QUALITATIVE ANALYSIS OF A WELDED STRUCTURE BASED ON A TEMPORARY BRIDGE CONSTRUCTION – A CASE STUDY

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Abstract

Currently, manufacturing companies operate in difficult market conditions. The demand for specific products depends on many factors, including mainly meeting customer requirements by the offered goods. Due to the variety of offers available on the market, users have ever bigger and stricter requirements. At the same time, ensuring high quality products and optimizing the company's operations requires the use of appropriate solutions that allow for an effective combination of these two aspects. In the case of the welded structure of a temporary bridge, the appropriate quality of the welds is a very important role. Therefore, after the final assembly of the structure, a detailed analysis is carried out. For this purpose, specific methods are used, the task of which is to identify and assess the occurring non-conformities. The article discusses the issues related to the corrosion protection of the welded structure surface. An analysis of the results obtained by using the control method in the study was carried out, and on this basis, the identification of any non-conformities was made. Finally, recommendations for companies in the metal industry are presented, which will allow for quality improvement in the production process.

Keywords: Welded structure, quality, production, efficiency, non-conformities

1. INTRODUCTION

The inspection of welded joints is crucial to ensure the appropriate quality and safety level of steel structures. This is due to the fundamental influence of these elements on the durability and strength of the constructed buildings. For this reason, the issue of control is strongly procedural, and various types of methods and variations of these methods are used for control. It should be noted that errors in the welds may have various consequences, depending on the type of structure [1]. Among them should be mentioned in particular:

- structures at a special level - in which the defects may cause serious consequences, such as stresses that may result in cracking,
- main structures where the consequences of defects may affect the durability and strength factor,
- auxiliary structures for which the defects do not have significant consequences.

Weld testing methods allow for the verification of obtaining appropriate quality levels and the detection of non-conformities. The appropriate class of construction and quality levels are assumed by the designer before the start of production and at the time of establishing specific terms of the contract with the customer. Quality levels relating to the joints in a structure of steel are specified in the standard PN-EN ISO 5817. There are three levels of non-conformities, which were named with the letters B, C and D. These levels refer to the requirements of high, medium and mild [3-5].

In practice, various methods of quality control of welds are used. In the literature on the subject, there is a distinction between them as:

- Non-Destructive Testing, which includes visual inspection methods (VT), penetrant testing (PT), magnetic particle testing (MT), ultrasonic testing (UT) and X-ray testing (RT).
- Destructive Tests, which include hardness tests, strength tests, microscopic tests, macroscopic tests, as well as other working tests.

Due to the analyzed design of the temporary bridge structure and the methods used in this case, three solutions will be subject to detailed characteristics, namely VT, MT and UT. The first is based on a visual inspection of the tested elements, as well as their assessment in terms of standards related to the method by appropriately qualified personnel, characterized by having appropriate permissions. This method is always used first, as it allows the identification of the greatest number of non-conformities at low cost. The costs are related to the time and commitment of the employee who performs the test and the necessary tools. It should also be noted that the testing technique was included in the PN-EN ISO 17637 standard.

The MT is used to detect defects in ferromagnetic welds of welded joints. The first step in this procedure is to purify the weld. Then it is magnetized, which can be done with the use of yoke electromagnets, a source of excitation current with the use of contact electrodes or adjacent conductors. Typically, a tangential field strength ranging from 2 kA/m to 6 kA/m is used. In the next step, the detection factors are applied. This is done by spraying or dusting. The time to maintain the magnetization is important, which should allow for specific indications. Their registration is made by making sketches, photographs, or using electro-optical scanning. The MT, also called ultrasonic defectoscopy, is based on the use of pulsed sending of ultrasonic waves to the tested material. These waves are created with the use of a piezoelectric transducer and are created because of vibrations that arise after applying an electric current to the surface, with a frequency in the range of 0.5 to 15 MHz. A head and an appropriate fluid are used to apply the refrigerant. It can be oil or water with an admixture of a wetting agent or a non-freezing corrosion inhibitor.

