STM JOURNALS

Journal of
Polymer & Composites

ISSN: 2321-2810 (Online)
ISSN: 2321-8525 (Print)
Volume 12, Special Issue 1, 2024
DOI (Journal): 10.37591/JoPC

http://engineeringjournals.stmjournals.in/index.php/JoPC/index

Research JoPC

Experimental Investigation of Hardness of FSW Al 5083 Alloy for Naval and Marine Application

Devarshi Kapil[1],Ashish Swarnkar[2], Saurabh Pachauri[1,]*, Manish Dixit[1]

Abstract

Friction stir welding (FSW) is a relatively novel method of solid-state joining. This connecting method is adaptable, environmentally benign, and low-energy. The present study focuses on hardness testing on welded butt joints, introducing the Friction Stir Welding procedure on aluminium alloys Al 5083, which are known for their remarkable performance in severe conditions. It is widely used in naval and marine applications due to its excellent resistance to seawater damage. After welding, Al 5083 retains its extraordinary strength. FSW joints were developed for Al 5083 alloys that were similar. At varying tool rotational speeds of 770, 1200, 1200 RPM (Annealed), 1600 friction stir welds of Al 5083 were formed. The tests were carried out using Rockwell hardness testing procedure. The weld zone has the lowest hardness at 770 RPM and the highest hardness (pre-annealed) at 1200 RPM. Prior to characterisation in order to understand the weld quality, several tests were performed on the welds for evaluating the integrity of joints.

Keywords: FSW, hardness, rotation speed, aluminium alloy, fractography

INTRODUCTION

Numerous pieces of work were produced using the friction-stir welding technique. The rotational speed was variable for each sample, but the welding speed and axial load remained constant. Workpiece welded at 1000 rpm with an HSS tool resulted in higher tensile strength and lowered flexural and impact strength. After extensive testing, it was shown that the alloys (AA-6063 and AA-5083) could be successfully welded together using the FSW process at speeds ranging from 500 to 1200 RPM. Workpieces welded at 1000rpm had the highest tensile strength, ultimate tensile strength and yield strength. It also has a minimum impact strength of 207.403MPa and a flexural strength of 207.403MPa. Due to its brittleness, the fracture had the maximum hardness value. A tool's impact strength reduces with increasing rotational speed, whereas its hardness decreases with decreasing rotational speed [1]. A kissing bond indicates that the two surfaces are close enough to make atomic connections but not close enough for the initial surface asperities to deform sufficiently in contact. The primary cause of charge welds that fail to kiss bond is a lack of deformation of the initial contacting surfaces. As a result, the oxide layer's inadequate breakdown prevents metallic connections from forming between two layers of metals. By adopting a mechanism based on sliding friction between tool surfaces and aluminium in the nearby shear zone, kissing bonds can be produced in both FSW and ESW welds. Sliding friction circumstances are mainly because of insufficient shear deformation rather than sticking friction conditions. When the web reaches the end, sliding friction causes a kissing bond in ESW. A kissing bond develops in the FSW when the aluminium in the shear zone slides across the pin surface. From the preceding, it can be concluded that kissing bond formation in ESW &

*__Author for Correspondence__
Saurabh Pachauri

[1]Assistant Professor, Department of Mechanical Engineering, Institute of Engineering & Technology, Dr. B R Ambedkar University, Agra Uttar Pradesh, India
[2]Research Scholar, Department of Mechanical Engineering, MNIT, Allahabad Uttar Pradesh, India

Received Date: January 06, 2024
Accepted Date: March 07, 2024
Published Date: April 24, 2024

Citation: Devarshi Kapil, Ashish Swarnkar, Saurabh Pachauri, Manish Dixit. Experimental Investigation of Hardness of FSW Al 5083 Alloy for Naval and Marine Application. Journal of Polymer & Composites. 2024; 12(Special Issue 1): S227–S236p.

