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ARCHIVES
of
FOUNDRY ENGINEERING

DOI: 10.1515/afe-2016-0072

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (2299-2944)
Volume 16
Issue 3/2016

167 – 171

Repair of Structural Steel Surface Groove by Using Flame Welding Method by Spraying Pure Iron Powder

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Received 02.12.2015; accepted in revised form 21.01.2016

Abstract

To improve mechanical properties and increasing useful life of metal pieces, different methods of welding are used for repairing surface crack of metal pieces. In this research, performance of flame welding method by spraying pure iron powder evaluated for repairing surface grooves of structural steel. First, four specimens including one control specimen and other three specimens grooved specimens in depth of 1mm and in length of 12.5mm and groove width in the sizes of 0.5, 0.75 and 1mm.were prepared then, powder melted using oxyacetylene reducing flame and spraying iron powder in the flame path and attached to the inner surface of the groove and finally, the specimen repaired. Results showed that after repairing surface groove, tensile strength of the repaired specimens were reached to the tensile strength of control specimen with the margin of 2.5%.

Keywords: Oxyacetylene, Reducing flame, Tensile strength

1. Introduction

Nowadays industrial game, preventive measures for maintenance and repair of the machinery and equipment are of special importance. Failure to identify cracks and action to prevent its growth and spread causes the tragic events. Failure in the metals mostly occur in premature. So, it provides crisis conditions. For example, emergence of failure in the metal pieces of military equipment during attack, defend or retreat will determine a disaster. Another example is that emergence of failure in the metal pieces of drilling equipment when drilling oil or gas well leads to rework and spending high costs. Another example is the emergence of failure in the diesel engine parts of ships during the chase pirates and enemy that leads to failure in doing task and even destruction. In all above cases, a quick and simple repair can prevent the stop of device and provide the ability to pass from crisis. Then, one can repair or replace defective pieces in appropriate conditions.

One of the most commonly used methods for repairing surface cracks of the metal pieces is to use arc welding with manual electrodes. The biggest limitation of this method is to create numerous metallurgical defects in the repair site [1]. Other methods include flame welding by spraying powder [2-4], Welding on the furnace [5] and drilling and screw-working [6].

Fatigue strength and tensile strength are improved with the help of flame welding method by spraying iron powder done in the location of the cross connection in repairing surface cracks of steel cross connections [3-4].

In repairing surface crack of nickel base super alloy with the help of flame welding by spraying powder was shown that repaired structure is more fine grain and has more strength than conventional repair methods [7-8].

In welding on the furnace method, the whole piece is heated and so, surface oxidation is occurred and partly leads to change microstructure. In addition, this method is useful for big pieces [5].

Drilling and screwing alone is not known as an effective method, but if it used in combination with other methods will be useful [6].

In this paper, it is tried to repair steel surface grooves with the help of flame welding method by spraying pure iron powder in the flame path. So, the goal is to determine performance of repairing structural steel surface groove by the flame welding by and spraying the pure iron powder in the flame path. In the other words, the purpose of this research was to achieve the tensile strength of control specimen after repairing of grooved specimens.

2. Materials and Method

Rough steel sheet purchased from Sepahan Steel Company and chemical composition of the sheet was determined by using Applied Research Laboratories (ARL) machine in Razi Metallurgical Research Center (RMRC) and it listed in Table 1. According to ASTM A370 standard [9], tensile test specimens in thickness of 6mm were prepared according to Figure 1 and provided in Razi Research Center. In RMRC, three tensile test specimens were used for determining tensile strength of base metal and elongation of relative length of base metal using tensile machine GOTECH7100L. According to Table 2, average tensile strength of control specimen determined 462 *MPa* and average elongation of relative length of base metal was determined 33.3%. Therefore, the purpose of this research was to achieve the tensile strength of 462 MPa and relative elongation of 33.3% after repairing of grooved specimens. Also, metallographic of specimens in the sizes of 8×15mm prepared and provided in RMRC.

