QUALITY ASSESSMENT OF THE WELDING OF COMPONENTS OF THE BURNING WALL IN THE CASE OF THE ENERGY BOILER

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Abstract: The quality of joints in welded structures very often determines their suitability for further safe operation. The quality of welds assessed at least B, according to the PN-EN ISO 5817 standard, is the criterion for allowing many welded structures to be used in working conditions. The quality level B can be considered good, provided that the tested construction is not intended for use in extreme working conditions or in high-risk conditions. Strict acceptance criteria are applied to such environments, and the welds tested preferably meet the requirements of class B and do not have any defects. Even small discrepancies in the form of blisters, concave faces, etc. (qualifying for quality class B welds) should not be found in welds used for responsible steel constructions working in hazardous conditions. These defects may cause a loss of consistency of the material and, consequently, lead to a serious disaster. The article evaluated the quality of welded joints of selected welded elements of a power boiler. The inspection of welded joints was aimed at confirming the correctness of their performance and compliance with the technological and construction documentation as well as with the tightened technical acceptance conditions. As a result of visual and non-destructive tests, ultrasonic joints were allowed or withdrawn from further safe operation.

Keywords: quality, welded joint, power plant boilers, product quality.

1. Introduction

The quality of welded joints determines the reliability and durability of the product. It is therefore important to properly control the quality of welded joints. In production processes, quality control must be ensured before, during and after the entire welding process (Gęmbalska-Kwiecień, 2017a; Gembalska-Kwieciek, 2017b; Hadryś et al., 2016; Szczucka-Lasota, and Wolniak, 2017a; Szczucka-Lasota et al., 2017a; Szczucka-Lasota et al., 2017b; Szczucka-Lasota et. al., 2016; Wolniak, 2016; Wolniak, 2014; Wolniak, 2017a; Wolniak, 2017b; Wolniak 2018; Wolniak and Skotnicka-Zasadzień, 2014; Wolniak and Skotnicka-Zasadzień, 2017; Węgrzyn et al., 2016a; Węgrzyn et al., 2016b; Węgrzyn et al., 2017).

In many cases it is also justifiable to control welded joints during the product life cycle. The purpose of controlling welded joints is to ensure the proper quality of the product as well as welded structures (Piwnik et al., 2017; Rachwał et al, 2014; Rachwał et al. 2016; Rachwał et al., 2017; Rachwał and Wolniak, 2015; Rachwał and Wolniak, 2018a; Rachwał and Wolniak, 2018b). The weakest element determines the lifetime of the entire structure. Inspection of welded joints is aimed at confirming their correctness and compliance with technological and construction documentation as well as with technical acceptance conditions. Industrial boilers belong to the group of welded structures. The quality of joints of these constructions depends primarily on the quality of the welds (Restecka and Wolniak, 2018, Restecka and Wolniak, 2017a, restecka and Wolniak, 2017b, Restecka and Wolniak, 2016; Wolniak and Restecka, 2017; Wolniak and restecka, 2018)). Boilers as an energy facility must be characterized by adequate durability and operational readiness.

The assessment of the status of power units is of considerable economic and technical importance. They are carried out in order to determine the suitability for further work in specified conditions, selection of elements and planning their evaluation, testing, repair, modernization or replacement and determining the time of further operation, which will be safe. The assessment of weld quality is one of the main components of the boiler wall element evaluation (Łuczak, and Wolniak, 2015; Pacana et. al., 2017; Pacana et al., 2016; Skotnicka-Zasadzień, 2014; Skotnicka-Zasadzień, and Masoń, 2016; Skotnicka-Zasadzień et al., 2017; Szczucka-Lasota, and Wolniak, 2017b; Sułkowski, and Wolniak, 2018). In order to ensure safety when using welded constructions, the quality levels of welded joints or the adequately determined limit values of the non-compliances checked are assumed. The quality level is determined by the designer with the fact that the quality level refers to individual joints or welds and not to the whole structure (Cieślik, 2017).

