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Repair of Structural Steel Surface Groove by Using Diffusion Welding of Pure Iron Powder

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Abstract

Metal pieces wear out due to variable loading, because cracks formed on their surface of them. In order to increase useful life of metal pieces with the help of different methods of welding, surface cracks are repaired. In this research, performance of the diffusion welding of pure iron powder through magnetic induction evaluated for repairing structural steel surface cracks. First, four specimens prepared including one control specimen and other three specimens grooved specimens in length of 6.25mm and in depth of 1mm and groove width in the sizes of 0.5, 0.75 and 1mm. Then by a coil, the induced current created in the piece surface. After crossing the current, the powder melted and the groove repaired due to diffusion welding. To prevent oxidation, the atmosphere inside the coil filled with argon gas. The results show that after repairing surface groove, tensile strength of the repaired specimens reached to the tensile strength of control specimen with the margin of 7.5%.

Keywords: Magnetic induction, Tensile strength, Useful life

1. Introduction

Nowadays industrial world, problems and solutions are divided into different categories. Economic, geographic conditions and existing facilities each is involved in creating and solving industrial needs. In certain conditions, it changes reaction rate of these equations in its favor so that in these certain conditions, solving problem is not only a demand but the only lifeline or the last trump card. This is where the past priorities faded and all mobilized to a single goal. Certain circumstances are created in terms of technical or logistical crisis or in times of war and defending the home. Consider a moment that the non-performance of an organ in a system can cause irreparable

damage to the whole system. In such special conditions, passing through the crisis is a priority and perhaps one should pass this step in the short term and at the expense of non using piece. In these conditions, the role of repairs and emergency solutions is clear and engineers are persuaded to invent a useful way.

Failure in the metals mostly occurs 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 devices and provide the ability to pass from crisis. Then, one can repair or replace defective pieces in the 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 [1]. The biggest limitation of this method is to create numerous metallurgical defects in the repair site. 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 installation location of the cross connection in repairing surface cracks of steel cross connections [3-4].

It was shown that repaired structure is more fine grain and has more strength than conventional repair methods in repairing surface crack of nickel base super alloy with the help of flame welding by spraying powder [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 using it in combination with other methods will be useful [6].

In this paper, it is tried to repair structural steel surface grooves with the help of diffusion welding method with pure iron powder through magnetic induction in argon gas atmosphere. So, the goal is to determine performance of repairing structural steel surface groove by the diffusion welding and using magnetic induction in argon gas atmosphere. 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 (base metal) purchased from Sepahan Steel Company and chemical composition of the sheet determined by using Applied Research Laboratories (ARL) machine in Razi Metallurgical Research Center (RMRC) and listed in Table 1. According to ASTM A370 standard [9], tensile test specimens in thickness of 6mm prepared according to Figure 1 and provided in RMRC.

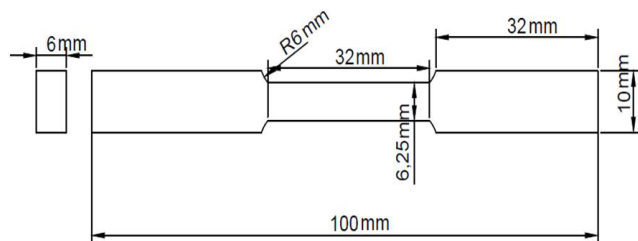


Fig 1: Sizes and shape of tensile specimen

In RMRC, three tensile test specimens 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 base metal determined 462 MPa and average elongation of relative length of base metal determined 33.3%. Also, metallographic of specimens in the sizes of 8×15mm prepared and provided in RMRC.

Table 1.
Chemical composition of steel (control specimen)

C	Si	S	P	Mn	Ni	Cr	Mo	V	Cu
0.10	0.06	0.010	0.023	0.68	0.002	0.006	0.001	0.003	0.100
Ti	As	Sn	Co	Al	Pb	Sb	Nb	W	Fe
0.001	0.007	0.010	0.002	0.007	0.001	0.001	0.001	0.004	Base

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), Fig 2, and the Iron powder pure is grain size of 24 microns. Quantitative analysis presented in Table 3.