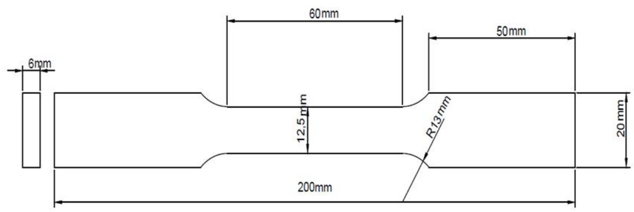

Fig. 1. Sizes and shape of tensile specimen

Table 1.
Chemical composition of steel (control specimen)

C	Si	S	P	Mn	Ni	Cr	Mo	V	Cu
0.12	0.05	0.011	0.025	0.70	0.001	0.004	0.002	0.003	0.11
Ti	**As**	**Sn**	**Co**	**Al**	**Pb**	**Nb**	**W**	**Fe**	
0.001	0.008	0.02	0.05	0.006	0.001	0.002	0.003	Balance	

Table 2.
Mechanical properties of steel (control specimen)

Specimen No.	Tensile strength MPa	Elongation in percent
1	461	33.5
2	456	34
3	470	32.5
Mean	**462**	**33.3**

To repair, 300g of the pure iron powder purchased from Azna Ferroalloy Company. Scanning electron microscopy (SEM) image with the energy spectrum (EDS), Figure 2, and the average grain size of iron powder is 33 microns.

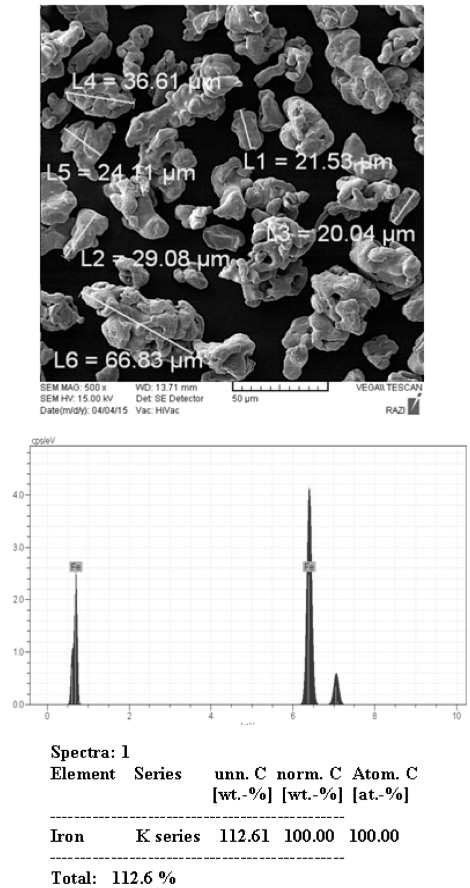

Fig. 2. Image of Iron powder with scanning electron microscopy TESCAN VEGA

According to Figure 3, microstructure of the control specimen includes Ferrite and Perlite in the form of string and layer. Nital solution of 2% was used for simulation and time of keeping in the Etch solution was 5 seconds.

For studying performance of the structural steel surface groove repairing with the help of flame welding by spraying pure Iron powder, in total, four specimen categories were prepared including one control specimen (without groove) and three grooved specimens with groove width sizes of 0.5, 0.75 and 1mm but with the same groove length (10mm) and the same groove depth (1mm). Each category of specimen included four specimens that three specimens were used for tensile test and the other one specimen was used for metallographic test. Repair steps were as follow:

1. The surface was cleaned.
2. Reducing oxyacetylene flame was lit.
3. Groove to be preheated for 5 seconds.
4. Pure Iron powder was sprinkled on the path of reducing oxyacetylene flame to get into the groove.
5. Powder melted in the path of flame.
6. Connection was created after the collision of the molten powder with the wall of groove.

