Chapter 7

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WELDED JOINTS' INCOMPATIBILITIES ANALYSIS IN PRODUCTION OF SEMI-TRAILERS CAR

Abstract: This paper analyzes causes and effects of formation of incompatibilities in the welding process of structure elements of car semi-trailers. There were identified most frequently occurring incompatibilities in this process, and was set out for them RPN. Based on conducted research there was proposed implementation of corrective and preventive actions in identified critical areas. There was carried out recalculation of RPN value after the implementation of corrective actions. This paper presents the importance of visual control elements in the process of monitoring the output elements from the welding process of construction. As the most important element of corrective actions was considered the process of continuous employee training and implementation of seven principles of the Toyota Management (apply visual control to ensure that no problem is in hiding).

Key words: 7th Toyota's principle of management, visual control, welding process, incompatibility, FMEA method

7.1. Introduction

Current market requirements impose the necessity of paying attention to the problem of realizing the process of welding metal structures at an adequate quality level of welded joints, as well as at a cost production level acceptable by the client. This is why the engineer is obliged to select the welding technology in order to rationally shape the production costs of welded products which, consequently, is reflected in increasing the efficiency of the welding process. The use of MIG/MAG methods is of great significance in the contemporary welding production as it is

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characterised by a constant rising trend (70-75% of the produced goods and welded constructions), welded by means of MMA method (20-15% of welded constructions), welded by SAW method (approx. 10% of the constructions) and welded by means of new and special welding methods - WE, WL, plasma arc-welding and hybrid welding. 10% of the welded products) (PTAK W., TABOR A. 2008).

The examination unit presented in the dissertation is WIELTON S.A., a company producing semitrailers, trailers and lorry sidings, as well as agricultural accessories. The company is a leading Polish producer of semitrailers and trailers, with 24% market contribution. The company's development strategy is focused on constant improvement and optimizing production processes, mainly due to implementing modern design solutions, such as automation and robotization of the production process. One of the main elements of production processes is the process of welding constructions intended for platforms and curtainsiders, as well as for containers and tip wagons. Statistically 75% of all welding operations performed by the company are realized by means of MAG (Metal Active Gas) method, 23% by MIG (Metal Inert Gas) method and SAW (Submerged Arc Welding) operations constitute only 2%. The ability to compete depends, to a great extent, on being able to provide top quality of products and services (KOPCIUSZEWSKA E., BORKOWSKI S. 2004). This is why so much emphasis is put on keeping statistics related to failing to provide adequate level of quality, exactly in the process of welding the structure (HRUBEC J., ŽABÁR P., PRÍSTAVKA M., ŠKŮRKOVÁ K. 2008). Analysis of the quantitative statistics for incompatibilities occurring in the production line has been performed on the basis of data provided by the quality control department of the company.

7.2. Structure of welding incompatibilities

Execution of welded structures without defects is virtually impossible. The main causes of occurring incompatibilities in welded joints are (CZUCHRYJ J., STACHURSKI M, 2005):

- derogation from proper welding technology,
- improper selection of basic and additional materials,
- improper structure solutions of joints,
- low qualification ns of welders,
- failure of welding equipment.

Good quality of welded structures can be obtained through effective organization of control of anticipated welding works. Integral components of this control are non-destructive testing of performed welded joints. For detection of incompatibilities occurring in welded joints are used various methods of research. Depending on responsibility and class of construction there are chosen individual, single flaw detection methods or their team (combination) consisting of several, usually two independent testing methods used in parallel. Non-destructive testing method and level of research are determined based on the following factors (FERENC K., FERENC J., 2009, KARPIŃSKI S., MOSZUMAŃSKI J., RADWAN-WIATROWSKI K., 2001):

- welding method,
- basic material, additional material, condition of its processing,
- type of joint and its dimensions,
- shaping element,
- levels of quality,
- expected types of welding incompatibilities and their location.

