doi:10.2478/mape-2018-0017
Date of submission of the article to the Editor: 03/2018
Date of acceptance of the article by the Editor: 05/2018
MAPE 2018, volume 1, issue 1, pp. 129-135

ANALYSIS OF WELDINGS' INCOMPATIBILITY IN CONSTRUCTIONS

Eng. Magdalena Mazur, PhD.
Czestochowa University of Technology, **Poland**

Eng. Lenka Kucharikóvá, PhD.
University of Žilina, **Slovak Republic**

Abstract: The paper presents an analysis of the causes and consequences of nonconformity that has been made in the welding of structural elements. The most frequent incompatibilities in this process were identified and RPN determined for them. The implementation of corrective and preventive actions in the identified critical areas was suggested based on the conducted analysis. After the implementation of corrective actions the re-calculation of the value of the RPN has been made. The paper presents the importance of visual inspection in the process of supervising finished products from the construction welding process. Elements of selected processes carried out in welded structures over two months were analyzed.

Keywords: welding processes, production incompatibilities, FMEA method, visual inspection

1. INTRODUCTION

The implementation of special processes as an important element in the production of the offered product is additionally burdened with a special system of monitoring and control of the achieved results. Current market requirements impose the need to pay attention to the problem of the welding process of metal structures at an appropriate level of welded joint quality, as well as at the level of cost production accepted by the customer. Therefore, the process engineer is obliged to choose welding technology in order to rationally generate production costs for welded products, which in turn translates into an increase in the welding process efficiency (Ptak and Tabor, 2008; Szataniak et. al., 2014). Due to the limited possibility of product quality control only at the exit from the production system, special processes are subject to special requirements including planning, preparation and supervision of the quality of their execution (Ulewicz, 2016; Zasadzien and Zarnovsky, 2018; Brodny et al., 2016).
The research subject presented in the article is a company producing semi-trailers for trucks and agricultural machinery. One of the main elements of the production processes is the welding process of structures constituting the podium of the manufactured trailers of all types (platform or curtain, and the construction of dump trucks, as well as containers and railway wagons). The guidelines of the standards indicate the necessity to carry out technological operations from the group of special processes on the basis of documented technological instructions, including within its scope: requirements of employees' qualifications; principles of planning technological operations, product qualification, quality control during the process, and testing procedures. That is why so much emphasis is put on the statistics relating to the provision of adequate levels of quality at all stages of production of the product offered. The analysis of quantitative statistics on incompatibilities in the production line was carried out on the basis of data provided by the quality control department of the research entity.

2. THE STRUCTURE OF WELDING INCOMPATIBILITIES

Making welded constructions without any defects is practically impossible. The basic causes of incompatibilities in welded joints are (Czuchryj and Stachurski, 2005; Lipiński and Wach, 2014):

- deviations from the correct welding technology,
- incorrect selection of basic and additional materials,
- improper connection construction solutions,
- low qualifications of welders,
- inoperative welding equipment.

Good quality of the welded construction can be obtained by effective organization of the control of the anticipated welding work. An inseparable component of this inspection is non-destructive testing of welded joints. A variety of test methods are used to detect nonconformities occurring in welded joints. Depending on the responsibility and class of the structure, the individual elements of the quality assurance system are selected. The basis of the quality assurance system in the welded processes are single defectoscopy methods or their assembly (combination) consisting of several, usually two independent methods of testing applied in parallel. The method of non-destructive testing and the level of tests are determined based on the following factors (Ferenc and Ferenc, 2009; Dudek and Lisiecka, 2016):

- welding method,
- the base material, the additive material, condition of treatment,
- type of connector and its dimensions,
- shape of the element,
- quality levels,
- expected types of welding incompatibilities and their location.

