Journal of Oil, Gas and Petrochemical Technology 9(1): 39-48, Winter and Summer 2022

RESEARCH PAPER

Corrosion Investigation of Projection Friction Stir Spot Welding of Al 2024 Sheets in Oil and Gas Industry

A. Arabzadeh[1], B. Korojy[2*], S.M. Mousavizade[3], S.A. Hosseini[4]

1,2,4. Department of Materials and Polymer engineering, Faculty of Engineering, Hakim Sabzevari University, Sabzevar, Iran

3. Department of Materials Science and Engineering, Faculty of Engineering, University of Gonabad, Gonabad, Iran

ARTICLE INFO

Article History:
Received 2022 April 14
Revised 2022 July 28
Accepted 2022 July 30

Keywords:
Friction stir spot welding
Oil and gas industry
Corrosion behavior

ABSTRACT

In order to determine a suitable alternative welding method for the substituation of fusion and resistance welding in oil and gas industry, a new method of projection friction stir spot welding with constant diameter and depth of protrusion was herein used for the welding of 2024 aluminum sheets. By studying the previous research that was done on the friction stir spot welding of this material, the rotational speed of 800rpm was chosen for this purpose. Hence, the microstructure along with the corrosion behavior of the projection friction stir spot welding of Al2024 joints was investigated as a novel welding technique in oil and gas sector which produced reliable, safe, smooth and keyhole-free joints. The microstructural changes of different welding areas were studied by novel field emission scanning electron microscopy and consequently the hardness profiles of different areas were drawn. The effect of corrosive oil solution containing salts on the welded specimens was studied and various types of pitting and intergranular corrosion were observed in different welding areas. Eventually, the accumulation of corrosion products was observed in the stirred area of the weld and the TMAZ showed the highest rate of the intergranular corrosion..

How to cite this article
Arabzadeh A, Korojy B, Mousavizade SM, Hosseini SA. PCorrosion Investigation of Projection Friction Stir Spot Welding of Al 2024 Sheets in Oil and Gas Industry, Journal of Oil, Gas and Petrochemical Technology, 2022; 9(1): 39-48. DOI:10.22034/JOGPT.2022.333583.1104.

1. INTRODUCTION

Heat treatable aluminum alloys are broadly used in several industries for different engineering applications. However, joining of these alloys using usual fusion welding technique is difficult because of some new microstructure formation by fusion welding that decreases the mechanical properties of the weld[1, 2]. In addition, fusion welding of some light metals faces other difficulties like welding defects and corrosion damages[3]. One of the most important joining methods used in the oil and gas industry is the resistance spot welding (RSW); however, like fusion welding, this method also causes defects in alloys with low melting point.[4]. As a good replacement for the conventional fusion welding and RSW techniques, Friction stir welding was introduced in 1991[5]. FSW produces less defects and microstructural changes and improves the mechanical strength of the weld compared to all conventional joining techniques.[1, 6]. FSW is linear and its spot type,

* Corresponding Author Email: b.korojy@hsu.ac.ir

Friction Stir Spot Welding (FSSW) developed by Kawasaki heavy machine factory is considered as a suitable, more acceptable and more advanced alternative to RSW.[4] It has been also used by different companies and in different industries all over the world since 2003 [4, 7].

Despite having similar basic principles, there are some main differences between FSSW and FSW. In the FSSW process, the connection is made in a small pointing area by dipping and pulling out the rotating tool. (figure 1).

FSSW is a welding method which runs in the solid state and originally prohibits solidification defects. This is because the maximum temperature is lower than that found in fusion welding and RSW makes this welding method a suitable process for joining metals with high thermal conductivity[8]. The other advantage of FSSW process is to develop very fine recrystallization grains in the stir zone[8]. The main problem with this method is leaving a keyhole [9] on the joint surface (figure 1), which threateningly reduces the mechanical properties of the joint and creates a weak area for the corrosion to begin [10]. In recent years, various techniques have been explored to avoid creating this defect. Each of the proposed techniques has its own problems and limitations.[8].

One of the new techniques developed for solving the keyhole problem is called Protrusion Friction Stir Spot Welding.This method uses a circular metal protrusion on the surface of the work piece (figure2)[11]

General corrosion of aluminum alloys in salty oil solution is usually very low, while the pitting corrosion mostly has destructive effects on these metals in chloride medium. The extent of corrosion and the depth of the pores depend on the purity of these aluminum alloys, so that the purest of them (Series 1xxx) is the most resistant to the pitting corrosion. [13]. Factors such as temperature and pH as well as the number of dissolved elements are effective in the pitting corrosion process. In addition, the morphology of existing phases and their distribution can also affect the pitting corrosion. Therefore, the welding method is considered as a factor that affects the pitting corrosion.[1, 13, 14].