FSW can be regulated by avoiding friction between the plasticized metal at the tool surface and elevated temperatures [2].

For smooth finishing and good material strength, the automotive and aerospace industries use FSW. Two separate aluminium plates were used for the FSW method, and two different materials were used to determine the plates' tensile and hardness. After welding, the formation of cracks was discovered, the tensile strength was enhanced, and various tools were employed to examine the results. Welding tool rotation speed was 500-1000rpm at a welding speed of 25mm/min, with a down-load pressure of 5MPa. The tensile strength fabricated at 500rpm and 25mm/min is superior. Visual inspection revealed speed cracks. We can say that increasing welding speed, decreasing tool rotation speed, and reducing thickness increase tensile characteristics. A square tool is superior to a cylindrical tool for aluminium alloys [3]. Experiments were conducted on 5mm thick plates bonded together using the FSW technique. The test was done on a workpiece fabricated at 710rpm, 900rpm, and 1120rpm tool speeds. Moreover, the welding speeds were 20 mm per minute, 40 mm per minute, and 60 mm per minute. A moderate tool rotating speed resulted in the achievement of high-quality mechanical characteristics. The microstructure consisted of grains with inner metallic compounds in an Aluminum matrix-free of eutectic melting. There was no microporosity, stringers, or segregation. The mechanical characteristics of Al alloy 5083 at 710 rpm were the best. Low tensile strength is the consequence of increasing tool rotation speed. Due to excessive friction heat generated, the topmost hardness value is 73.25 at a rotating speed of 1120 rpm and welding speed of 20mm/min [4]. A water-cooled specimen with a rotating speed of 600 rpm and a welding speed of 30 mm/min was found to have a high cooling rate, allowing grains to form more quickly. When the water-cooled specimen was rotated at 600 rpm and welded at 30 mm/minute, the heat-affected zone dissipated. The highest temperatures were in the stir zone, which caused microstructure changes that produced unique grain sizes and precipitates for each sample. The water-cooled sample's enhanced tensile strength was most likely caused by its finer grain structure, which raised the stir zone's hardness. Water-cooled samples are significantly tougher than air-cooled samples in the stir zone. [5]. The material AA 5083-T4 is chosen for testing, and two techniques of welding are used: TIG and FSW. Weld quality may be measured by looking at weld-bead shape, mechanical characteristics, and distortion. FSW welding has a tensile strength roughly 3 to 4 times that of TIG welding. In contrast to TIG welding, which has a larger heat-affected zone and results in changes to the weld zone's mechanical characteristics like microstructure, microhardness, and tensile strength, FSW welding has a smaller heat-affected zone, which suggests that the weld zone's qualities remain the same as the parent material. Visual inspection can reveal cracks and porosity in FSW, but it is impossible to notice with the naked eye in TIG welding. FSW has a higher microhardness value than TIG welding [6]. The mechanical properties of the 5083 AL alloy that is friction-stir welded as well as the microstructure of the stir zone will be investigated in this work. Tiny equiaxed grains in varied FSW settings make up microstructures. However, during FSW, when the friction heat flow dropped, the stir zone's grain size shrank in a similar manner. The friction-stir welded alloy 5083 AL grew more ductile as the friction heat flow decreased. The parent material's formability was improved by the stir zone's finer grain size.[7]. This study will discuss the hardness distribution of AW-5083 AL alloy's FSW. We utilized two different kinds of tools: conical and cylindrical. After welding, metallographic analysis of selected joints revealed proper structural bonded joint construction. When the plasticized components of linked sheets are combined at a solid-state temperature of approx. 4500 ^{0}C, bonding takes place. Along with an improvement in strength attributes, the joints become harder. The hardness of FS welded joints with conical pins was around 86HV, whereas the native material was approximately 83HV. When compared to the original material, all samples show the same variation in hardness across various weld zones. Hardness value increases 5.5 percent for weld nuggets and 4.7 percent for the thermo-mechanically impacted zone. Hardness decreased by 1.1 percent in the heat-affected area. the mechanical impact of the pin tool, which breaks up the grain and processes the welded material to become thermoplastic. [8]. A systematic experimental technique was used to test the process forces and heat input with various parameters in order to produce AA-5083 welds. The development of FSW tools and welders was based on empirical models. In the FSW process, the welding speed, tool speed, probe diameter, and tool shoulder diameter all have an impact on the forces and heat input. The primary

ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

elements influencing X-force are rotation speed, welding speed, pin diameter, and the connection between tool diameter and rotation speed. The welding speed, tool diameter, rotation speed, and potential two-level interactions all have an impact on the heat input in FSW [9].

Seawater and industrial chemical environments have little effect on Al 5083. It also maintains its strength after welding. It is the most robust non-heat-treatable alloy on the market. It uses railroads, cars, tip trucks, mine ships, cages, and pressure vessels in addition to ships, cars, and vehicle bodies [10].

MATERIALS AND METHODS

Materials

For this project, Al 5083 Alloy is the used material. The specimen is 120 mm in length, 70 mm in width, and 6 mm in thickness [11].

Table1. The main chemical elements of the alloy Al 5083[12].

Aluminium (Al)	Magnesium (Mg)	Manganese (Mn)	Iron (Fe)	Silicon (Si)	Copper (Cu)	Chromium (Cr)	Zinc (Zn)
Base	4.79	0.79	0.22	0.15	0.08	0.08	0.05

Specimen Preparation methods

The specimens that can be welded are firmly fastened at 5 mm for the pin diameter and 16 mm for the shoulder diameter, respectively. The tool is cylindrical and tapered. The pin is 4.5 mm in length. Plastic deformation and complicated material movement are involved in FSW. Tool geometry, along with other welding parameters, greatly affects the temperature distribution and material flow pattern.[13].

These variables have an impact on the material's microstructure and mechanical properties. The following are the parameters of the FSW process [14]. [15].

A sample of Work-Piece is taken of 6mm thick Aluminum Alloy 5083 used for study –

- *Diameter of tool pin*: 5 mm
- *Length of tool pin:* 4.5 mm
- *Tilt angle of tool*: 2^0
- *Axial force*: Constant
- *Tool Material*: Medium Carbon Steel
- *Shoulder Diameter*: 16 mm
- *Rotation Speed (Tool):* 770 RPM, 1200 RPM, 1600 RPM
- *Welding Speed:* 25 mm/min


(a)

Figure 1. (A) Experimental Setup (B)Rockwell Hardness Testing Machine

Hardness Test

Their hardness measures metals' deformation resistance. Variation in hardness is what gives welded joints their characteristic mechanical behaviour. This test uses the Rockwell Hardness Machine to measure hardness. The Rockwell Hardness Machine's experimental configuration is shown in Figure 1.

The welded specimen is polished for hardness testing to see the indentation. The welded zone is divided into five columns named C1, C2, M, C3 & C4, respectively, shown in Figure 2.

Figure 2. Hardness Specimen

Hardness Test Results

Specimens that have been welded at 770 RPM, 1200 RPM, 1600 RPM, and 1200 RPM pre-annealed are used in the hardness test. Table 2 shows the five-point average Rockwell Hardness Number (RHN) for each point noted on the specimen.