According to the PN-EN ISO 6520-1 standard, welding incompatibilities are classified in six basic groups: cracks, void – gaps in the weld metal, solid inclusions – foreign solids trapped in the weld metal, lack the full weld remelting, incompatibilities in shape and dimension, various welding incompatibilities – all incompatibilities that can not be included in groups from 1 to 5 (PN-EN ISO 6520-1:2009). The quality of welded joints depends strictly on compliance with the requirements of welding standards, the choice of welding materials and the qualifications of the staff (welders and technicians). The quality of the weld is evaluated continuously using non-destructive tests. Both radiographic and ultrasound examinations are expensive due to the need to invest in expensive devices. The use of visual inspection is limited to the detection of surface incompatibilities only (Figures 1-3). Therefore, an effective quality assurance system in welded processes requires the use of many types of controls at the same time. Examples of identified non-conformities in the analyzed company are shown in Fig. 1-6. Supervision of incompatibilities is carried out both by visual counter (100%) and non-destructive testing, which most often allow to identify geometric incompatibilities of welds. This type of non-compliance requires the use of additional inspection steps (Figures 4 and 5) using X-ray examinations as well as the visual inspection applied on a large scale. In the analyzed period, the most frequently occurring incompatibilities are incomplete filling of the welding groove (Figure 2), and the convexity of the weld (Fig. 5). The greatest universality in detecting structural incompatibilities of welded welds is characterized by radiographic examination, using the phenomenon of electromagnetic absorption of ionizing radiation and its registration on X-ray plates. Both surface pores and cracks did not require the use of additional control processes, they are surface incompatibilities and are detected in a visual inspection.

After the welding operation, the visual inspection of the weld is made. The control performed by the employees is the first stage of quality control, supplemented in subsequent stages by inspection of the weld structure using X-ray examinations.

Fig. 1. Crack in the weld

Fig. 2. Incomplete filling of the welding groove

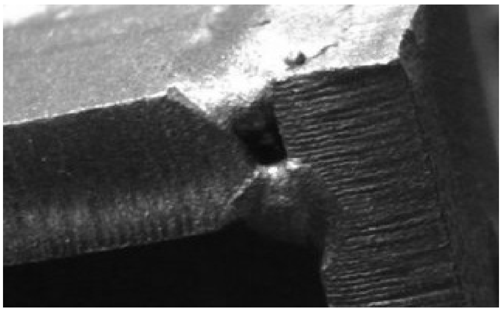

Fig. 3. Lack of penetration ridge

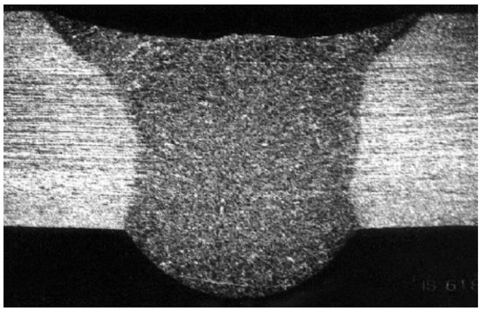

Fig. 4. The concave face of the weld

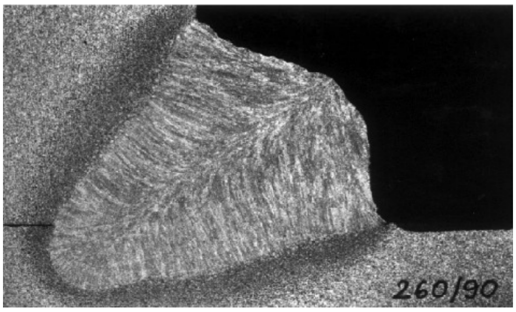

Fig. 5. Excessive convexity of the fillet weld

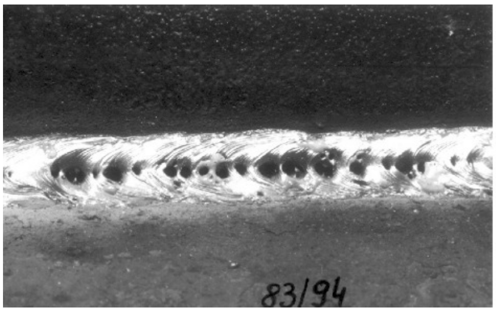

Fig. 6. Surface pores

Visual tests are the simplest and cheapest method of testing, they are obligatory for all types of welded structures. They are carried out before any other tests. These tests are carried out after the welding process, on joints in the state as they were made. The beginning of these tests should be at the stage of preparing the elements for welding, and end with the final inspection of the joints (PN-EN 13018 Standard; Ptak and Tabor, 2008). Visual qualifications require appropriate employee qualifications and detailed characteristics of the study and all its aspects.