The UT is based on the principle of propagation of this type of waves in solids. They give two kinds of information: a transmissive signal or a reflected signal (from a surface or a discontinuity). It returns to the head and, after being converted into electric, can be observed on the oscilloscope screen. In some cases, the registration results are used in computer memory, which is connected to the detector. The individual elements of the solid appear on the screen in the form of a bottom echo or defect echo. Knowledge of the geometry of the tested element and the characteristics of the head allows to determine the location of the defect in the tested structure.

These distinguished methods are the basis of non-invasive methods of testing welded joints. They enable the detection of non-conformities and their assessment in terms of meeting the requirements contained in the standards and the client's order. Their use allows for the effective preparation of the structure for delivery and ensuring its high level of quality [6-8]. The analysis shown here may be of interest to a wide audience. The technological aspect issues will interest welders [9] and power engineers [10]. Quality engineers will pay attention to detection issues [11,12], and process engineers will pay attention to optimization, both in production [13-15] and service [16]. Equally important is the use of appropriate protective coatings [17] and anti-corrosion protection [18-20], even in biotech industry [21]. It may also be of interest to material science practitioners [22] as well as analysts [23,24].

2. RESULTS

In the case of welded joints, it is necessary to identify any non-conformities. They can lead to a reduction in the quality of the structure and create real threats during its use. In the case of the analyzed temporary bridge, the three previously mentioned methods were used. In the first stage, VT was used. All welded joints (100 %) in the temporary bridge structure were tested. The implementation of the method was based on a careful inspection of the welds, as well as taking basic measurements with the use of basic tools in this area, such as a caliper. Based on the performed observation and measurement, it was possible to identify several groups of non-conformities occurring in the welds. Among them should be highlighted:

- dimensional deviations according to tolerances,
- welding spatter,
- incorrect geometry of the welds,
- incomplete fusion,
- undercut,
- poor fusion.

Dimensional non-conformities were caused either by inaccuracies in the task or by misinterpretation of the joint. The remaining defects resulted from the parameters of the welding process. Different faults can be caused by different factors. The most probable reasons for their occurrence are presented in **Table 1**.

Table 1 Possibilities of eliminating welding non-conformities

Type of non-conformities	Probable causes
Welding spatter	Wrong selection of welding parameters, too long arc or high voltage, use of a damaged electrode, wet or dirty electrode, contamination of the welded material and / or additional material, incorrect polarity
Incorrect geometry of the welds	Too much additional material, electrode diameter too large, incorrect electrode angle, magnetic arc deflection, weld pool too large
Undercut	Extended and wide arc at low current or high welding speed, extensive weaving movements, welding current too high, wrong electrode angle
Incomplete fusion	Inadequate preparation of the joint, wrong angle of the electrode, too low welding parameters, too high current, contamination of the edges of the welded sheets, magnetic deflection of the arc
Poor fusion	Defective joint design, improper joint preparation, use of excessive arc length, excessive welding speed, too large diameter of the electrode used

The use of the VT made it possible to identify non-conformities on the surface of the welded joints [25,26]. Their percentage share in the total number of welds performed is presented in **Figure 1**. It should be noted that in some cases of joints there was more than one non-conformity. The total share of all defective welds was 30 %.