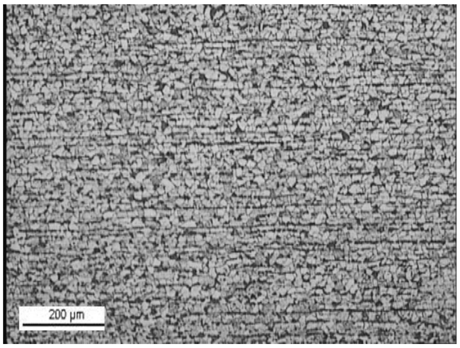

Fig. 3. Microstructure of the base metal, ferrite phase is bright and perlite phase is dark, optical microscopes of Dewinter Company

3. Results and Discussion

After repair, tensile properties of the grooved specimens with the groove width sizes of 0.5, 0.75 and 1mm were determined and introduced in Table 3, Table 4 and Table 5, respectively. To determine performance of repair method, tensile strength of the repaired specimens was compared with the tensile strength of control specimen in Table 6 and Figure 4.

Table 3.
Tensile properties of the repaired specimen with the groove width size of 0.5mm

Specimen No.	Elongation in percent	Tensile strength MPa	Comments
1	23.5	468	Specimen failed around the repair area
2	23.0	466	
3	24.0	473	
Mean	**23.5**	**469.0**	

Table 4.
Tensile properties of the repaired specimen with the groove width size of 0.75mm

Specimen No.	Elongation in percent	Tensile strength MPa	Comments
1	28.0	455	Specimen failed around the repair area
2	28.5	454	
3	27.5	450	
Mean	**28.0**	**453.0**	

Table 5.
Tensile properties of the repaired specimen with the groove width size of 1mm

Specimen No.	Elongation in percent	Tensile strength MPa	Comments
1	32.5	454	Specimen failed around the repair area
2	31.5	453	
3	31.5	447	
Mean	**31.8**	**451.3**	

Table 6.
Comparison of tensile properties of the repaired specimens with control specimen

Groove size mm	The average tensile strength MPa	The average elongation of relative length %
0.5	469	23.5
0.75	453	28
1	451.3	31.8
Control without groove	462	33.3

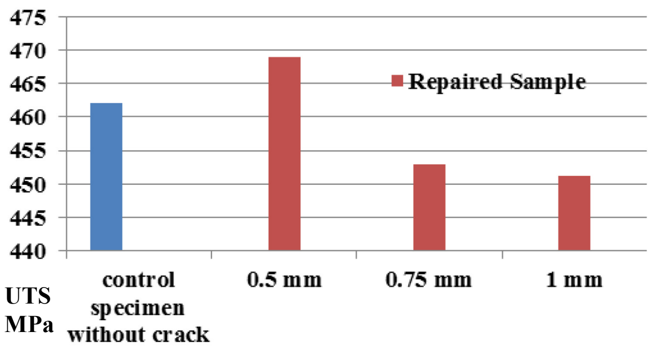

Fig. 4. Comparison of tensile strength of control specimen and repaired specimens

Based on the obtained results from the tensile test, only average tensile strength of the repaired grooved specimen with the groove width size of 0.5mm showed 7MPa more than the average tensile strength of control specimen. While average tensile strength of the repaired grooved specimens with the groove width size of 0.75 and 1mm showed relatively 10 MPa (2.5%) less than the average tensile strength of control specimen.
Therefore according to Figures 5 to 7, metallurgical defects in the repaired grooved specimens with the groove width of 0.75 and 1mm were more than repaired specimen with the groove width size of 0.5mm and so, its effect was appeared in the form of tensile strength reduction.
According to the Manual spraying method in this research, in the Cases where the ceramic tube of pure iron powder spraying, was removed from the flame axle, the unmelted powder was sprayed into cracks. Therefore, the black areas in the images (5,6 and7) can be seen is pure iron powder.

