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Damages of burner pipes due to the working conditions and its repair welding

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Abstract

Repair welding represents the activity that restores the working capability of machine or construction caused by some damage due to working or environmental condition. Damages of burner pipes, part of the facility "Cold Rolling Mill" Steelwork in Smederevo, which appeared on welded joints during the manufacturing of the burner, and its repairing are presented in this paper. The damages occurred on welded joints along the weld as a result of the working conditions that burner was exposed to. Due to high temperatures that can reach up to 850 °C and "explosion" during gas burning, a crack may appear on the inner side of the burner. The base material of the burner pipes is stainless steel X12NiCrSi35-16. Repair welding is preceded by a series of operations, and one of them is the selection of an electrode. It turned out that inadequate selection of the electrode for repair welding had contributed to the occurrence of cracks on welded joints. Selecting a new electrode and examining its characteristics, as well as performing test welding of pipe that is still in exploitation, had confirmed the importance of proper selection of materials for repairing of burner pipes.

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Keywords: burner pipe, repair welding, damages, steel X12NiCrSi35-16;

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1. Introduction

Welded structures play an important part in modern industrial production. Pressure vessels which are manufactured by welding represent a very significant part of the equipment used in many industrial branches, such as process, chemical and petrochemical industries, and are also often used in refineries, nuclear and thermal powerplants, etc. Maintenance and repair are different operations, but with many common attributes. Both require individuals possessing with a broad knowledge of welding and materials. Electrode (chemistry content and mechanical properties) must be determined in the planning of maintenance and repair procedure, and fracture can have an influence on the selection of electrode or additional material used for repair welding procedure [1-3].

Despite the rigid regulations in terms of welded joint quality, which were defined based on theoretical knowledge and practical experience, there are still numerous examples of crack initiation during exploitation and resulting structure failures [4-6]. Due to this, welded joints are subjected to control during the manufacturing and delivery, as well as in regular intervals during exploitation. For the purpose of welded joint inspection, non destructive test methods are applied, including: ultrasound, magnetic particles, x-ray, penetrant methods, acoustic emission etc.

Current experience indicates the behaviour of welded joints with cracks is unpredictable, due to the effect of various factors, such as residual stresses, geometric deviations, considerable micro-structural heterogeneity of certain welded joint areas, which are related to the size of the crack and the position and sharpness of its tip.

The damages of burner pipes in the Hladna Valjaonica Zelezare Smederevo facility is presented in this paper, along with the procedure used for reparing them. The conditions under which the pipe was working resulted in the need for repair welding, or the purchase of a new burner, whereas the type of damage lead to the need to change the electrode used for welding. The selected Castolin 6825 electrode was confirmed suitable for this application.

2. Repair pipes damage

Burner pipes are a part of the heating chamber, made of self-supporting steel mantle coated with fireproof material. The burner is used for heating during the continuous annealing of a cold rolled strip, and the combustion of natural gas takes place inside of it. Heat generated in this way is used to heat the chamber through which the strip passes via “W” burners.

Due to high temperatures, reaching up to 850°C, and the “explosions” during gas ignition, cracks may occur in the entry part of the “W” burner. Some of the damages to the “W burner” are shown in figure 1, whereas they were present in the base material. It should be noted that the welded joints represent the locations most vulnerable to crack initiation. Shown in figure 1 are certain cases in which cracks in the burner pipes have occurred along the length of the welded joint itself, which is rarely encountered in practice.

Fig. 1. Damages to the entry part of the “W” burner pipe; cracks along the welded joint.

During previous repairs (repair welding) of burner pipes in the Zelezara Smederevo, electrodes with 25% Cr and 20% Ni content (Hereinafter referred to as type 25/20 electrodes) were used. Practical experience had shown that in most welded joints made using these electrodes, cracks initiated in the weld metal, due to the working conditions to which the pipes were subjected, including high temperature and its cyclic change.

Damages to the pipe resulted in the need to consider the use of a different electrode and another repair welding technology.

3. Burner pipe repair welding

3.1. Pipe base material - X12NiCrSi35-16

Damages of burner pipes resulted in the need to repair the pipe in question. The repair process involved the cutting off of the damaged part and replacing it with a new pipe, which was connected to the burner by welding. Steel X12NiCrSi35-16, a stainless nickel alloy, was used as the base material for the pipes, and its chemical composition is shown in table 1. It belongs to a group of uncommon austenitic and austenitic-ferritic heat resistant steels. The mechanical properties of this steel are given in table 2. Shown in figure 2 is the micro-structure of the base material, which is austenitic with spheroid pearlite. A significant amount of carbides can be observed in the base material structure.