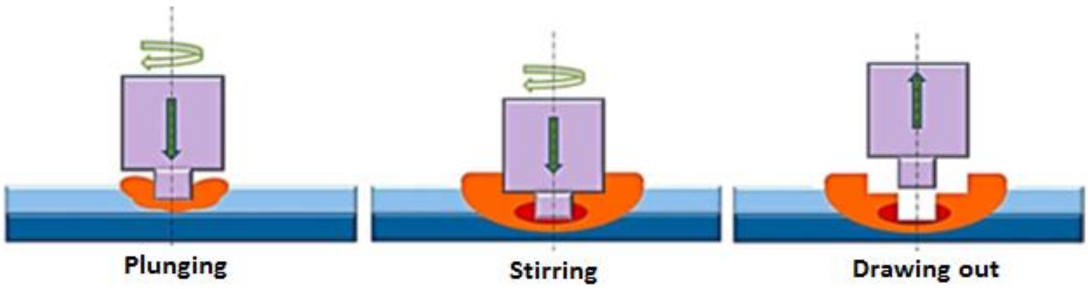


Figure1. Friction stir spot welding steps[8]

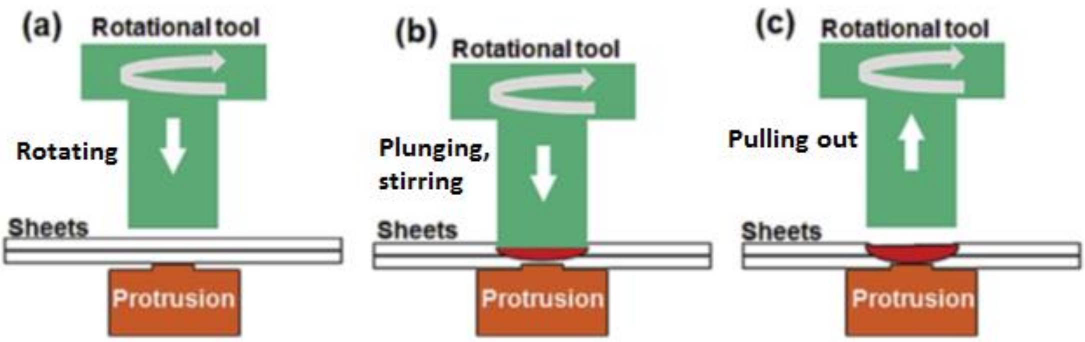


Figure 2. Schematic representation of the PFSSW method which consists of (a) rotating, (b) plunging and stirring, (c) pulling out [4, 11, 12]

Different microstructural regions arise in FSW process, including the stirred zone (SZ) which is sometimes known as nugget zone (NZ), thermo-mechanically affected zone (TMAZ), heat affected zone (HAZ), and base metal (BM)[15-18]. The schematic illustration for the location of these different welding zones which are the same in FSW, FSSW and PFSSW is shown in figure 3. These microstructural areas are expected to exhibit different properties because each region has unique specification with different depositions[15, 19]. No plastic deformation occurs in HAZ and it is only affected by temperature, so the grains in this area are like base metal in size and shape. In TMAZ close to the stir zone, the material is simultaneously exposed to heat and plastic deformation. The stir zone is the only area that experiences the highest plastic deformation and temperature, even reaching 500º C [20]. The microstructure is generally composed of coaxial fine grains due to the complete dynamic recrystallization [21].

Many studies have been conducted on the microstructure, corrosion behavior and other specifications of FSW for various aluminum alloys, including Al2024 alloy, which often indicate that the friction stir welded zones are more sensitive to local corrosion in comparison with the base material [21-26].

The effect of welding parameters on the corrosion behavior of AA2024-T3 friction stir welding was studied. The results showed more electronegative in weld than in the base metal. [25] Effect of rotational speed on the microstructure of FSW was studied. It was found that for low rotational speed, the localized intergranular corrosion happens in the stir zone, while for high rotation, corrosion occurs mostly in HAZ[21].

The corrosion resistance of AA2A14 aluminum alloys welded by friction stir method in exfoliation corrosion solution was studied by means of several electrochemical techniques[27, 28]. A study on the effect of various factors, specially time of immersion on the corrosion rate of this alloy showed that the intensity of corrosion increases over time[28].

The mechanical properties of this novel welding method have been investigated [3, 8], however, to the best of our knowledge no investigation has ever been done regarding its corrosion resistance. That's why in this paper, microstructure and corrosion behavior of different welding zones of PFSSW for Al2024-T3 sheets by constant tool rotational speed of 800 rpm in 3.5% NaCl solution (which usually exist in desalting plant of oil industry) immersion test were investigated by different methods.

2. Research Method

The material used was 1 mm thick of the AA2024-T3 aluminum sheet (Al–4.9Cu–1.28Mg–0.629Mn–0.239Fe–0.125Zn –0.15Ti wt.%). T3 Indicates that the alloy has been given a solution heat treatment following hot working, quenching, cold working, and being naturally aged to a stable condition.

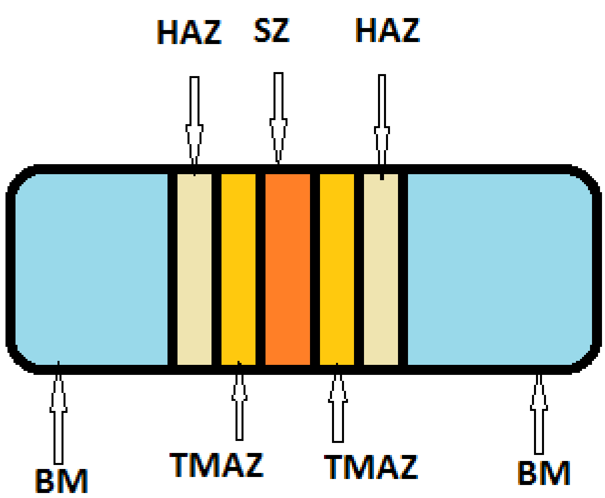


Figure 3. Schematic illustration and location of different welding zones in FSW, FSSW and PFSSW

This temper indicates the use of a specific solution heat treatment (i.e., holding in a furnace at a sufficiently high temperature for the important alloying elements to go into solution, where they are retained upon quenching and provide a source of precipitation-hardening constituents). The amount of cold work is controlled to provide specific amounts of strain hardening with a commensurate increase in strength. This is a widely-used temper type for 2xxx series alloys such as 2024, which naturally age efficiently following the cold work[29]. The process of similar joining of this alloy was performed in a complete overlapped configuration (figure 4). Surface contamination on all samples was removed with acetone before any test. In order to resist high wear at elevated temperatures, high-strength steel rotational tool of H13 hardend steel was selected. The smooth surfaces of this tool can be seen in Figure 4 on the upper surface of the specimens.