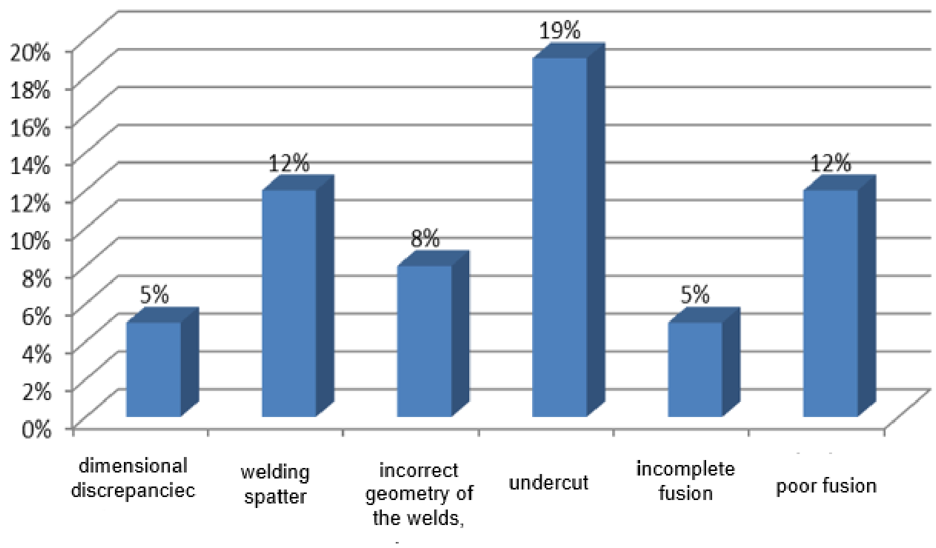

Figure 1 Percentage of identified non-conformities in the total number of all welded joints

The analysis of the non-compliance parameters showed that most of the problems do not reduce the quality of the structure. These nonconformities are within the scope of the previously established design guidelines.

In the next stage, the methods of MT were used. Welds with previously disclosed non-conformities were analyzed. The analysis showed two main non-conformities, namely poor fusion and undercutting. Their percentage share in the total number of welds after the test and after the analysis of compliance with the previously determined parameters is presented in **Figure 2**. On the other hand, **Figure 3** shows the analysis performed after the UT. In this case, the characteristics of the welds with incompatibilities, which could not be excluded by the magnetic-particle method. Their analysis based on the UT test results showed that their parameters are within the accepted ranges. Thus, they do not affect the quality of the welded structure and do not require repair.

During the analysis of the control processes, which was presented, it should be noted that the subsequent methods excluded non-conformities, which in the previous review were not fully understood in terms of meeting the design guidelines. Ultimately, the ultrasonic method confirmed the absence of any non-conformities that did not fall within the given ranges. In the discussed case, the analysis showed that the non-conformities occurring in the welded joints are within the limits specified at the beginning of the project. Thanks to this, the structure could be forwarded for corrosion protection and sent to the final customer. In the event of detection of unacceptable non-conformities, it would be necessary to repair the welded joints. Following the repair, the welds would have to undergo the specified quality control procedure once again. Only its positive result would allow for the further implementation of the production process [11].

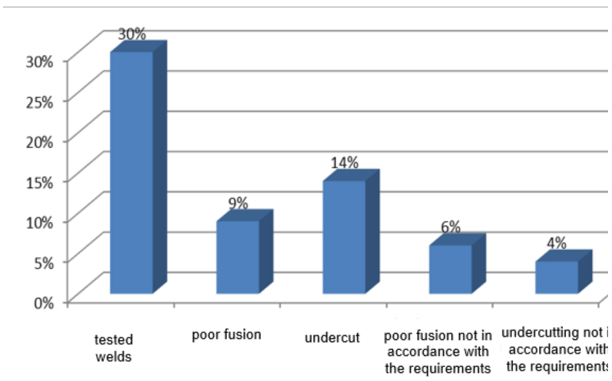

Figure 2. Percentage of non-conformities identified by the MT method in the total number of welded joints

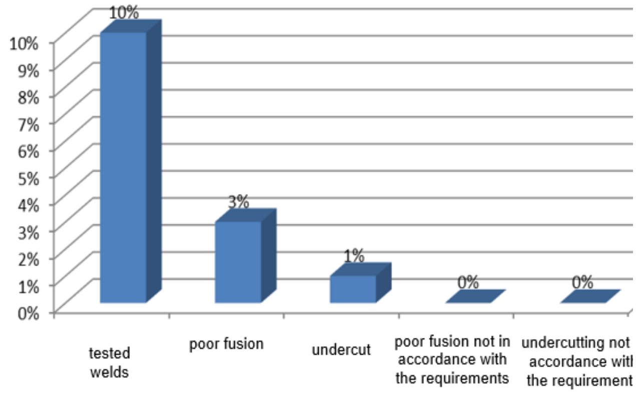

Figure 3 Percentage of non-conformities identified by the UT method in the total number of welded joints