Table 3.
SEM of the iron powder with scanning electron microscopy TESCAN VEGA

Element Series	unn. C [wt.-%]	Norm. C [wt.-%]	Atom. C [at.-%]
Iron K series	112.61	100.00	100.00
Total	112.6%		

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

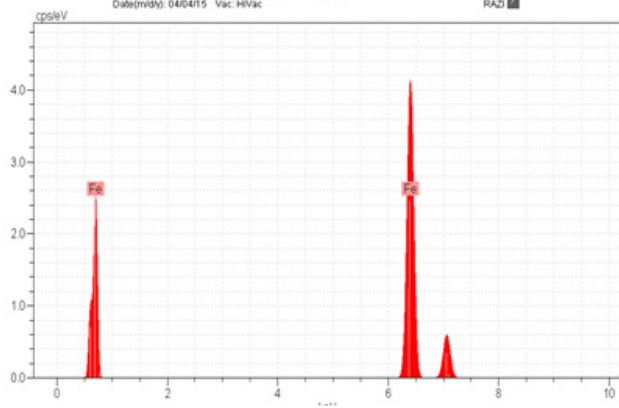
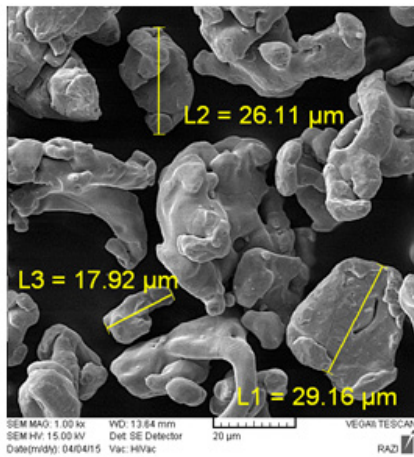


Fig. 2. Image of iron powder with scanning electron microscopy TESCAN VEGA

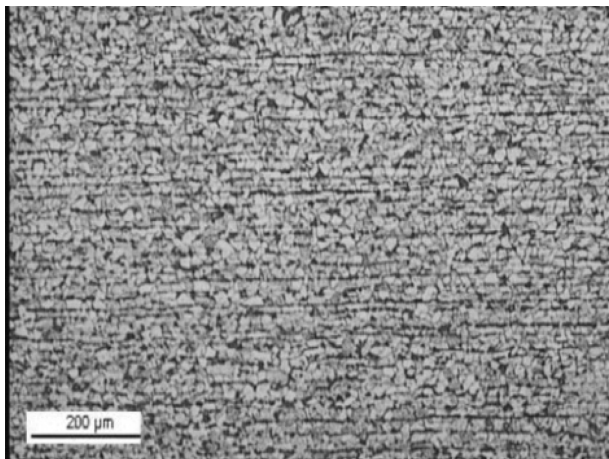


Fig. 3. Microstructure of the base metal, ferrite phase is bright and perlite phase is dark, optical microscopes of Dewinter Company

For studying performance of the structural steel surface groove repairing with the help of diffusion welding of pure iron powder through magnetic induction, in total, four specimen categories 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). Were prepared each category of specimen included four specimens that three specimens used for tensile test and the other one specimen used for metallographic test. Repair steps were as follow:

1. Groove of the grooved specimens were filled with powder and all four specimen categories were placed inside induction furnace made in Tepka Company.
2. The induction furnace was turned on. To prevent oxidation, the argon gas was injected into the furnace.
3. All category of specimens were kept for 15 minutes at a temperature of 1350° C. Temperature was measured by Laser Pyrometer made of America Aktstch Company.
4. Specimens were cooled in air to ambient temperature.
5. From each category of specimens (four specimens), category three were used to study tensile properties and the other one was used to study the microstructure.