The diameter and height of the protrusion located just under the sheets were 10 mm and 0.4 mm, respectively. Other welding variables including constant rotational speed, dwell time and maximum penetration depth of the tool were 800rpm, 14s and 0.1mm respectively. The basis for choosing these welding variables was obtained by studying the previous research that was done on the friction stir spot welding of this material with the same thickness and the same environmental condition[3, 8].To control the penetration depth, the situation of the tool towards the work-piece surface with zero inclination degree was held constant.

In order to observe the microstructure of the weld samples, the specimens were polished and etched by Keller's reagent for 30 s. Optical and FESEM (MIRA3 TESCAN) were used to characterize the samples faced 3.5% NaCl solution as desalting plant solution.

The grain size in different welding areas and base metal was estimated according to ASTM E112 standard by line intercept method [30]. In order to compare different welding zones and base metal, hardness test was performed on different areas and hardness profile was drawn.

3. Results and Analysis

3.1. Macrostructure and the appearance of the weld

The appearance of upper and bottom surfaces of Al2024 plates after performing PFSSW along with the whole macrograph of the welded sheets are shown in Figure 5.

As can be seen in the picture, welding surfaces have a smoother and more uniform surface than other spot-welding methods. Tensile strength and other mechanical properties of this welding technique which have been previously studied show better mechanical properties and strength of this welding method[3, 8].

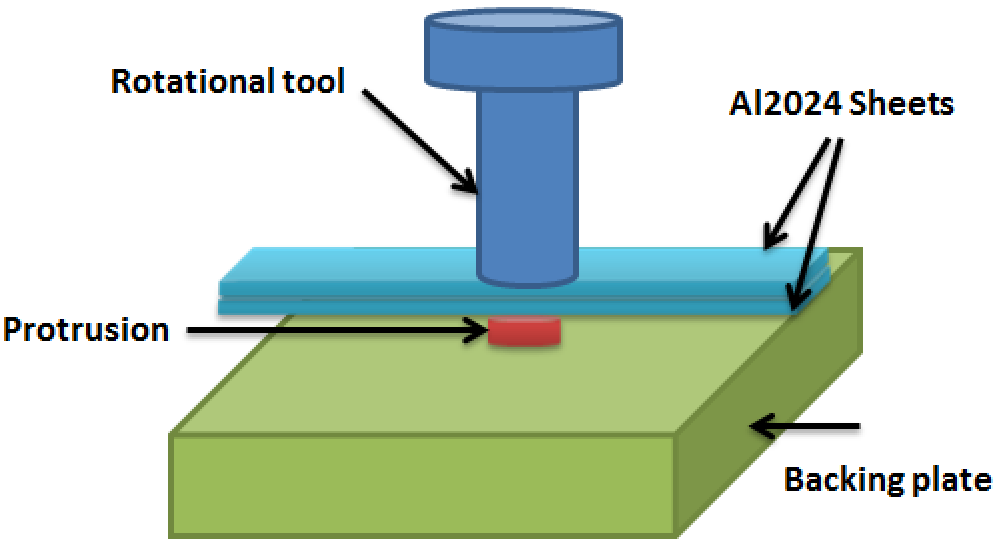
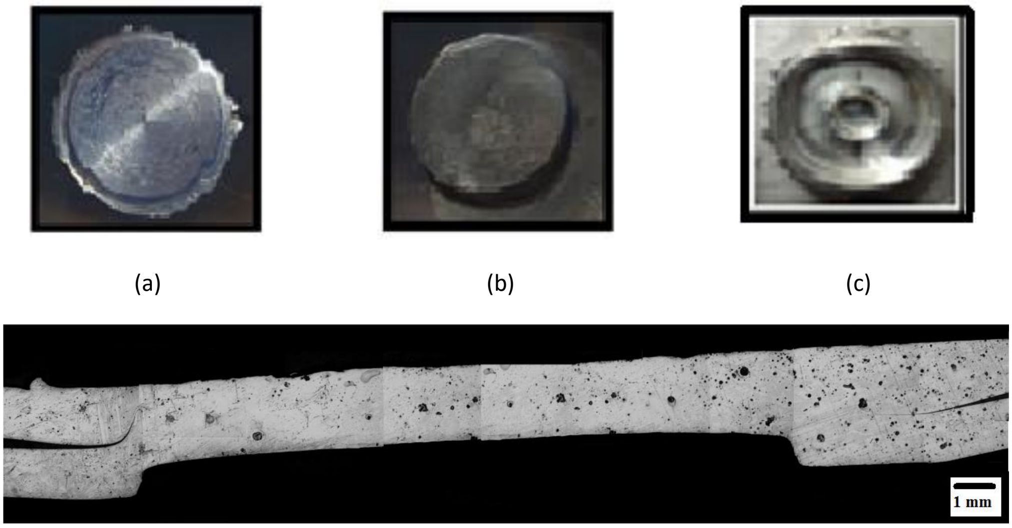