Table 2. Hardness Values at 770 RPM

770 RPM					
S. No.	**C_2**	**C_1**	**M**	**C_3**	**C_4**
1.	86	85	81	90	80
2.	85	89	84	87	83
3.	89	80	85	86	88
4.	84	86	83	86	84
5.	90	87	86	84	89
Average Hardness	86.8	85.4	83.8	86.6	84.8

Table 3. Hardness Values at 1200 RPM

1200 RPM					
S. No.	**C_2**	**C_1**	**M**	**C_3**	**C_4**
1.	89	91	86	86	88
2.	86	89	85	85	83
3.	89	91	85	86	87
4.	85	90	84	86	89
5.	88	87	87	88	88
Average Hardness	87.4	89.6	85.4	86.2	87

Table 4. Hardness values at 1200 RPM (Annealed)

1200 RPM (Annealed)					
S. No.	**C_2**	**C_1**	**M**	**C_3**	**C_4**
1.	83	86	83	88	90
2.	89	88	88	88	87
3.	88	84	88	86	86
4.	88	87	86	88	88
5.	89	90	90	89	90
Average Hardness	87.4	87	87	87.8	88.2

Table 5. Hardness values at 1600 RPM

1600 RPM					
S. No.	**C_2**	**C_1**	**M**	**C_3**	**C_4**
1.	86	89	83	90	87
2.	86	89	86	90	87
3.	90	88	84	81	86
4.	87	91	86	87	85
5.	90	87	89	80	82
Average Hardness	87.8	88.8	85.6	85.6	85.4

Average Hardness at Different RPM

The specimen's five-point average hardness along its length was 87 RHN. The five-point average hardness along the weld line for welded specimens is shown in Table 6.

Table 6. Average hardness at different RPM.

Tool RPM	770 RPM	1200 RPM	1200 RPM(ANNEALED)	1600 RPM
Average Hardness (RHN)	85.4	87.4	86.2	86.6

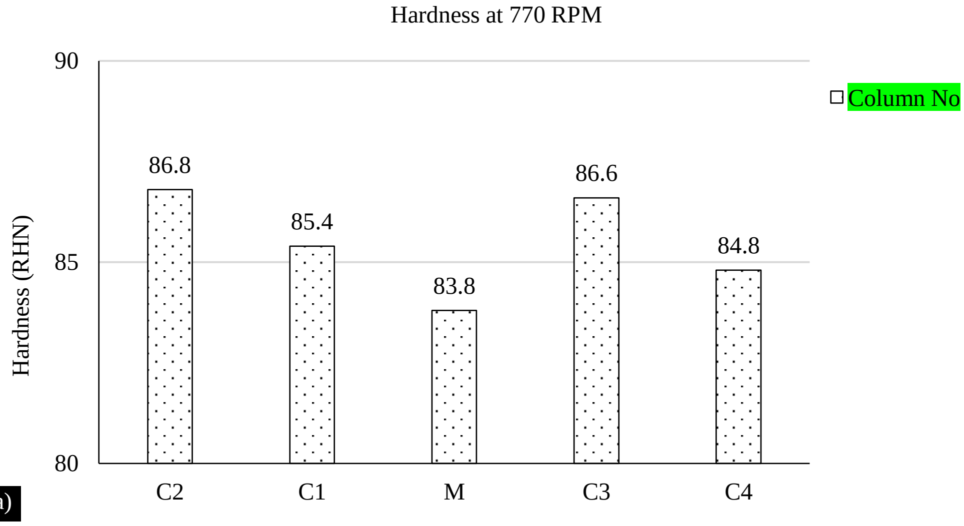
Average Hardness at Different Welding Zones

For many welding zones, including Weld Nugget (WN), Thermo-mechanical Affected Zone (TMAZ), and Heat Affected Zone (HAZ) at 770 RPM, 1200 RPM, and 1600 RPM, hardness values were gathered and provided in Table 7. The most minor hardness is found on WN, while the maximum hardness is found on HAZ, as shown in the table.