3. Results and Discussion

According to Figure 4, after repairing, microstructure of base metal includes needle ferrite and partial areas of perlite are dark because the specimens were repaired at 1350° C for 15 minutes and then cooled in the air to ambient temperature (it is called control specimen). For this reason, the tensile properties of control specimen that had been placed inside the furnace with repaired specimens were determined and presented in Table 4. As shown in Table 4, the average tensile strength and relative elongation of the control specimen were 459 MPa and 33.8%, respectively. Therefore, the purpose of this research was to achieve the tensile strength of 459 MPa and relative elongation of 33.8% after repairing.

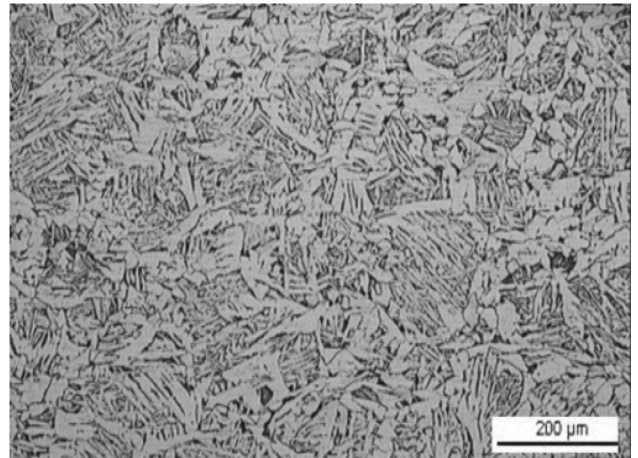


Fig. 4. The micro structure of control specimen that had been placed inside the furnace with repaired specimens, ferrite is bright phase and perlite is dark phase, optical microscope company Dewinter

Tensile properties of the grooved specimens with groove width size of 0.5, 0.75 and 1mm after repairing were determined and presented in Tables 5, 6 and 7, respectively.

To examine performance of repair method, tensile strength of the repaired specimens were compared with tensile strength of the control specimen in Table 8 and Figure 5.

Table 4.

Tensile properties of control specimen that had been placed inside the furnace with repaired specimens

Specimen No.	Tensile strength MPa	Elongation in percent
1	459	34.5
2	460	33.0
3	458	34.0
Mean	459	33.8

Table 5.

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

Specimen No.	Elongation in percent	Tensile strength MPa	Comments
1	33.0	469	Specimen failed around the repair
2	32.0	472	Specimen failed around the repair
3	33.0	470	Specimen failed around the repair
Mean	32.7	470	

Table 6.

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

Specimen No.	Elongation in percent	Tensile strength MPa	Comments
1	27.0	460	Specimen failed around the repair
2	29.5	450	Specimen failed around the repair
3	28.5	456	Specimen failed around the repair
Mean	28.3	455	

Table 7.

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

Specimen No.	Elongation in percent	Tensile strength MPa	Comments
1	19.5	426	Specimen failed around the repair
2	18.0	429	Specimen failed around the repair
3	19.5	421	Specimen failed around the repair
Mean	19.0	425	

Table 8.

Comparison of tensile properties of the repaired specimens with control specimen

groove size	The average tensile strength MPa	The average elongation of relative length %
0.5	470	23.7
0.75	455	28.3
1	425	19.0
Control without groove	459	33.8

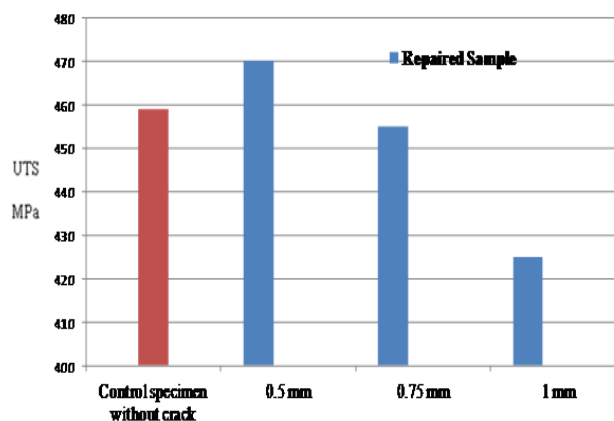


Fig. 5. Comparison of tensile strength of the control specimen and the repaired specimens

Considering the samples for 15 minutes were kept at temperature of 1350 °C. After the repair, is the grain coarsening microstructure show Fig 4, the grains coarsening reduces the yield strength and impact resistance. This is an influence negative of steel.