Figure 4. Schematic of rotational tool, welding plates, protrusion and backing plate in this investigation



(d)

Figure 5. Macrograph of (a) upper surface, (b) bottom surface and (c) top surface of FSSW for ref[31]. (d) cross section of PFSSW

3.2. Hardness profile

Hardness measurements in different welding areas were performed and the hardness profile of which is depicted in Figure 6. The hardness values were symmetrical towards the center region of the weld. Significant changes in hardness values occurred at the interface of different welding areas. The highest amount of hardness was in the base metal which occurred in the vicinity of HAZ. Due to the heat input, heat transfer as well as changes in the microstructure caused by recrystallization during the welding created different hardness values in different areas.

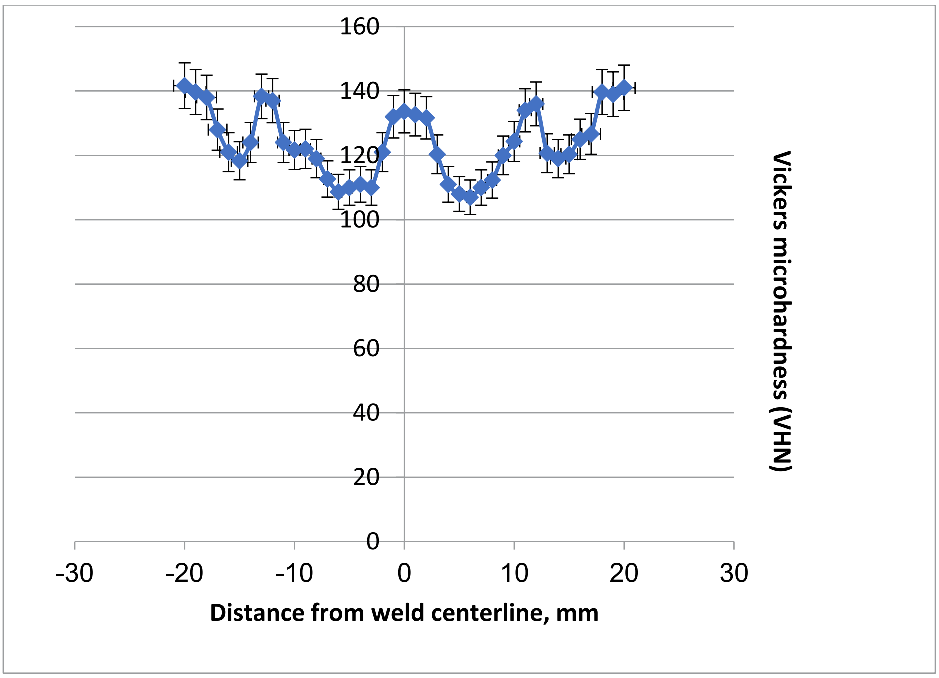


Figure 6. Vickers microhardness profile of cross section of PFSSW

3.3. Microstructure

3.3.1. Optical microscopy

Microscopic images of different welding areas and base metal are shown in Figure 7. As the grain size distribution in different regions shows, the microstructure of the base metal and HAZ, due to experiencing almost the same temperature, show a similar structure including large recrystallized grains with the average grain size of 21µm. In TMAZ, the grains were affected by plastic deformation during the welding. The grains were completely recrystallized in the stirred zone with the average grain size of 11µm which was smaller in size than the grains in other welding areas.

3.4. Field Emission Scanning Electron Microscopy

In order to investigate the corrosion behavior of PFSSW samples in addition to the amount and distribution of different precipitates and intermetallic particles, FESEM of different zones were done on the cross-sectional area of welding samples before and after the immersion of samples in 3.5 %NaCl solution for 12h at room temperature which are presented in Figures 8 and 9, respectively.

As can be seen from Figure 8, two general forms of the particles were found in the experimental samples: Small uniform shape of Al2CuMg and nonuniform shape of Al-Cu-Fe-Mn precipitates because of stirring action in this welding process, particles in SZ were more homogeneous [25, 32, 33]. Pitting in AA 2024 generally takes place at the site of S phase (Al2CuMg) the anodic part, which has lower pitting potential than the Al matrix that is the cathodic part. Al2CuMg phase is usually present as larger precipitates along the rolling direction and as smaller precipitates at the grain boundaries. Dissolution of Al2CuMg at the grain boundaries causes intergranular corrosion[1].

Distribution in size and density of intermetallics from base metal to HAZ, TMAZ and SZ shows an increase in density and reduction in size of the particles , so the size of these particles in BM and HAZ was almost 26 µm, and smaller particles ranged from 16-18 µm with increase in numbers for TMAZ. The high density of smaller particles (about 6 µm) was found in SZ. The high density of smaller particles in SZ is directly related to the complete recrystallization in this zone, because of experiencing more heat input [34].