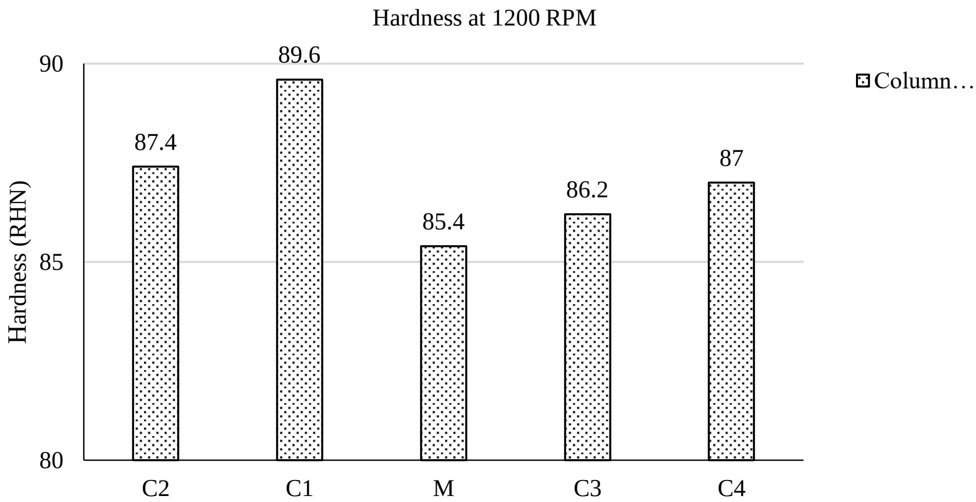
Table 7. Average hardness at different welding zones.

Weld Zones	770 RPM	1200 RPM	1200 RPM(ANNEALED)	1600 RPM
WN	83.8	87	87	85.6
TMAZ	86	87.4	87.4	87.2
HAZ	85.8	88	87.8	86.6

In the following figures, Hardness at 770 RPM, 1200 RPM, and 1600 RPM are found minimum on column M. Hardness of pre-annealed specimen welded at 1200 RPM shows an improvement in hardness in all columns.

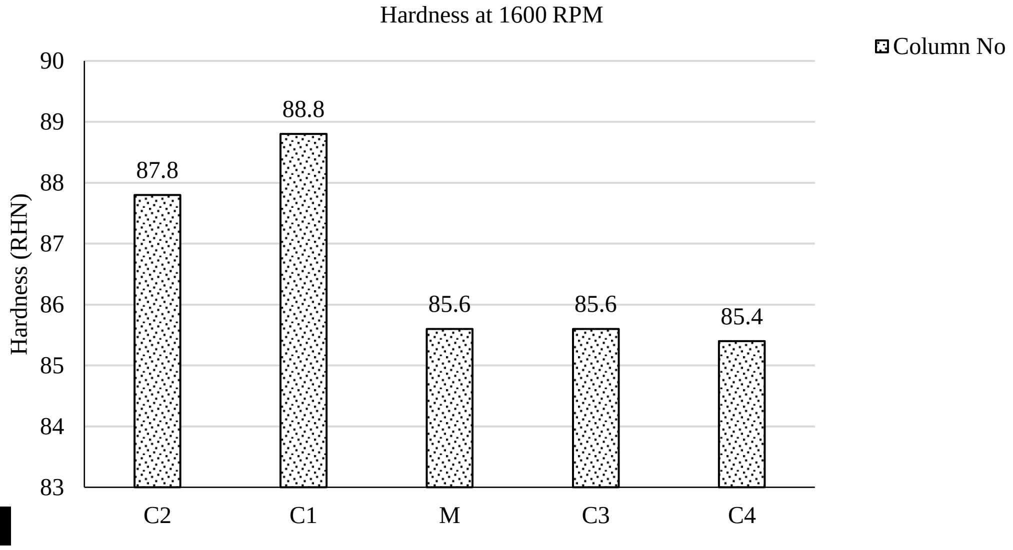


(a)