Pursuant to PN-EN ISO 6520-1 standard welding incompatibilities are classified into six groups: 1 – cracks – tears in solid state, both in the joint's metal, in the heat impact zone, as well as in the base material, which can be caused by cooling or stresses; 2 – voids – deficiencies in the joint's metal formed by gas that got inside it; 3 – permanent inclusions – foreign bodies trapped in the joint's metal; 4 – incomplete fusion and lack of weld penetration – no or too shallow joints between the joint's metal and the base material; 5 – discrepancies related to shape and dimension – inadequate shape of the joint's external surface or incorrect geometry of the connection; 6 – various welding incompatibilities – all incompatibilities that can be classified as belonging to group 1 - 5 (PN-EN ISO 6520-1:2009). The quality of welded joints strictly depends on observing requirements set forth in welding-related standards, selection of welding materials and the staff's qualifications (welders and technicians). Evaluation of the weld performance quality is made in a continuous way, by means of NDT. Both radiographic and ultrasound tests are expensive due to the necessity of investing in expensive tools. Visual inspection is only limited to detecting surface incompatibilities (Figures 7.1. – 7.3). Examples of incompatibilities that have been identified in the examined company are shown in Figure7.1. – 7.6. The most common incompatibility in the welding process was the excessive convexity of the fillet weld (Fig. 7.5.). Radiographic tests are characterized with the greatest universality in detecting structural non-conformities of welds since they use electromagnetic absorption of ionizing radiation and record it in X-ray films [4] (Fig. 7.4. – 7.6.).

After the welding process the welds undergo visual inspection. This inspection, performed by the staff, is the first quality control stage, completed later on by controlling the weld's structure by means of X-ray tests.

Visual inspections are the simplest and cheapest method of research, which are compulsory for all kinds of welded constructions. They are carried out before proceeding to other research. These researches are carried out after completion of welding process, on joints in state such as they were made. Start of this research should be in phase of elements preparation for welding, and end with the final control of joints (PTAK W., TABOR A. 2008, Norma PN-EN 13018).

Fig. 7.1. Weld crack.

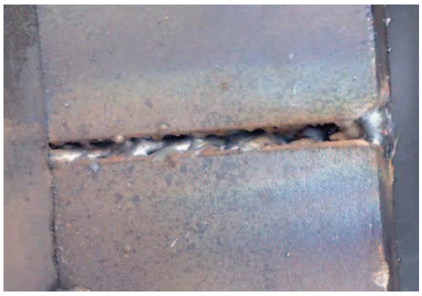

Fig. 7.2. Incomplete filling of the weld groove.

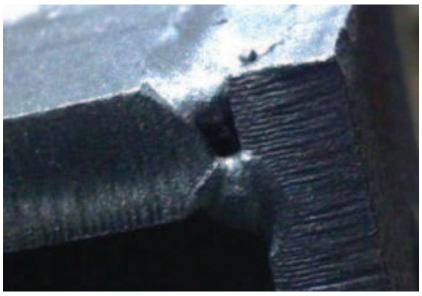

Fig. 7.3. Lack of root fusion.

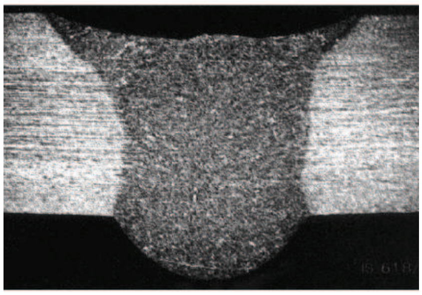

Fig. 7.4. Incompletely filled groove of weld.

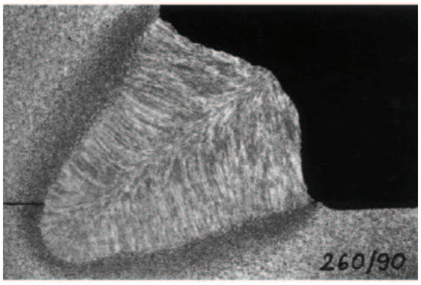

Fig. 7.5. Excessive convexity of the fillet weld.

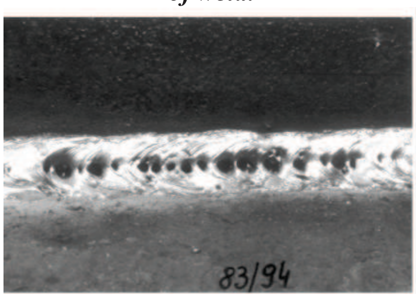

Fig. 7.6. Surface piping.