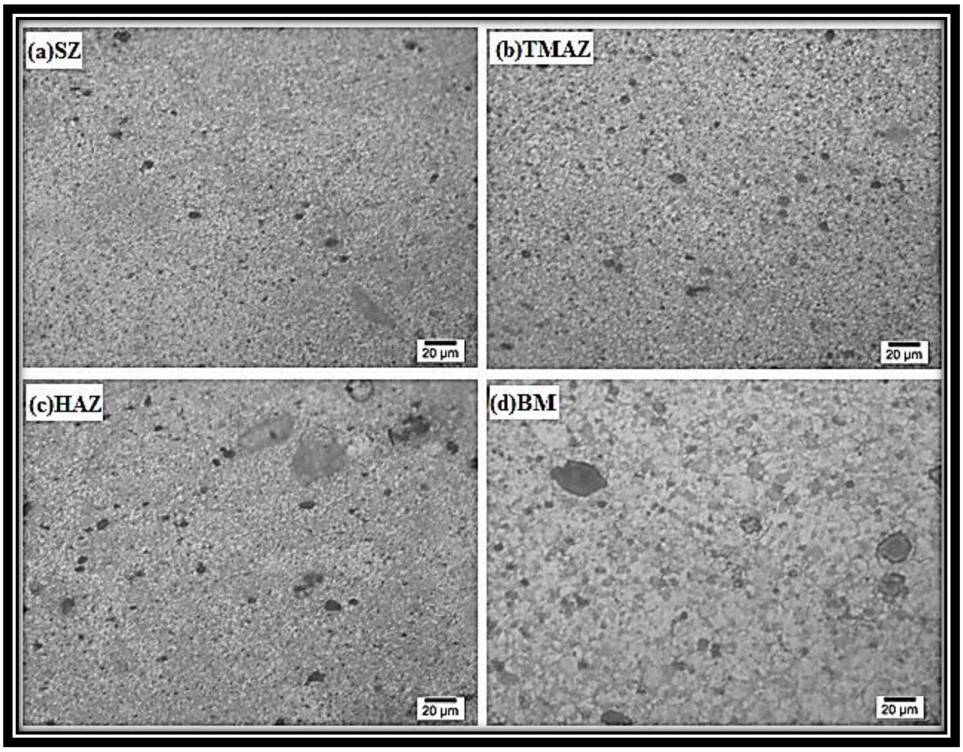


Figure 7. Optical micrograph of different zones in PFSSW of 2024-T3 Aluminum alloy, SZ(a), TMAZ(b), HAZ(c), BM(d)

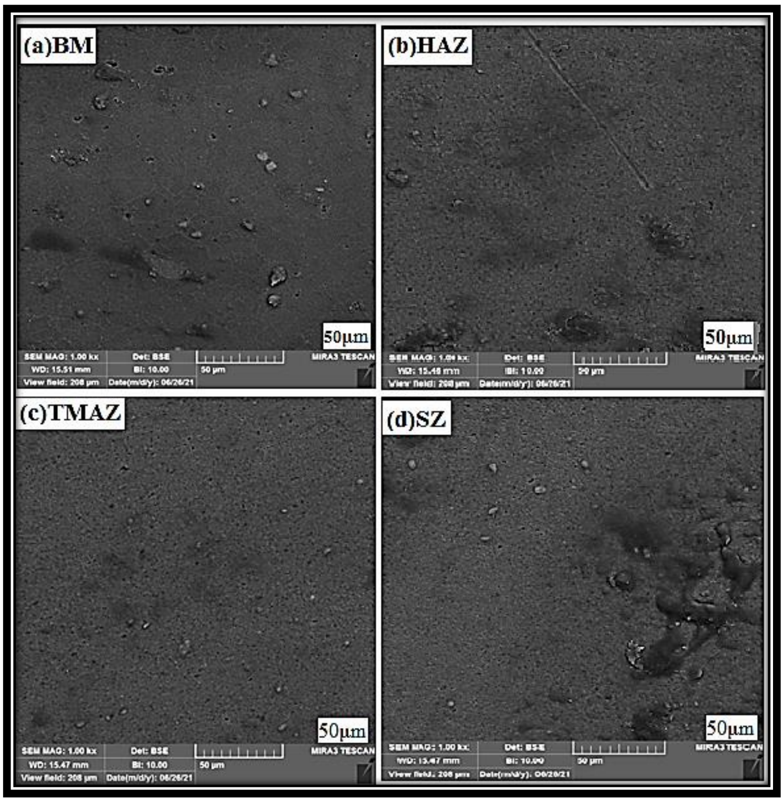


Figure 8. FESEM observation of different precipitate distribution in Base metal (a), HAZ (b), TMAZ(c) and SZ (d) before immersion test