3. ANALYSIS OF THE CAUSES AND EFFECTS OF INCOMPATIBILITIES IN THE PRODUCTION OF WELDED STRUCTURES

Analysis of the types and effects of possible incompatibilities is one of the methods using to preventing and eliminating the effects of defects that may occur in construction and manufacturing processes. Its use at the construction stage consists in examining all possible and suspected errors before approving the structural solution. In the production process, this method is used to examine the possibility of errors in the course of production and assembly, and its purpose is to identify and assess risks. The risk assessed is related to weak points that occur during planning, production, development and manufacturing process. The conclusions in the analysis allow to significantly reduce this risk indicator (Tubis, 2018). The FMEA method allows to: improve the product quality, better adapt the product to customer requirements, reduce costs, reduce the number of complaints (improve the defect rate) and improve the reliability of products (Bozdag et al., 2015). Using the FMEA method, the factors influencing the quality of welded joints in the chassis of the construction machine were identified. Using the data from the FMEA analysis, you can improve all processes carried out in the company, so that the number of non-conformities arising in the production of the frames is as low as possible. Table 1 presents factors influencing the occurrence of incompatibilities in the production of frames.

Table.1. Identification of factors influencing the formation of incompatibility of welded joints in steel constructions

No.	INCOMPATIBILITY	CAUSE	EFFECT	Sev.	Det.	Occ	RPN	CORRECTIVE ACTION	Sev.	Det.	Occ	RPN
1.	N_1 – no ridge penetration	Incorrect beveling of the edges of joined elements	Negative result of visual or ultrasound examination	10	5	5	250	Introduction of an additional self-check operation in the technological process before welding	10	5	3	150
2.	N_2 – incorrect ending	Lack of proper qualifications of the welder	Negative result of visual test	10	5	6	300	The emphasis on self-control and training for welders	10	3	6	180
3.	N_3 – excessive weld asymmetry	Bad setting of combined items	Negative visual test result, need for corrections	8	6	4	56	Expansion of the self-monitoring system	8	2	3	48
4.	N_4 – lack of completed weld	Low qualifications of employees	A large number of incompatibilitie s, high costs	8	2	7	112	Modernize the self-control system, train for welders	8	2	4	64
5.	N_5 – uneven weld	Wrong welding technology	Underrated aesthetics of the product	9	7	5	315	Modernization of welding technology, increasing the scope of visual examinations	9	6	3	162
6.	N_6 – gaps in the weld	Wrong welding technology	Understood endurance of the product	4	4	6	96	Modernize the control system, train for welders	4	3	6	72
7.	N_7 – excessive convexity of the fillet weld	Wrong welding technology	A large number of incompatibilitie s, costs of complaints	8	1	9	72	Expanding the control system	8	1	7	56
8.	N_8 – craters	Extinguishing the arc too fast	Low aesthetics of the product	4	6	3	72	The emphasis on self-control and training for welders	4	6	2	48
9.	N_9 – incomplete filling of the welding groove	Inattention of the employee	A large number of incompatibilitie s, high costs	3	7	6	126	Training for employees, additional visual inspection	3	5	4	60
10.	N_{10} – crack of welds	Hydrogen, tensile stresses	Deferred strength of the structure	4	4	6	96	Additional magneto-powder and visual tests	4	3	4	48
11.	N_{11} – continuous flooding between stitches	Wrong welding technology	Deferred strength of the structure	3	4	4	48	Increased importance of welding supervision	3	4	3	36
12.	N_{12} – pores	Insufficient protection for a warm weld pool	Low weld quality	4	3	4	48	Training for employees, emphasis on self-control	4	3	3	36
13.	N_{13} – inundation in the fillet weld	Incorrect arc voltage parameters	Deferred strength of the structure	5	6	5	180	Implementation of welding instructions	5	6	3	90
14.	N_{14} – the concave face of the weld	Wrong parameters of the welding process	Low aesthetics of the product	8	1	7	56	Implementation of welding instructions	3	4	2	24
15.	N_{15} – leakage	Wrong prepared welding groove	Low weld quality	10	3	6	180	Expansion of the self-control system, training of welders	4	4	6	96

The FMEA analysis is based on three main indicators: severity, occurrence and detection. The assessment of indicators is carried out on a scale of 1-10. The ratio of these indicators allows to take into account three aspects of product quality.
The optimal value of the Risk Priority Number for the analyzed processes has been set at level = 150. Five from the all incompatibilities exceed this value: N1 – no ridge penetration (RPN = 250), N2 – incorrect ending (RPN = 300), N5 – uneven weld (RPN = 315), N13 – inundation in the fillet weld (RPN = 180), and N15 – leakage (RPN = 180). For particular defects, corrective actions were defined, after the implementation of which the RPN was estimated again. A graphical interpretation of the RPN value change before and after the implementation of corrective actions is presented in Figure 7.