Table 1. Chemical composition of steel X12NiCrSi35-16 [7]

Element	C	Si	Mn	P	S	Cr	Ni	Cu	Al
Percentage [%]	0.270	2.583	2.057	0.029	0.024	21.01	31.84	0.063	0.045
Element	Mo	Ti	As	V	Nb	Sn	Pb	W	Co
Percentage [%]	0.079	0.058	0.015	0.023	0.409	0.153	0.004	0.123	0.365

Table 2. Mechanical properties of X12NiCrSi35-16 [7]

Yield stress, Rp0.2	Tensile stress, Rm	Elongation, A	Hardness
>230 MPa	550-750 MPa	>28%	<220 HB

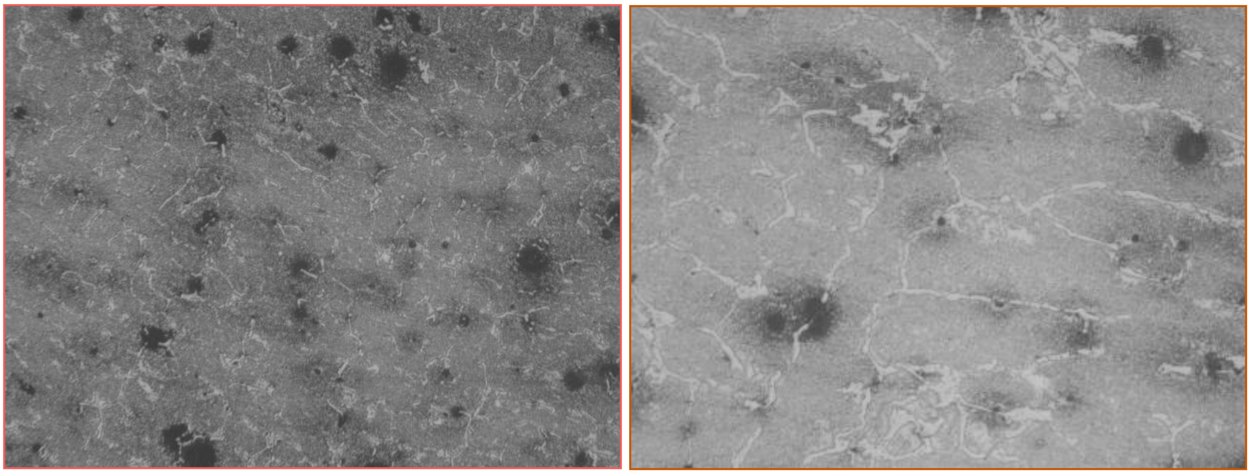

Fig. 2. Micro-structure of base material used for burner pipes (X12NiCrSi35-16); a large amount of carbides can be observed in the micro-structure.

3.2. Selection of welding technology, filler material

The manual arc welding procedure was selected for the purpose of repairing the burner pipes. The quality of the filler material, along with the performing of welding activities, greatly affect the quality of the welded joint. The selection of filler material itself requires adequate treatment and storing of such materials, in order to prevent defects that may occur due to the presence of impurities or moisture [8-10].

Earlier pipe repairs were performed using type 25/20 electrode, and it was concluded that these electrodes were not the best solution for this purpose, due to a large number of cracks occurring in the welded joints, as mentioned in the previous text. As a consequence, the decision was made to use a different electrode, and for this purpose, Castolin 6825 was selected. Specimens taken from the burner pipe were tested in terms of hardness and macro and micro-structure. The chemical composition of this electrode is given in table 3, whereas its mechanical properties can be seen in table 4.

Table 3. Chemical composition of electrode Castolin 6825 [11]

element	C	Si	Mn	P	S	Cr	Ni	Cu	Mo	Nb+Ta	Fe
%	0.01	0.2	0.69	0.005	0.002	20.95	63.52	0,01	9.2	3.4	1.84

Castolin 6825 is a manual electrode used for joining nickel alloys, duplex and Super austenitic stainless steels, 9% nickel steels and dissimilar combinations with carbon steels. It has excellent resistance to stress corrosion cracking, pitting, crevice and intergranular corrosion. It also has very high dilution tolerance with nickel and ferrous alloys, and it is characterized by superior positional weldability as well as service temperatures from cryogenic to 980 °C [11].