The firing chamber plays a very important role in the operation of power boilers. It must not be allowed to be unsealed, which could cause serious danger. In this case, the power plant is forced to emergency shutdown of the boiler for the period of repair, which is associated with huge parking costs for the company. That is why it is so important that all welding works of the discussed structure are made at the highest possible level. A defect in one weld can cause a serious disaster.

The aim of the paper is to presents the analysis and assessment of the weld quality of a fragment of the furnace chamber wall in a power plant. Through visual and radiographic examinations it was possible to detect the occurrence of defects in the welds after the welding process. As part of the work, a visual assessment was made as well as an analysis of the radiographic examination results was carried out.

Conducted research enabled classification of welds, identification places of occurrence of nonconformity and also the quality and classification of welds was assessed. As a result of the research, a decision was made to replace some connections in the structure.

2. Subject of research

The welded joints of the boiler elements of the boiler were subjected to testing. The entire length (100%) of welded joints on the fragment of the front wall of the furnace chamber was subjected to testing. The area of the study was welds and the zone of heat influence. Welds were intended for the study immediately after the welding process. 16M steel was welded, i.e. a low-carbon steel with a ferritic matrix retaining good ductility and ductility – both hot and cold. The chemical composition of steel is given in Table 1.

Table 1.
Chemical composition of 16M steel [%]

Chemical composition	C	Mn	Si	$P_{(max)}$	$S_{(max)}$	$Cr_{(max)}$	$Ni_{(max)}$	Mo	Al
[%]	0,12-0,20	0,50-0,80,	0,15-0,35	0,040	0,040	0,30	0,35	0,25-0,35	0,2

The increased content of molybdenum and the presence of chromium determined the use of the steel in question for structures operating in conditions of elevated temperature and in a corrosive environment in which water vapour evolves. In addition, this steel is characterized by high resistance to creep, resistance to long-term loads, stability of mechanical properties, hence its allocation to the elements of power boilers.

The research material consisted of butt welds, welded joints made by TIG (arc welding with a tungsten electrode – tungsten in the shield of inert gases) in the discussed steel. During the test, safe and adequate access to all welded joints was ensured.

3. Method, purpose and scope of research

The visual tests were carried out on ready-made welded joints in appropriate conditions in accordance with Chapter 3 of PN-EN 970.

The purpose of the test was to check to what extent welded joints meet the requirements of the PN-EN ISO 5817 standard. It should be noted that in the case of visual assessment of welds of the fragment of the furnace chamber wall, no cleaning or post-welding treatment was performed earlier. The parameters, such as the shape and dimensions of the weld, were therefore evaluated. It was checked whether the profile of the weld surface as well as the risers meet the requirements of the standard, whether the weld surface is regular, whether the stitch intervals are even and do not raise any objections and whether the width of the weld is the same along the entire joint.

The next step was to check the quality of the weld face. It was checked if all leaks, burnouts, flooding on the entire length of the joint are within the limits set in the standard. The final result of the study was compared to the criteria presented in the PN-EN ISO 5817 standard and the weld quality class was determined.

In order to determine the dimensions of welded joints and the geometrical dimensions of non-conformances that may occur on the surface of the joints, appropriate devices and measuring instruments were used that had valid calibration certificates. We used, among others Luxmeter used to measure light intensity, a magnifying glass and a flashlight as a source of light, indelible markers and personal protection equipment. The equipment before the test was checked for its purity, completeness as well as technical efficiency. During the visual examination, the illuminance on the tested surfaces during the evaluation was 550 lx, while the distance of the test, i.e. the distance from the eye to the test weld, was about 500 mm. The evaluator examined the weld at an angle of 30 to 90 °. The lighting direction is not it could cause dazzle, shadows, and did not distort the assessed surface. Visual and general examinations are carried out during visual examinations. General consisted of: identification of the tested object, checking the completeness of the object, checking whether the joints they are also welded completely, checking whether the object and welded joints are suitable for testing in terms of cleanliness. During the detailed examination, the intensity lighting on the surface of the test was checked, the place where the welds crossed, any possible incompatibilities on the surface of the joints were identified and the characteristic dimensions of the identified non-conformities were measured.