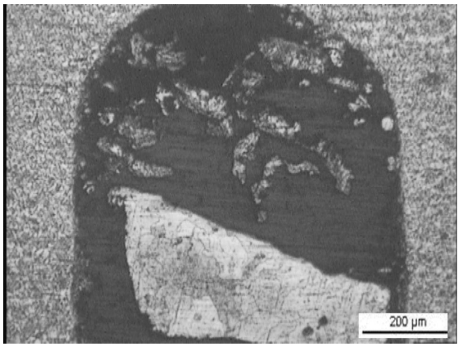

Fig. 5. Repaired specimen with the groove width size of 0.5mm, metallurgical defects in the dark color in the repaired place, optical microscope of Dewinter Company

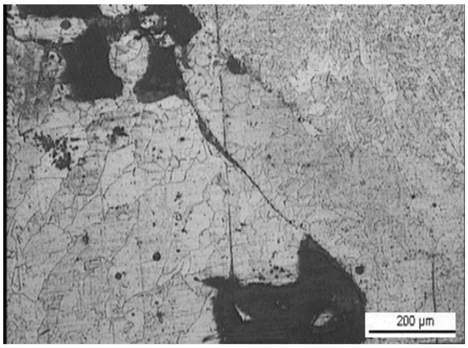

Fig. 6. Repaired specimen with the groove width size of 0.75mm, metallurgical defects in the dark color in the repaired place, optical microscope of Dewinter Company

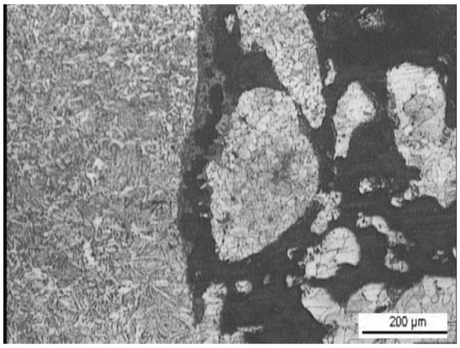

Fig 7. Repaired specimen with the groove width size of 1mm, metallurgical defects in the dark color in the repaired place, optical microscope of Dewinter Company

4. HAZ (Heat Affected Zone)

In this method the mass of the filler material (m) is very low, so according to the Eq 1, The heat input (Q) is very low and as a result the HAZ is too short. It is an advantage of this method.

$$Q = m.C.\Delta T \quad (1)$$

The macroscopic image of penetration illustrated in Figure 8.

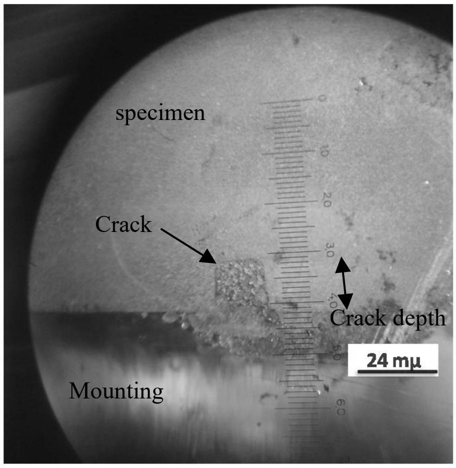

Fig. 8. The macroscopic image to check the influence of pure iron into the repaired steel specimens with groove width size of 1 mm, by microscope of Dewinter Company

5. Conclusions

In this research, it was tried to repair structural steel surface grooves with the help of flame welding by spraying pure iron powder in the reducing flame path of oxyacetylene. So, four specimen categories were prepared including one control specimen and three other specimens as grooved specimens with 12.5mm length, 1mm depth and 0.5, 0.75 and 1mm groove width sizes. According to the obtained results from tensile test, this method was useful for surface grooves of structural steel with the groove sizes from 0.5 to 1mm, because repair could maintain tensile strength of grooved specimens with the sizes from 0.5 to 1mm in comparison with tensile strength of control specimen with the margin of 2.5%.

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