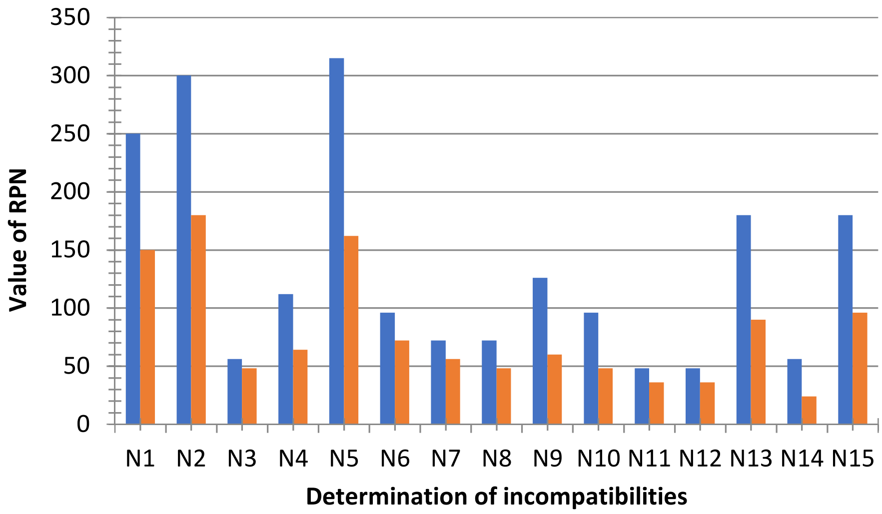

Fig. 7. Risk priority number for particular incompatibilities of welded joints in steel constructions

In order to reduce the number of occurrences of incompatibilities related to the lack of root penetration, abnormal ending, leaks, flooding and uneven weld in the frame welds, the following corrective actions were determined: introduction of additional self-inspection operation in the technological process before welding, increased pressure on self-control and training for welders, modernization of welding technology, increasing the scope of visual examinations (Pałubicki and Kukiełka, 2017; Nowakowska-Grunt and Mazur, 2016).
In order to motivate employees to work effectively, it is necessary to introduce a motivational system within the framework of which employees would be rewarded for effective work. So far, the motivation of employees in the enterprise surveyed consisted only in using verbal persuasion, and sometimes even coercive measures. The tested enterprise should implement and apply appropriate methods of motivating employees. Employees' motivation should focus on active participation in activities that are introduced to improve the quality of products and services provided. The content provided during trainings should be strengthened by creating the right motivation system in the company. At the same time, emphasis should be placed on positive motivation, rewarding employees who perceive and solve quality problems. Above all, it is necessary to increase the payment, improve working conditions, reduce working hours (through better organization of the production process, eliminate overtime) and award incentive bonuses.

4. SUMMARY

Welding of car semitrailer frame structures can be considered as special processes, where one of the key determinants of quality are the operator's qualifications and experience. In the analyzed case, the most important element of the process and its result is the experience of the welder and the employee involved. Based on the company's motivational system, all employees should be included in the process of quality assurance and improvement both at their workplace as well as throughout the organization. In the case of a welder, these will be activities aimed at improving visual control (Wolniak and Skotnicka, 2010), (Pacana and Ulewicz, 2017).

As a result of the analysis the causes of incompatibilities in the welding processes using by the FMEA method, the reasons for RPN exceed the limit of the priority risk number were determined. In order to reduce the number of incompatibilities in the frame welding processes, the following corrective actions have been identified: introduction of an additional self-inspection operation in the technological process prior to welding, increasing attention to self-control and training for welders, modernization of welding technology, increasing the scope of visual examinations. Identification of the most serious incompatibilities in the welding process allowed for further actions to determine the causes of non-compliance with the use of the Ishikawa diagram. The use of this diagram will allow to learn the detailed causes responsible for the occurrence of incompatibilities, and additionally graphically present the relationship between effects and transients between individual factors. The next stage of the analysis is to determine the risk of individual weld incompatibilities in subsequent production cycles, and to introduce preventive actions. In order to motivate employees to work more effectively, it is necessary to introduce a motivational system within the framework of which the employee will be rewarded for effective work (Kardas, 2015). The tested enterprise should implement and apply appropriate methods to motivate employees to actively participate in activities to improve the quality of products and services provided. The content provided through training should be strengthened by creating the right motivation system in the company. At the same time, emphasis should be placed on positive motivation, rewarding employees who perceive and solve quality problems.