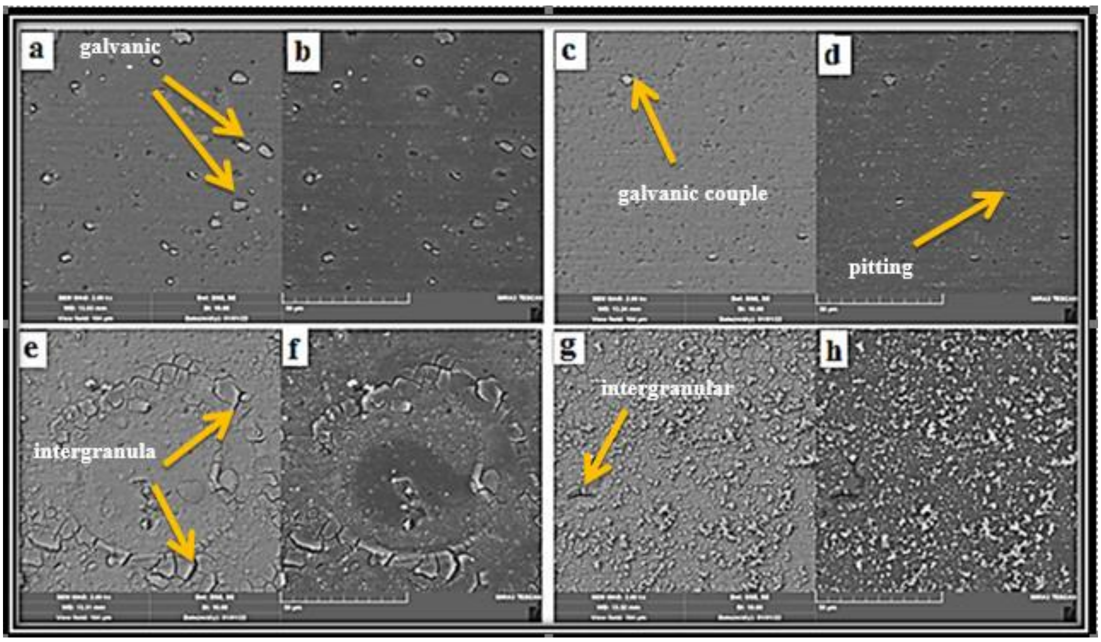


Figure 9. FESEM observation of corroded PFSSW samples of Base metal (a,b), HAZ(c,d), TMAZ(e,f) and SZ(g,h) after immersion test in 3.5%NaCl solution

This increase in the particles and decrease in size from HAZ to SZ is related to the plastic deformation during the welding. Figure 9 exhibits the back scattered and secondary images of FESEM in corroded PFSSW samples of Al2024-T3. For microstructure and corrosion investigation, the vicinity of TMAZ turned out to be the most critical site. The microstructural changes in different areas exhibit the galvanic couples producing corrosion damage after immersion in 3.5%NaCl desalting plant solution. Careful examination of the microstructure of different areas after being exposed to the corrosive environment showed that some of these areas were more sensitive to pitting and intergranular corrosion. As shown in Figure 9(e,f), the TMAZ shows the highest rate of the intergranular corrosion.

After being placed in 3.5% NaCl desalting plant solution, pitting and intergranular corrosion were created in different welding areas. Some galvanic couples were also seen in the microstructure of different areas, especially in the base metal between the precepitates and the parent metal. It shows that the amount and type of precipitates is the key parameter in the corrosion resistance of Al2024 PFSSW. In the stir zone, a small amount of intergranular corrosion was observed along with the accumulation of the corrosion products.

4. Conclusion

In this paper, PFSSW process was performed for 2024 aluminum alloy with a rotational speed of 800rpm to investigate the microstructure and corrosion behavior of this type of welding in desalting plant of oil industry by placing samples in chloride corrosive solution, which yielded the following results:

- In terms of appearance, the upper and lower surfaces of the welded sheets by PFSSW were smoother and more uniform than other spot welding methods.
- The share of TMAZ in pitting corrosion was more than other welding areas, and the corrosion products accumulated mainly in the stirred zone of the weld.
- The type and amount of precipitations is a key parameter and plays an important role in the corrosion resistance of Al2024 Friction Stir Spot Welding.
- The highest hardness occurred in the stirred zone and base metal and the lowest hardness occurred in the areas between TMAZ-HAZ.
- Due to the potential difference between precipitates and particles with the base metal, galvanic corrosion was observed in some areas.
- The increase in susceptibility to intergranular corrosion at PFSSW process may have been caused by the initial melting of copper-rich particles such as Al2CuMg.

Nomenclature

ASTM	American Standard for Testing and Material
BM	Base metal
FESEM	Field Emission Scanning Electron Microscopy
FSSW	Friction Stir Spot Welding
FSW	Friction Stir Welding
HAZ	Heat Affected Zone
NZ	Nugget Zone
PFSSW	Projection Friction Stir Spot Welding
RPM	Rotation Per Minute
RSW	Resistance Spot Welding
SZ	Stir Zone
TMAZ	Thermo-Mechanically Affected Zone

References

[1] S. J. Kalita, “Microstructure and corrosion properties of diode laser melted friction stir weld of aluminum alloy 2024 T351,” *Applied Surface Science,* vol. 257, no. 9, pp. 3985-3997, 2011.

[2] P. Pao, S. Gill, C. Feng, and K. Sankaran, “Corrosion–fatigue crack growth in friction stir welded Al 7050,” *Scripta Materialia,* vol. 45, no. 5, pp. 605-612, 2001.

[3] F. Zarghani, S. Mousavizade, H. Ezatpour, and G. Ebrahimi, “High mechanical performance of similar Al joints produced by a novel spot friction welding technique,” *Vacuum,* vol. 147, pp. 172-186, 2018.

[4] N. Farmanbar, S. Mousavizade, and H. Ezatpour, “Achieving special mechanical properties with considering dwell time of AA5052 sheets welded by a simple novel friction stir spot welding,” *Marine Structures,* vol. 65, pp. 197-214, 2019.

[5] W. Thomas, “Friction Stir Butt Welding, International Patent Application No. PCT/GB92,” *GB Patent Application No. 9125978.8,* 1991.