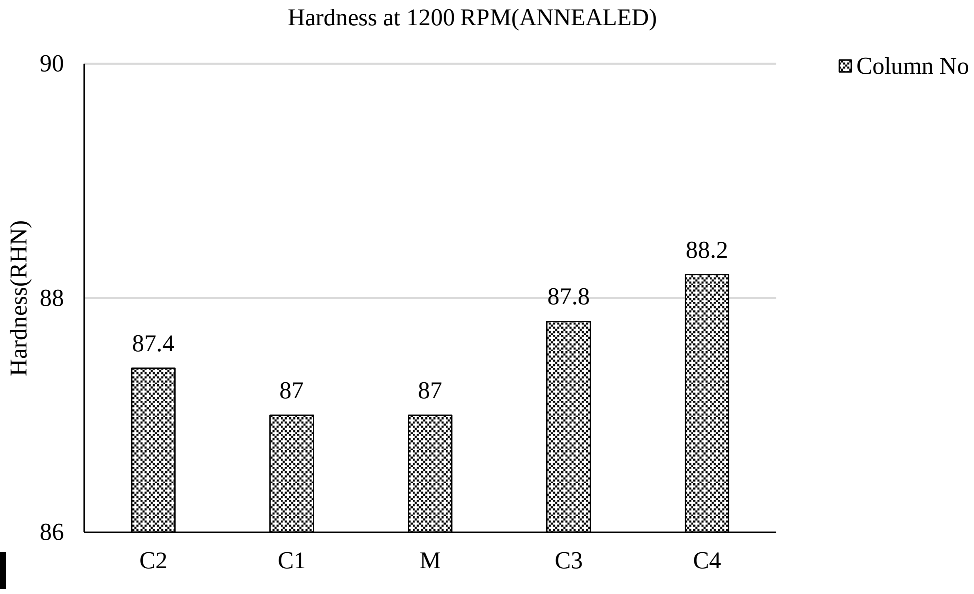


(b)

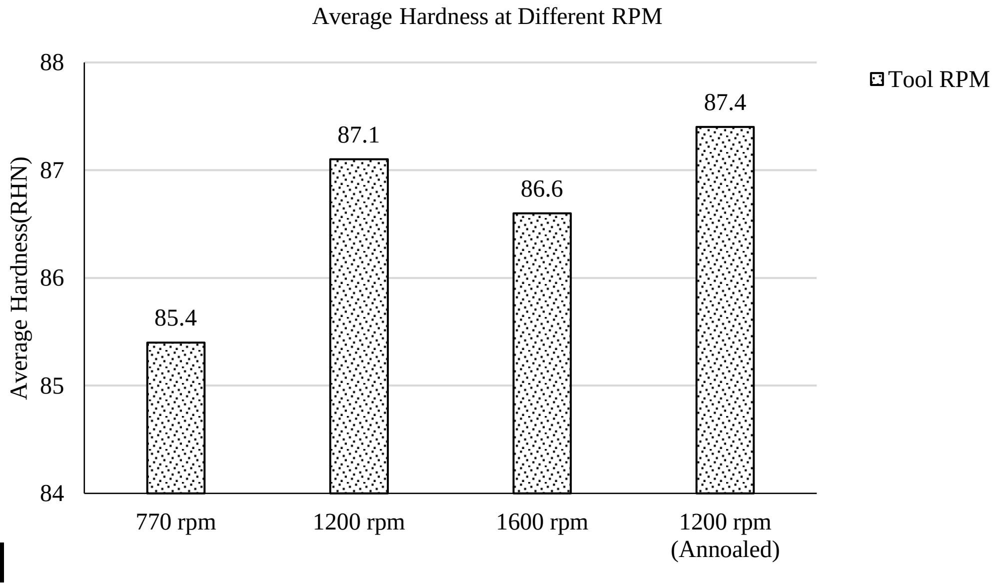
Journal of Polymer & Composites
Volume 12, Special Issue 1
ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)



(c)



(d)



(e)