7.3. Analysis of causes and effects of incompatibilities formation in the production of welded structures

Analysis of types and effects of possible errors is one method to prevent and cope with effects of defects that can occur in construction and manufacturing processes. Its use at construction stage consists in examining all possible and likely defects before approving construction solution. In production process, this method is used to study the possibility of errors occurrence during manufacturing and assembly, and its objective is to identify and assess the risk associated with vulnerabilities that occur during planning, production, development, and manufacturing process allowing to significantly reducing this risk. FMEA method allows to: improve product quality, better adaptation of the product to customer requirements, reduce costs, reduce the number of complaints (improvement in defect index) and to improve the reliability of the products (BORKOWSKI S. 2005).

There was carried out identification of factors affecting the quality of welded joints in the chassis frame of construction machine using FMEA method. Using data from FMEA analysis can be improved all the processes implemented within the company, so that the number of incompatibilities occurring during manufacture of frames was the lowest. Table 7.1 presents factors affecting the occurrence of incompatibilities in the production of frames.

Optimal value of Risk Priority Number for the analyzed process was set at 150 level. Five incompatibilities exceeded this value: N_1 - lack of root fusion (RPN = 250), N_2 - abnormal termination (RPN = 300) and N_5 - uneven knit line RPN = 315), N_{13} - undercut in fillet weld (RPN = 180), and N_{15} - leakage (RPN = 180). For individual defects were defined corrective actions after the implementation of which there was re-estimated RPN.

Table 7.1. Identification of factors affecting the formation of incompatibilities of welded joints in steel structures using FMEA

No.	INCOMPATIBILITIES	CAUSES	EFFECTS	SEV	DET	OCC	RPN	CORRECTIVE ACTIONS	SEV	DET	OCC	RPN
1.	N_1 – Lack of root fusion	Bad edge beveling of connected elements	Negative result of visual inspection or ultrasonic	10	5	5	250	Introduction in technological process of additional self-control operation before proceeding to welding	10	5	3	150
2.	N_2 – Abnormal termination	Lack of appropriate qualifications of welder	Negative result of visual inspection	10	5	6	300	Putting emphasis on self-control and training for welders	10	3	6	180
3.	N_3 – Excessive asymmetry of the weld	Wrong setting of connected elements	Negative result of visual examination, need for corrections	8	6	4	56	Development of self-control system	8	2	3	48
4.	N_4 – Lack of end	Low qualifications of workers	A large number of incompatible products, high costs	8	2	7	112	Modernize the system of self-control, to carry out training of welders	8	2	4	64
5.	N_5 – Uneven knit line	Improper welding technology	Understated aesthetics of product performance	9	7	5	315	Modernization of welding technology, increasing the range visual inspection	9	6	3	162
6.	N_6 – Hot cracks in the weld	Improper welding technology	Understated strength of the product	4	4	6	96	To modernize control system, carry out training of welders	4	3	6	72

7.	N_7 – Excessive convexity of the fillet weld	Improper welding technology	A large number of incompatible products, the costs of complaints	8	1	9	72	Development of control system	8	1	7	56
8.	N_8 – Craters	Too fast extinction of arc	Low aesthetics of product performance	4	6	3	72	Putting emphasis on self-control and training for welders	4	6	2	48
9.	N_9 – Incomplete filling of the weld groove	Inattention of employee	A large number of incompatible products, high costs	3	7	6	126	Training for staff, additional visual control	3	5	4	60
10.	N_{10} – Weld crack	Hydrogen, tensile stresses	Understated structural strength	4	4	6	96	Additional magnetic-powder test and visual control	4	3	4	48
11.	N_{11} – Interpass continuous undercut	Improper welding technology	Understated structural strength	3	4	4	48	Increasing the importance of welding supervision	3	4	3	36
12.	N_{12} – Piping	Inadequate protection of liquid weld puddle	Low quality of weld	4	3	4	48	Training for staff, putting emphasis on self control	4	3	3	36
13.	N_{13} – Undercut in fillet weld	Wrong parameters of arc voltage	Understated structural strength	5	6	5	180	Introduction of welding instructions	5	6	3	90
14.	N_{14} – Incompletely filled groove of weld	Poorly chosen welding parameters	Low aesthetics product performance	8	1	7	56	Introduction of welding instructions	3	4	2	24
15.	N_{15} – Leakage	Poorly prepared weld groove	Low quality of weld	10	3	6	180	Development of self-control system, training of welders	4	4	6	96

Graphical interpretation of changes in the value of RPN before and after implementation of corrective actions is shown in Figure 7.7.