[6] M. Ericsson and R. Sandström, “Influence of welding speed on the fatigue of friction stir welds, and comparison with MIG and TIG,” *International journal of fatigue,* vol. 25, no. 12, pp. 1379-1387, 2003.

[7] N. Pathak, K. Bandyopadhyay, M. Sarangi, and S. K. Panda, “Microstructure and mechanical performance of friction stir spot-welded aluminum-5754 sheets,” *Journal of Materials Engineering and Performance,* vol. 22, no. 1, pp. 131-144, 2013.

[8] S. Dourandish, S. Mousavizade, H. Ezatpour, and G. Ebrahimi, "Microstructure, mechanical properties and failure behaviour of protrusion friction stir spot welded 2024 aluminium alloy sheets," *Science and Technology of Welding and Joining,* vol. 23, no. 4, pp. 295-307, 2018.

[9] M. Tier *et al.*, "The influence of refill FSSW parameters on the microstructure and shear strength of 5042 aluminium welds," *Journal of materials processing technology,* vol. 213, no. 6, pp. 997-1005, 2013.

[10] Y. Chen, S. Liu, D. Bakavos, and P. Prangnell, "The effect of a paint bake treatment on joint performance in friction stir spot welding AA6111-T4 sheet using a pinless tool," *Materials Chemistry and Physics,* vol. 141, no. 2-3, pp. 768-775, 2013.

[11] S. Mousavizade and M. Pouranvari, "Projection friction stir spot welding: a pathway to produce strong keyhole-free welds," *Science and Technology of Welding and Joining,* vol. 24, no. 3, pp. 256-262, 2019.

[12] A. Arabzadeh, S. M. Mousavizade, B. Korojy, and S. A. Hosseini, "Projection Friction Stir Spot Welding: A New Welding Technique for Creating Safe and Reliable Aluminum Welds," *Iranian Journal of Oil and Gas Science and Technology,* vol. 9, no. 3, pp. 61-76, 2020.

[13] J. R. Davis, *Corrosion of aluminum and aluminum alloys*. Asm International, 1999.

[14] A. Aballe, M. Bethencourt, F. Botana, M. Marcos, and J. Sánchez-Amaya, "Influence of the degree of polishing of alloy AA 5083 on its behaviour against localised alkaline corrosion," *Corrosion science,* vol. 46, no. 8, pp. 1909-1920, 2004.

[15] A. Davoodi, Z. Esfahani, and M. Sarvghad, "Microstructure and corrosion characterization of the interfacial region in dissimilar friction stir welded AA5083 to AA7023," *Corrosion science,* vol. 107, pp. 133-144, 2016.

[16] M. S. Moghaddam, R. Parvizi, M. Haddad-Sabzevar, and A. Davoodi, "Microstructural and mechanical properties of friction stir welded Cu–30Zn brass alloy at various feed speeds: Influence of stir bands," *Materials & Design,* vol. 32, no. 5, pp. 2749-2755, 2011.

[17] R. S. Mishra and Z. Ma, "Friction stir welding and processing," *Materials science and engineering: R: reports,* vol. 50, no. 1-2, pp. 1-78, 2005.

[18] M. Sarvghad-Moghaddam, R. Parvizi, A. Davoodi, M. Haddad-Sabzevar, and A. Imani, "Establishing a correlation between interfacial microstructures and corrosion initiation sites in Al/Cu joints by SEM–EDS and AFM–SKPFM," *Corrosion science,* vol. 79, pp. 148-158, 2014.

[19] P. Dong, D. Sun, B. Wang, Y. Zhang, and H. Li, "Microstructure, microhardness and corrosion susceptibility of friction stir welded AlMgSiCu alloy," *Materials & Design (1980-2015),* vol. 54, pp. 760-765, 2014.

[20] M. Mahoney, C. Rhodes, J. Flintoff, W. Bingel, and R. Spurling, "Properties of friction-stir-welded 7075 T651 aluminum," *Metallurgical and materials transactions A,* vol. 29, no. 7, pp. 1955-1964, 1998.

[21] E. Bousquet, A. Poulon-Quintin, M. Puiggali, O. Devos, and M. Touzet, "Relationship between microstructure, microhardness and corrosion sensitivity of an AA 2024-T3 friction stir welded joint," *Corrosion Science,* vol. 53, no. 9, pp. 3026-3034, 2011.

[22] J. Lumsden, M. Mahoney, C. Rhodes, and G. Pollock, "Corrosion behavior of friction-stir-welded AA7050-T7651," *Corrosion,* vol. 59, no. 03, 2003.

[23] G. Frankel and Z. Xia, "Localized corrosion and stress corrosion cracking resistance of friction stir welded aluminum alloy 5454," *Corrosion,* vol. 55, no. 02, 1999.

[24] R. Fonda, P. Pao, H. Jones, C. Feng, B. Connolly, and A. Davenport, "Microstructure, mechanical properties, and corrosion of friction stir welded Al 5456," *Materials Science and Engineering: A,* vol. 519, no. 1-2, pp. 1-8, 2009.

[25] M. Jariyaboon, A. Davenport, R. Ambat, B. Connolly, S. Williams, and D. Price, "The effect of welding parameters on the corrosion behaviour of friction stir welded AA2024–T351," *Corrosion Science,* vol. 49, no. 2, pp. 877-909, 2007.