The macroscopic image of penetration illustrated in Figure 9. Based on to the obtained results from the tensile test, only average tensile strength of the repaired grooved specimen with the groove width size of 0.5mm shows 11MPa 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 is unchanged in comparison with the average tensile strength and average tensile strength of the repaired grooved specimen with the groove width size of 1mm shows relatively 34 MPa less than the average tensile strength of control specimen. Because according to Fig 6 to 8, metallurgical defects caused by dispersing the powder particles due to the pressure of argon gas from the groove place in the specimen with the groove width of 1 mm are more than repaired specimens with the groove width size of 0.75 and 0.5mm and therefore its effect is appeared in the form of tensile strength reduction.

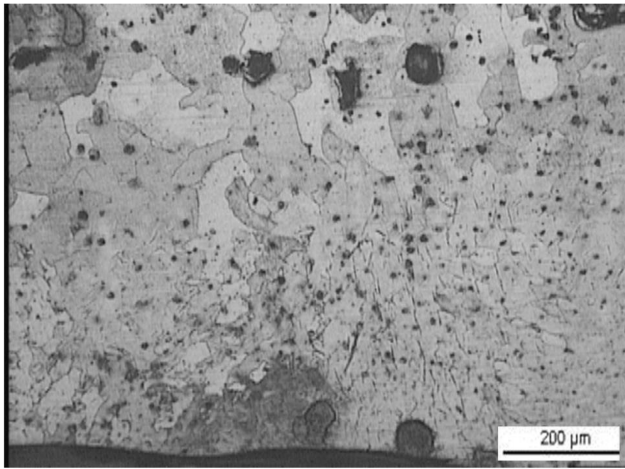


Fig. 6. Repaired specimens with groove width size of 0.5mm, metallurgical defects in dark color repaired in the place resulted from dispersing powder particles due to the pressure of argon gas, optical microscope of Dewinter Company

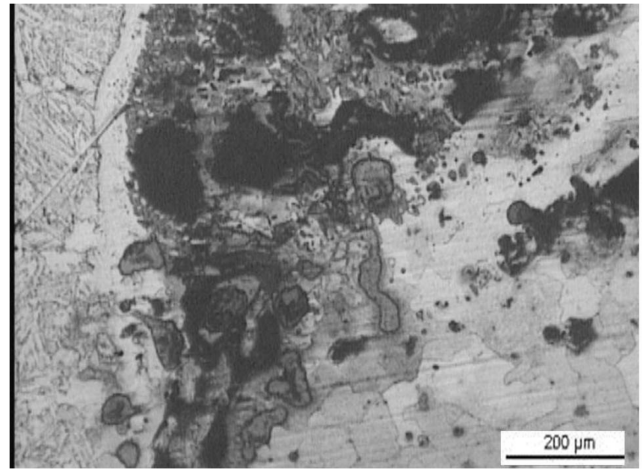


Fig. 7. Repaired specimens with groove width size of 0.75mm, metallurgical defects in dark color repaired in the place resulted from dispersing powder particles due to the pressure of argon gas, optical microscope of Dewinter Company