3.3. Repair welding

Welding of pipes was performed using the manual arc welding procedure (MAW). Shown in figure 3 is the appearance of the prepared U groove, which was made by grinding.

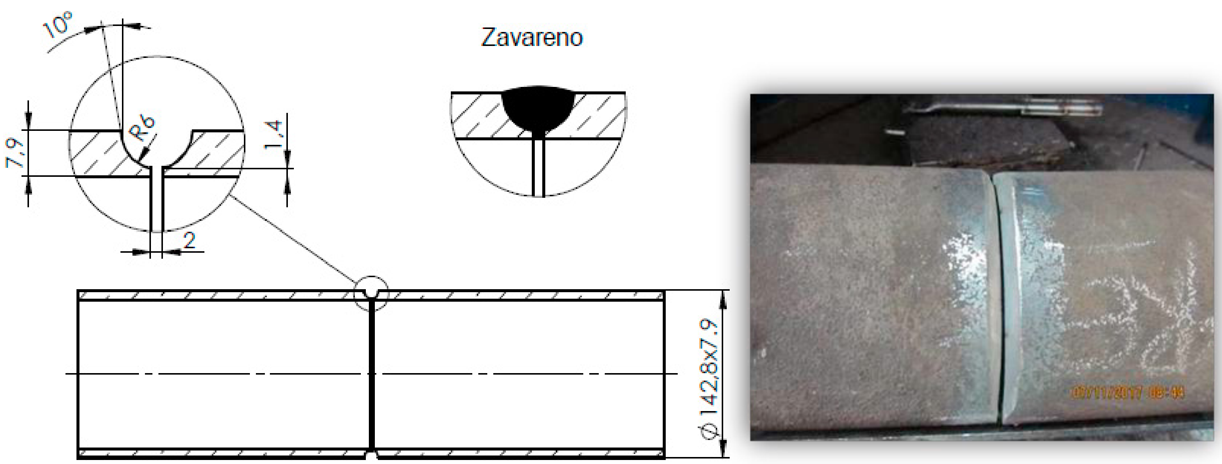

Figure 3. Prepared U groove in the pipe.

Welding amperage was 70 A, whereas the voltage ranged from 20-22 V. Welding was performed in 4 passes, with frequent interruptions, i.e. the whole joint was made using short welds in order to avoid overheating of the material above 100°C (similar to grey cast). Welding of the burner was performed in the „wall“ position without electrode swinging.

After the fourth pass was finished, the chemical composition of the final layer was tested. The share (percentages) of all elements are shown in table 4. It can be seen that the carbon percentage is 0.

Table. 4 Chemical composition of electrode Castolin 6825

Element [%]	C	Si	Mn	P	S	Cr	Ni	Cu	Mo	Nb+Ta	Fe
Tested	/	0.130	0.73	/	/	17.67	57.37	0.007	8.68	/	14.3

The appearance of the welded burner pipe (the welded joint) is shown in figure 4. The weld was tested using the penetrant method and no defects were detected in it. After this, the repaired pipe was put in exploitation.

Fig. 4. The appearance of the repaired burner pipe.

4. Discussion and conclusions

The selection of filler material represents a very important step within the algorithm of operations during repair welding, whereas its inadequate selection can lead to additional problems. The selection of the electrode is dictated by the exploitation conditions under which the repaired part will work, as well as the base material from which the equipment is made. The conditions to which the pipe is subjected indicate high and cyclic temperature changes which resulted in crack initiation along the full length of the weld metal (type 25/20 electrode). Due to high temperatures that can reach up to 850°C, cracks occurred, especially in the welded joint area.

For the purpose of repairing of burner pipes, a selection was made for the new electrode, and Castolin 6825 was tested. Repair welding was performed with this new electrode, in four passes. Its diameter was ø3.25, with an amperage of 70 A, and a temperature which did not exceed 100°C during the welding process. Chemical testing of the fourth (final) welded layer was performed, and certain differences were observed, compared to catalog values. After penetrant testing was performed, no defects were detected and the pipe was put in exploitation, while its behaviour was being monitored. The fact that the pipe was exploited without problems confirms the justifiability of the use of the new electrode.

In addition to its role in maintenance, repair welding also results in financial savings. Apart from direct savings achieved using repair welding in comparison to the costs of purchasing a new pipe (which would cost 4 times more money than the repair itself), one should take into account the indirect savings achieved by not having to wait for the new part to be manufactured (which would result in downtime).

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