After completed preliminary visual examinations, radiographic examinations were performed for which the Sentinel E1375 flaw detector was used. The test was carried out in accordance with the requirements of the regulations and according to the PN-EN ISO 10675-1 standard, with the examination of the joints examined by two walls. It was impossible to use a different geometrical system. The semi-elliptical method was chosen to assess the quality of welds in the part of the chamber wall. In this method, the image obtained on the radiograph for the quality assessment has the shape of an ellipse. This method is used because the perimeter seam is not accessible from the inside, and the welded pipe is of small diameter which forced the focal distance to be increased (Hadryś, Węgrzyn, Piwnik, Wszołek, Węgrzyn, 2016).

4. Results and their analysis

Visual inspection was carried out on 5 butt welds. The welds for the needs of the study were marked with the subsequent letters of the alphabet A, B, C, D, E.

The tests were carried out in accordance with the methodology presented in Chapter 2 of the article. The results of the tests were referred to the PN-EN ISO 5817 standard. In the course of visual tests it was found that welds with numbers C, D, E have face cavity, which according to the PN-EN ISO 5817 standard means incompatibility 511. The face groove is an elongated intermittent or continuous channel on the surface of the weld caused by insufficient amount of additional weld material. According to the standard, the tested welds have been classified to the quality level B. These joints are most often suitable for further use, provided that they are not exposed to particularly difficult operating conditions. In the analysed case, the dimensions of the limit value of the identified welding non-compliance do not disqualify them from the quality level B, however, the stricter requirements for welds used for power boilers can be the basis for disqualifying the discussed welds from further safe operation. During the visual assessment, no other external incompatibilities were found for the analyzed welded joints. Evaluation of weld quality in terms of their defectiveness it is therefore based on an analysis of the type of impact and the magnitude of non-compliances that have occurred. It was assumed that in the course of further research it should be determined whether the identified defects have a significant impact on the strength of the welds during the operation of the structure exposed to various types of loads.

The reduction of strength through the occurrence of incompatibility is usually the result reduction of the active cross-section of the weld and accumulation of stresses alongside defects, the so-called notch effect. Therefore, a detailed analysis of the obtained results, allows to conclude that the discussed welds can be allowed to be used only when the results of supplementary tests assessing the quality of the performed connection by means of radiographic examination will be appropriate. Otherwise, corrective measures should be taken, such as: cutting the weld with a grinder and re-welding. The mere assessment of weld defects is difficult.

Radiographic examinations were carried out in accordance with the methodology described in PN-EN 1435: 2001/A1. The analysis of the radiographs obtained allows to state that no faults were found in welds A and B (according to PN-EN ISO 10675-1, PN-EN ISO 5817, PNEN ISO 6520-1). These welds are characterized by high quality of the joint made and can be accepted for further safe operation.

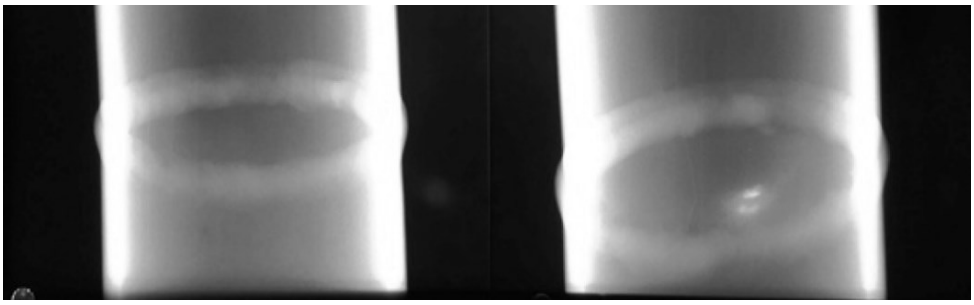

Figure 1. Radiographic examination of welds A and B. Source: Cieślik, J. *Ocena jakości spoin na wybranym fragmencie ściany kotła energetycznego elektrowni Siersza za pomocą badań wizualnych oraz radiograficznych, praca dyplomowa*. Promotor dr inż. B. Szczucka-Lasota. Katowice: Wyższa Szkoła Zarzadzania Ochroną Pracy, s. 43.