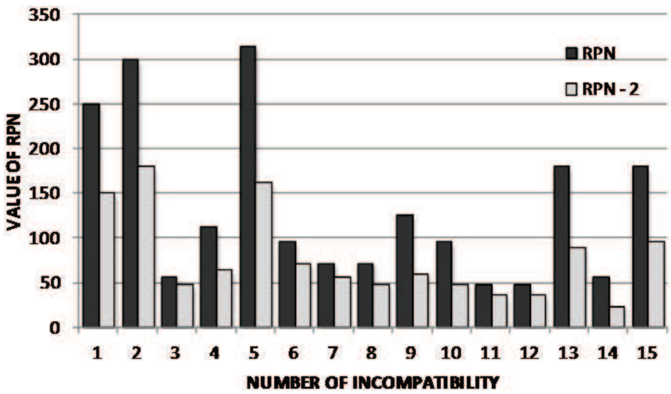

Fig. 7.7. Risk Priority Number values for each incompatibilities of welded joints in steel structures.

In order to reduce the number of occurrence of incompatibilities related to the lack of root fusion, improper completion, leakages, undercuts or uneven weld in joints frames there were set out following corrective actions: introduction in technological process of additional operation of self-control before proceeding to welding, increased emphasis on self-control and training for welders, modernization of welding technology, increasing the scope of visual inspection.

To motivate workers to work effectively should be introduced incentive system as part of the operation, which workers would be rewarded for their work effectively (ŠUJANOVÁ J. PAVLENDOVÁ G. 2005). So far in analyzed company the motivation of workers solely consisted in the use of verbal persuasion, and sometimes even coercive measures. In analyzed company there should be implemented and used appropriate methods to motivate workers to actively participate in efforts to improve the quality of manufactured products and services. Transmitted through training contents should be strengthened by creating in the enterprise appropriate motivation system. It should be emphasized to motivate positive, rewarding workers perceiving and solving quality problems. There should be first of all raised wages, improve working conditions, reduce operating time (through better organization of the production process to eliminate overtime) and grant incentive bonuses.

Analyzed welding process revealed a number of generated during its lasting non-compliance. Specified corrective actions have been predominantly focused on the worker (man) - as the main element and the main source of improvement. Highlighting the importance of employees (at every level of the hierarchy) is based on the concept of TOYOTARYZM, the concept constructed and devised by the author of the publication (BORKOWSKI S. 2012a). Toyotaryzm is a scientific discipline directed at continuous improvement and development of company. It emphasizes the concept of worker as an initiator of new ideas and improvements, which based on gathered during the production cycle information takes appropriate decisions, or forwards them higher. The model of the Toyotaryzm concept including the concept of process (BORKOWSKI S. 2012b) draws attention to the importance of man in company structures. Based on Toyota's management principles, in particular the principle 5 (Develop a culture of interruption of processes to solve problems, to immediately obtain appropriate quality) author draws attention to the importance of grassroots work to create a culture and commitment of workers performing the concept of company (BORKOWSKI S. 2012c).

7.4. Summary

Welding of structure of frames semi-trailers can be classified as special processes, in which one of the key determinants of quality are qualifications and experience of the operator. In the analyzed case the most important part of the process and its result is experience of involved welder. Based on widely understood concept of TOYOTARYZM (BORKOWSKI S. 2012b, BORKOWSKI S. 2012c) there should be, in accordance with the principles of Toyota system, incorporated all employees in the process to maintain and improve quality of both in their workplace as well as throughout the organization. In case of welder there would be operations aimed at improving the visual inspection.

As a result of analysis of causes and effects of formation of incompatibilities in welding processes using FMEA method there were identified reasons why RPN exceeds the limit of risks priority number. To reduce the number of incompatibilities in the process of welding frames, the following corrective actions were determined: introduction of additional self-control operation in technological process before proceeding to welding, increase emphasis on self-control and training for welders, welding technology modernization, increase the range of visual research. In order to motivate employees to work effectively there should be introduced incentive system in the operation, in which the employee will be rewarded for effective work. In analyzed company should be implemented and used appropriate methods to motivate employees for active participation in efforts to improve the quality of manufactured products and services. Transmitted through the training contents should be strengthened by the creation in the company proper motivation system. It should be emphasized to motivate positive, rewarding employees perceiving and solving quality problems.

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