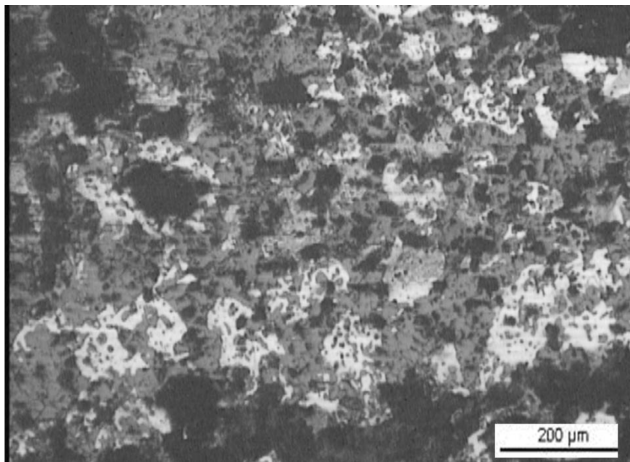


Fig. 8. Repaired specimens with groove width size of 1mm, metallurgical defects in dark color repaired in the place resulted from dispersing powder particles due to the pressure of argon gas, optical microscope of Dewinter Company

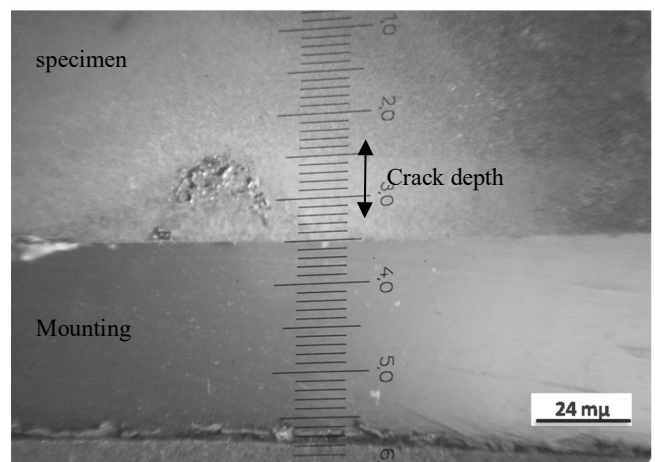


Fig. 9. The macroscopic image of penetration into groove width size of 0.75mm, optical microscope of Dewinter Company

4. Conclusion

In this research, it was tried to repair structural steel surface grooves with the help of diffusion welding with pure iron powder through magnetic induction in argon gas atmosphere. So, four specimen categories were prepared including one control specimen and three other specimens as grooved specimens with 6.25mm 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 7.5%.

References

- [1] Mirhedayatian, S.M., Vahdat, S.E., Jelodar, M.J. & Saen, R.F. (2013). Welding process selection for repairing nodular cast iron engine block by integrated fuzzy data envelopment analysis and TOPSIS approaches. *Materials & Design*. 43: 272-82.
- [2] Huan, S. (1995). Flame spray welding using tungsten carbide alloy powder: S. Huan et al. (Shenyang Polytechnic University, Shenyang, China). *PM Technology*. 13(4), 259–264. (In Chinese.). *Metal Powder Report*. 1996; 51:44.

- [3] Miki, C., Hanji, T. & Tokunaga, K. (2012). Weld Repair for Fatigue-Cracked Joints in Steel Bridges by Applying Low Temperature Transformation Welding Wire. *Weld World*. 56, 40-50.
- [4] Sterjovski, Z. (2010). Pad-Weld Repairs of in-Service High-Strength Steel Plate used in Seawater Environments. *Weld World*. 54, R173-R81.
- [5] Committee, A.I.H., Olson, D.L. (1993). *ASM handbook: Welding, brazing, and soldering*: ASM International.
- [6] Nakamura, H., Jiang, W., Suzuki, H., Maeda, K-i. & Irube T. (2009). Experimental study on repair of fatigue cracks at welded web gusset joint using CFRP strips. *Thin-Walled Structures*. 47, 1059-68.
- [7] Zhao, X., Wang, D. & Deng, C. (2014) Research on fatigue behavior of welded joint spraying fused by low transformation temperature alloy powder. *Materials & Design*. 53, 490-6.
- [8] Zhao, X., Wang, D. & Deng, C. (2011). Fatigue behavior of welded joint spray fused by nickel-base alloy powder. *Journal of Materials Processing Technology*. 211, 2039-44.
- [9] ASTM A370, (2014). Standard Test Methods and Definitions for Mechanical Testing of Steel Products, ASTM International, West Conshohocken, PA, www.astm.org