REFERENCES

Bozdag, E., Asan, U., Soyer, A., et al. (2015). Risk prioritization in Failure Mode and Effects Analysis using interval type-2 fuzzy sets. EXPERT SYSTEMS WITH APPLICATIONS Volume: 42(8), pp. 4000-4015.

Brodny, J., Stecuła, K. and Tutak, M. (2016). Application of the TPM strategy to analyze the effectiveness of using a set of mining machines. SGEM 2016 Conference Proceedings, Book1 Vol. 2, pp. 65-72.

Czuchryj, J. and Stachurski, M. (2005). Badania nieniszczące w spawalnictwie. Gliwice: Instytut Spawalnictwa.

Dudek, A. and Lisiecka, B. (2016). The Effect Of Alloying Method On The Microstructure And Properties Of The Pm Stainless Steel. In: Metal 2016: 25th Anniversary International Conference On Metallurgy And Materials, pp. 1045-1050.

Ferenc, K. and Ferenc, J. (2009). Konstrukcje spawane. Połączenia. Warszawa: Wydawnictwa Naukowo-Techniczne.

Kardas, E. (2015). The analysis of non-conformances of metal impeller using selected quality instruments. In: METAL 2015: 24th International Conference on Metallurgy And Materials, pp. 1970-1975.

Lipiński, T. and Wach, A. (2014). Influence Of Outside Furnace Treatment On Purity Medium Carbon Steel. In: Metal 2014: 23rd International Conference On Metallurgy And Materials, pp. 738-743

Nowakowska-Grunt, J. and Mazur, M. (2016). Effectiveness Of Logistics Processes Of Smes In The Metal Industry. In: Metal 2016: 25th Anniversary International Conference On Metallurgy And Materials, pp. 1956-1961

Pacana, A. and Ulewicz, R. (2017). Research of determinants motiving to implement the environmental management system. Polish Journal of Management Studies. Volume: 16(1), pp. 165-174 .

Pałubicki, S. and Kukiełka, K. (2017). Zarządzanie jakością w wybranym procesie produkcyjnym z zastosowaniem metody FMEA. AUTOBUSY 7-8/2017 pp. 256-261

PN-EN 13018 Standard. Badania nieniszczące. Badania wizualne. Zasady ogólne., Warszawa 2004.

PN-EN ISO 6520-1:2009 Standard. Spawanie i procesy pokrewne. Klasyfikacja geometrycznych niezgodności spawalniczych w metalach. Część 1: Spawanie. Polski Komitet Normalizacyjny, Warszawa 2009.

Ptak, W. and Tabor, A. (2008). Methods for assessing the quality of metal products. Welding production engineering. (in Polish). Krakow: Krakow University of Technology Publishing House.

Szataniak, P., Novy, F. and Ulewicz, R. (2014) HSLA Steels - Comparison Of Cutting Techniques. In: Metal 2014: 23rd International Conference On Metallurgy And Materials, pp. 778-783
Tubis, A. (2018). Process Assessment of Risks in the Production Company with the Use of Linguistic Variables and the FMEA Analysis. Advances in Intelligent Systems and Computing. Volume: 637, pp. 368-379.
Ulewicz, R. (2016). Quality management system operation in the woodworking industry [in:] Conference: International Conference on the Path Forward for Wood Products: A Global Perspective Location: Baton Rouge, LA, path forward for wood products: a global perspective, proceedings of scientific papers, 2016 pp. 51-56.
Wolniak R. and Skotnicka B. (2010). Metody i narzędzia zarządzania jakością: teoria i praktyka. Gliwice: Wydawnictwo Politechniki Śląskiej, 2010.
Zasadzien, M. and Zarnovsky, J. (2018). Improvement of selected logistics processes using quality engineering tools. MANAGEMENT SYSTEMS IN PRODUCTION ENGINEERING, Volume 26(1), pp. 55-59.