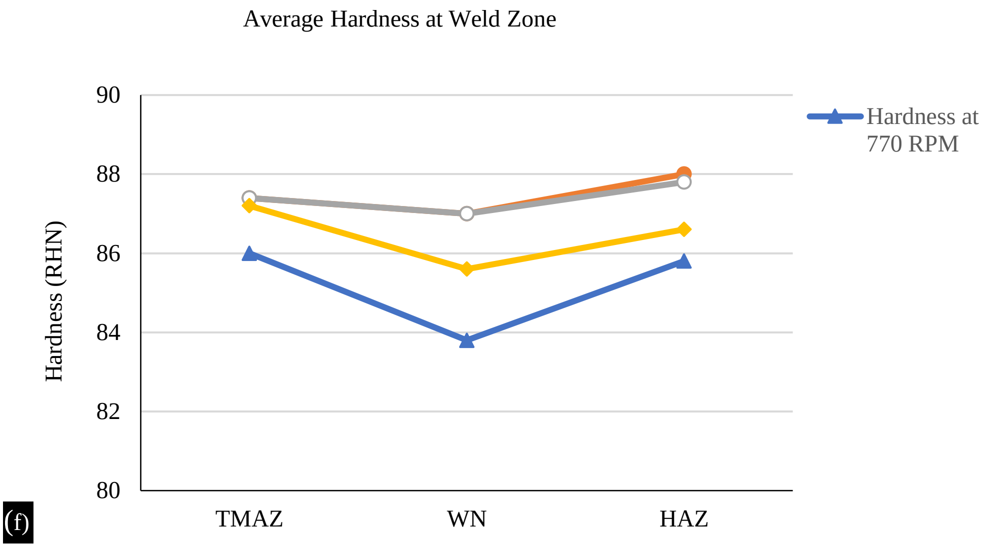


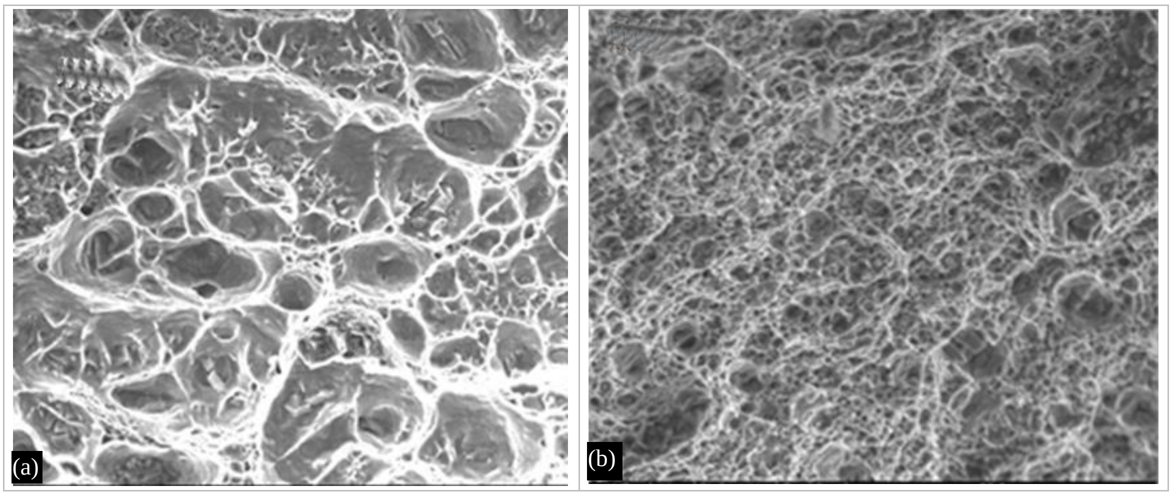
Figure 3. (A)Hardness at 770 RPM(B) Hardness at 1200 RPM (C)Hardness at 1600 RPM (D)Hardness at 1200 RPM (Annealed) (E)Average Hardness at different RPM (F) Average Hardness in Welded Zone at Different RPM

Figure 3 shows average hardness at tool rotation speeds of 770 RPM, 1200 RPM, 1600 RPM, and pre-annealed specimen at 1200 RPM. The maximum hardness is found in a pre-annealed specimen at 1200 RPM, while the minimum hardness is found at 770 RPM.