[26] M. Jariyaboon, A. Davenport, R. Ambat, B. Connolly, S. Williams, and D. Price, "The effect of cryogenic CO2 cooling on corrosion behaviour of friction stir welded AA2024-T351," *Corrosion engineering, science and technology,* vol. 44, no. 6, pp. 425-432, 2009.

[27] S. Sinhmar and D. K. Dwivedi, "A study on corrosion behavior of friction stir welded and tungsten inert gas welded AA2014 aluminium alloy," *Corrosion Science,* vol. 133, pp. 25-35, 2018.

[28] H.-l. Qin, H. Zhang, D.-t. Sun, and Q.-y. Zhuang, "Corrosion behavior of the friction-stir-welded joints of 2A14-T6 aluminum alloy," *International Journal of Minerals, Metallurgy, and Materials,* vol. 22, no. 6, pp. 627-638, 2015.

[29] J. G. Kaufman, *Introduction to aluminum alloys and tempers*. ASM international, 2000.

[30] A. Subcommittee, "ASTM E112-10 Standard test methods for determining average grain size," *ASTM, Philadelphia,* 2010.

[31] M. Paidar, A. Khodabandeh, H. Najafi, and A. S. Rouh-aghdam, "Effects of the tool rotational speed and shoulder penetration depth on mechanical properties and failure modes of friction stir spot welds of aluminum 2024-T3 sheets," *Journal of Mechanical Science and Technology,* vol. 28, no. 12, pp. 4893-4898, 2014.

[32] V. Guillaumin and G. Mankowski, "Localized corrosion of 2024 T351 aluminium alloy in chloride media," *Corrosion Science,* vol. 41, no. 3, pp. 421-438, 1998.

[33] C.-M. Liao, J. Olive, M. Gao, and R. Wei, "In-situ monitoring of pitting corrosion in aluminum alloy 2024," *Corrosion,* vol. 54, no. 6, pp. 451-458, 1998.

[34] W.-B. Lee, Y.-M. Yeon, and S.-B. Jung, "Mechanical properties related to microstructural variation of 6061 Al alloy joints by friction stir welding," *Materials transactions,* vol. 45, no. 5, pp. 1700-1705, 2004.

مقاله تحقیقاتی

بررسی خوردگی جوشکاری همزن اصطکاکی نقطه ای ورق های آلومینیوم ۲۰۲۴ در صنعت نفت و گاز

علی عرب زاده[1]، بهمن کروجی[2,*]، سید مصطفی موسوی‌زاده[3]، سید علیرضا حسینی[4]

۱. دانشجوی دکتری، گروه مهندسی مواد و پلیمر، دانشکده فنی و مهندسی، دانشگاه حکیم سبزواری

۲. استادیار، گروه مهندسی مواد و پلیمر، دانشکده فنی و مهندسی، دانشگاه حکیم سبزواری

۳. استادیار، گروه مهندسی مواد، دانشکده فنی و مهندسی، مجتمع آموزش عالی گناباد

۴. استادیار، گروه مهندسی مواد و پلیمر، دانشکده فنی و مهندسی، دانشگاه حکیم سبزواری

چکیده

جهت تعیین روش جوشکاری مناسب برای جایگزینی جوشکاری ذوبی و مقاومتی در صنعت نفت و گاز، از روش جدید جوشکاری همزن اصطکاکی نقطه ای زائده‌ایی برای ورق های آلومینیومی ۲۰۲۴ استفاده شد. با مطالعه تحقیقات قبلی که در مورد جوشکاری همزن اصطکاکی نقطه ای این ماده انجام شده است، سرعت دورانی ۸۰۰ دور در دقیقه برای این منظور انتخاب شده است. در این تحقیق، ریزساختار همراه با رفتار خوردگی جوشکاری همزن اصطکاکی نقطه ای اتصالات ورق‌های آلومینیوم ۲۰۲۴ بررسی شد. تغییرات ریزساختاری نواحی مختلف جوشکاری توسط میکروسکوپ الکترونی روبشی گسیل میدانی مطالعه شد و پروفیل سختی نواحی مختلف ترسیم گردید. اثر محلول خورنده حاوی کلرید سدیم بر روی نمونه ها بررسی و انواع خوردگی حفره ای و بین دانه ای در نواحی مختلف جوش مشاهده شد. در نهایت، تجمع محصولات خوردگی در ناحیه هم زده جوش نمایان بود و ناحیه متاثر از حرارت و عملیات ترمومکانیکی بیشترین میزان خوردگی بین دانه ای را نشان داد..

مشخصات مقاله

تاریخچه مقاله:

دریافت: ۲۵ فروردین ۱۴۰۱

دریافت پس از اصلاح: ۶ مرداد ۱۴۰۱

پذیرش نهایی: ۸ مرداد ۱۴۰۱

کلمات کلیدی:

جوش همزن اصطکاکی نقطه‌ای

صنعت نفت و گاز

رفتار خوردگی

*عهده‌دار مکاتبات؛ بهمن کروجی

رایانامه: b.korojy@hsu.ac.ir

تلفن: ۰۵۱۴۴۰۱۲۷۷۵

نحوه استناد به این مقاله:

Arabzadeh A, Korojy B, Mousavizade SM, Hosseini SA. PCorrosion Investigation of Projection Friction Stir Spot Welding of Al 2024 Sheets in Oil and Gas Industry, Journal of Oil, Gas and Petrochemical Technology, 2022; 9(1): 39-48. DOI:10.22034/JOGPT.2022.333583.1104.