according to the formula (1) (see Table 1):

\[
s_{ij} = \frac{a \cdot d - b \cdot c}{\sqrt{(a + b) \cdot (a + c) \cdot (b + d) \cdot (c + d)}}
\]

- The obtained contingency coefficients were grouped within intervals characterizing "force" of coherence between opinions of experts: depending on value of contingency coefficient, the level of correlation between decisions of experts has been set as follows: [-1; 0.3) – weak coherence, [0.3; 1] – strong (acceptable) coherence [6].

2. Results and discussion

The static experiment carried out according to the described technique shows a weak coherence between opinions of experts: when identifying a slag inclusion (301), strong coherence is observed only in 27.3% of cases, when identifying a lack of penetration (402) – in 8.3% of cases. The acceptable coherence of experts’ opinions when sorting projections of imperfections by types of considered defects was established only in 35.3% of cases.

It should be noted that rationing of the admissible sizes of defects makes sense only for a specific controlled object (part of object) and for established operative conditions. However, traditional RT only allows to define presence of discontinuity projections on radiographs [7, 8]. As shown above, radiographs do not allow to identify at the acceptable accuracy level even the discontinuity type, let alone such parameters as discontinuity curvature on all its surface, discontinuity depth, its orientation within the controlled object. However, those parameters are necessary for strength calculations [9].
Taking into account this fact, as well as the ambiguity of the existing criteria, acceptance levels based on RT results should be considered as a way of maintenance of technological discipline in the conditions of a specific industrial site and process. It allows to reject standard approaches to the RT-assisted quality evaluation based on defect type definition and to develop new criteria, whose application will increase repeatability of radiograph interpretation results. The developed criteria should comply with following requirements:

- Rules of identification of discontinuity images have to be unambiguous.
- The result of application of the developed criteria has to maximally coincide with results of the evaluation of quality (rejection) which is carried out according to the operating criteria.
- Application of the developed criteria has to provide significantly strong coherence of opinions.

To address the above problems, authors suggest dividing images of imperfections into classes, each of which includes defects of various types, but with shape-similar projections. For this purpose, it is expedient to use the criteria used in Ultrasonic Testing (UT): if the maximum sizes ratio of a projection is more than 5, it is considered as extended, 4 to 3: elongated (longish), 2 to 1: roundish. This classification takes into consideration influence of various types of defects on reliability of welded connections.

Implementing the above approach allows to increase quantity of cases of strong coherence (coincidence of opinions). It is confirmed with the results of experiment [10] involving 6 experts who were carrying out interpretation both according to proposed criteria and to those contained in the operative Russian regulatory documents (RD-25.160.10-KTN-016-15 was used as the example). This fact makes expedient attempts of broader application of the offered criteria of identification, e.g. for increasing objectivity of EN ISO 10675-1 requirements. Previously, a number of problems should be noted in this document:

- The provided norms of quality evaluation (rejection) for linear porosity and clustered porosity based on area of the defective site are less rigid than those for the single layer porosity and gas pores, which does not match with strength calculations and with numerous experiments carried out in order to establish influence of these imperfections on reliability of a welded connection [11]. So, to match the Admissibility Threshold 2, the area of the defective site with single layer porosity and gas pores should not exceed 1.5%, with clustered porosity: 8%, with linear porosity: 4%.
- The standard contains no definition of clustered porosity and linear porosity. Besides, various norms of quality evaluation (rejection) for cases of multilayered and single layer distribution of imperfections are provided in the document. This cannot be unambiguously established by results of application of traditional RT.
- The standard provides various norms of quality evaluation (rejection) for lack of fusion and shrinkage groove (imperfections which often is determined only by results of RT) in spite of the fact that their projections on radiograph are similar.
- The norm of quality evaluation (rejection) used in the standard for linear porosity (sum of projected areas of indications related to \( L \cdot w_p \), in % (\( A \)) – is not optimum. For example, at \( A=8\% \) (maximum admissible value for single-layer clustered porosity at the Admissibility Threshold 3) the above norm considers as admissible the existence in welded connection of 17 pores with a diameter of 3 mm, situated in sequence at a 3 mm distance. We consider that the total length of porous clusters at \( L=100 \) mm would be a more appropriate parameter for rejection.
3. Conclusions

In order to eliminate the above problems in ISO 10675-1 and according to the accepted approach to the identification of discontinuity projections, we suggest to accept the quality evaluation criteria provided in Table 2.

Table 2. Norms of quality evaluation (rejection) for various image categories (as exemplified by Admissibility Threshold 3 according to ISO 10675-1)

| №  | category of defect images | defect types corresponding to a category (ISO 6520-1) | Offered criteria of assessment (rejection) |
|----|--------------------------|-------------------------------------------------------|------------------------------------------|
| 1  | S (single)               | 2011                                                  | $A \leq 1.5\% \text{ at } L=100 \text{ mm}$ |
| 2  | C (cluster)              | 2013                                                  | $d \leq 0.3 \text{ s, but not exceeding 3.0 mm}$ |
| 3  | El (elongated)           | 2015, 2016, 301                                       | $h \leq 0.3 \text{ s, but not exceeding 3.0 mm}$ |
|    |                          |                                                       | $\Sigma l \leq s$, but not exceeding 50 mm within $L=100 \text{ mm}$ |
| 4  | Ex (extended)            | 402, 5013, 401, 2014                                   | not admissible                           |
| 5  | Cr (crack)               | 100                                                   | not admissible                           |

$d$: diameter of a roundish discontinuity projection  
$l$, $h$: length and width of a discontinuity projection  
$s$: weld thickness  
$L$: basic length.

It is obvious that the quality evaluation (rejection) carried out according to the offered technique is more transparent and allows to disambiguate the ISO 10675-1 to a certain extent. Besides, the researches [10] conducted earlier allow to count on a bigger repeatability of results of control, which can be checked if necessary according to the technique described in the article. However, the practical use of the offered identification criteria is only possible in case there will be established, for categories of images, a set of norms who, being used, will produce results identical to those of rejection according to the operating criteria. As we see, the above mentioned problems existing in ISO 10675-1 will not allow to do so. For this reason, expediency of introduction of the offered criteria can be only comprehensively studied in the course of ISO 10675-1 revision.

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