Summarizing the presented analysis, it should be noted that the choice of the methods described above is not accidental. The visual examination does not identify all the non-conformities that are present. In the analyzed case, they occurred in 20 % of all welded joints. These were subjected to ultrasonic analysis, which made it possible to exclude any irregularities that are not important for the quality, strength and safety of the construction. At the same time, it showed the presence of 10 % of non-conformities requiring further examination, carried out by the magnetic particle method. This stage made it possible to exclude other non-conformities, as they were within the given tolerance [12-14].

3. CONCLUSIONS AND RECOMMENDATIONS FOR ENTERPRISES

The analyzed quality control of the welded structure of the temporary bridge is very extensive. The control covers virtually all stages of production, and thus allows for early identification of any irregularities. At the same time, it is strongly focused on the control of welded joints, significantly affecting the quality and strength level of the finished product. Such activities are conditioned primarily by the safety issues of the created product and the need to meet the requirements. It is also worth noting that despite the checks carried out during the production process, various types of defects are still detected in the final stage. They can be the result of various factors. They indicate irregularities in the conduct of welding technology. At the same time, it is possible to propose methods to reduce the occurrence of non-conformities in this area. Their summary is presented in **Table 2**. The possibilities of avoiding non-conformities listed in **Table 2** indicate the need for changes in the technological preparation of welding. Important in this regard are not only the competences of employees, but also the inclusion of optimal operating parameters in specific instructions. This can be done by analyzing the results of the inspection of welded joints while recording the parameters and techniques used. Thanks to this, it will be possible to develop optimal welding procedures for specific welded materials and additional materials.

Another solution to improve the quality of the production process could be the implementation of the employee responsibility system for internal control. Assigning subsequent participants in the process of tasks related to the ongoing observation of the manufactured elements could allow not only early identification of defects, but also the analysis of the impact of the welding parameters used on the quality of the joint being made. Such a system would need to be associated with appropriate documentation with the signature of the person responsible for internal control. This solution would not only allow for greater transparency of activities, but also motivate employees in terms of the correctness of the joint performance.

Table 2 Possibilities of eliminating welding non-conformities

Type of non-conformities	Possibilities of eliminating these defects
Welding spatter	Checking and selecting the correct welding parameters, selecting the correct arc length, checking the electrode's dryness and absence of defects, changing the polarity, changing the ground cable clamps, using clean filler material and cleaning the welded material
Incorrect geometry of the welds	Selection of the appropriate angle of the electrode, reduction of the melting factor, selection of the appropriate amount of additional material, selection of the electrode with a smaller diameter
Undercut	Using a short arc, checking the angle of the angle, reducing the welding current, using the weaving technique
Incomplete fusion	Supervision of the technological conditions of welding, control of the appropriate slope of the electrode, selection of the correct parameters of the welding speed, the magnitude of the current and the arc length with the observation of the weld being made, change of the position of the earth return clamp, use of a short arc
Poor fusion	Increase the air gap, reduce the voltage, reduce the welding speed, use a smaller diameter electrode

The presented information allowed for an overall assessment of the effectiveness of the qualitative analysis of welded structures. The occurrence of errors in welding processes indicates the risk at individual stages of the manufacturing process. The proposed solutions should allow for the elimination of most of the factors adversely affecting the process. At the same time, they should contribute to increasing the quality level of the finished welded structure of the temporary bridge. Guidelines for the supervision of the welding process are necessary to ensure the safety of the structures created in this way.

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