On joints C, D, E, a defect in the form of face dentition (defect number according to the standard – 511) was confirmed and an additional discrepancy was found. This incompatibility is a gas bubble (no defect according to the norm – 2011). Bladder was observed in welds D and E.

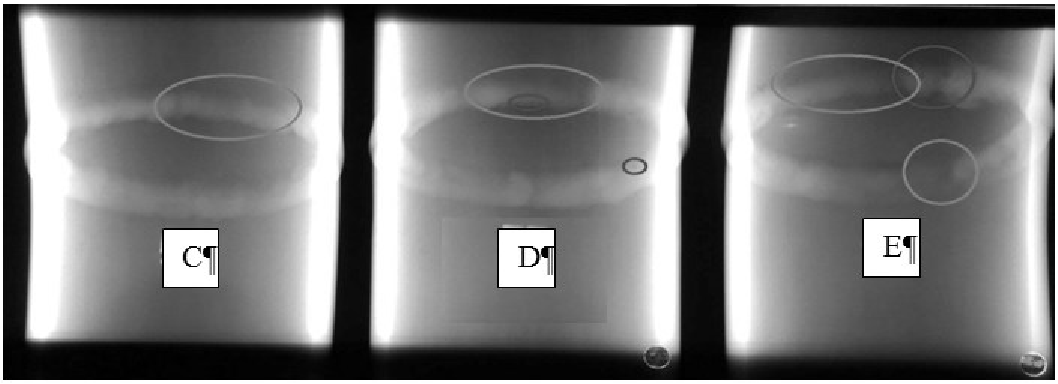

Figure 2. Radiograms of welds C, D and E with marked defects. Source: Cieślik, J. *Ocena jakości spoin na wybranym fragmencie ściany kotła energetycznego elektrowni Siersza za pomocą badań wizualnych oraz radiograficznych, praca dyplomowa*. Promotor dr inż. B. Szczucka-Lasota. Katowice: Wyższa Szkoła Zarzadzania Ochroną Pracy, s. 48-50.

Like a concave face, a gas bubble is a disadvantage that may be acceptable. The admittance of the element with the joint in which the blisters were observed depends mostly on the percentage of blisters on a given section or the entire weld.

In the analysed case, according to the PN-EN ISO 5817 standard, the identified gas bubble (defect number 2011) was determined as a percentage on the entire length of the weld. It was found that the identified size and number of blisters is acceptable, and the welds according to the PN-EN ISO 6520-1 standard characterize the first level of quality (class B).

Despite the very good quality results, the occurrence of both dented face and blisters was considered a sufficient condition to make a decision on replacing welds with new ones. In the case in question and with the stricter conditions set for joints working in boilers, it was considered that joints with C, D and E joints would not constitute a secure connection of the welded structure. The documentation received from the client contained precise guidelines that any non-compliance, even those that fall within the margin acceptable for the highest quality level, should be removed.

5. Conclusion

Analysis of the causes of non-compliance allows to conclude that the identified face cavity (on three welds) is the result of inaccurate welding process in forced positions. These items require significant operator experience. To make new welds, a team more experienced in welding this type of construction was hired.

Research suggests that there are discrepancies in the welds marked C, D, E. According to PN-EN ISO 6520-1, PN-EN ISO 5817 and PN-EN ISO 10675-1 norms, classifications were defected, i.e. gas bubble – 2011 (for welds D and E) and face dentition – 511 (for welds) C, D, E). Measurements of the size of identified defects in terms of standards, it can be stated that, nevertheless, the welds are characterized by the highest quality class of welds B. When interpreting results based on standards, it should be emphasized that the quality levels thus determined correspond only to the quality of production and not the usefulness of the product. Therefore, despite the highest quality class (class B), the occurrence of identified welding defects excludes welds from further safe operation. The test results in relation to the requirements for welds used for power boilers confirm this fact. The stricter requirements recorded in the documentation commissioning the joints clearly indicate that the welds must be replaced. In connection with the above, test reports were prepared and corrective measures were proposed. Welds were cut with a grinder and re-welded. The test results and proposals were forwarded to the client.

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