Figure 3 depicts the average hardness of different welding zones at various RPMs (E). The minimal hardness is obtained at the weld nugget for a specimen at a certain RPM. The weld zone's minimum hardness is discovered at 770 RPM, while the maximum hardness is found at 1200 RPM pre-annealed.

FRACTOGRAPHY

At IIT Kanpur's ACMS Department, fractography of specimens prepared at 770 RPM, 1200 RPM, 1600 RPM, and 1200 RPM (Annealed) were taken on an SEM (Quanta 200W). The microstructures of the friction-stir –welded 5083 Al alloy were studied, and the stir zones in friction-stir-welded 5083 Al alloy were refined equiaxed grains under various Friction-Stir Welding settings. Because the stir zone's grain size dropped, the hardness of the area rose as the friction heat flow decreased. The heat input rate rises with increasing rotational speed, resulting in fine microstructure and enhanced hardness. Below is fractography for various rpm at2000x.



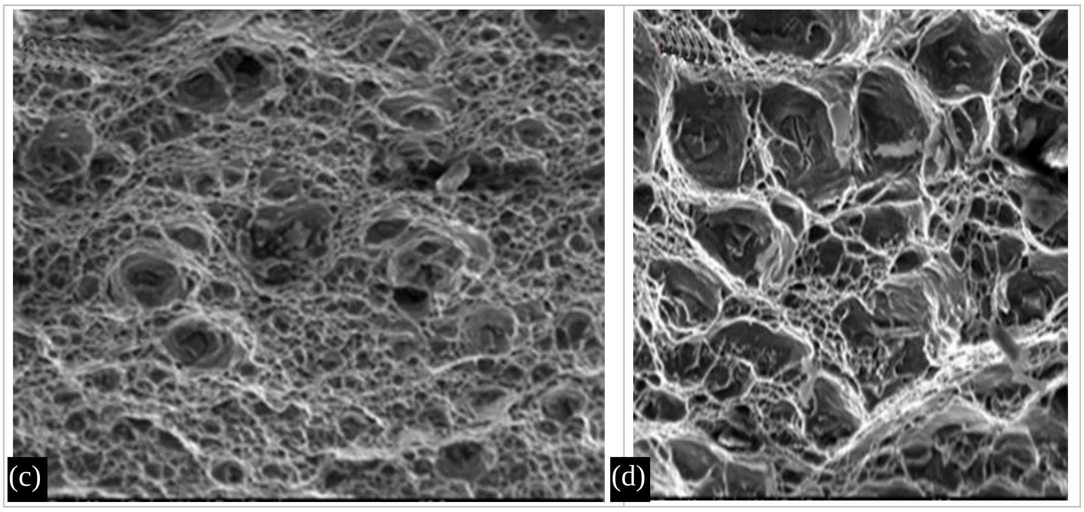


Figure 4. (A) Fractographs at 770RPM (B) Fractographs at 1200RPM (C) Fractographs at 1600RPM (D) Fractographs at 1200RPM (Annealed)

CONCLUSION

A variety of welded zones, separated into five columns (C1, C2, M, C3, and C4), were subjected to hardness tests using the Rockwell machine. The averages measured on different weld zones at different welding speeds demonstrate that the pre-annealed specimen welded at 1200 RPM produces the most significant Hardness values in all-welded zones, while 770 RPM gives the lowest hardness in the weld zone. The test database created in this study will be highly beneficial in designing and constructing friction stir welded aluminium ship constructions.

Acknowledgments

The authors express their gratitude to TEQIP-III for the financial support, the ACMS Lab at IIT Kanpur, and the shop employees for their invaluable assistance and enabling us to utilize the testing machine/equipment.

CONFLICTS OF INTEREST

The authors declare that they have no conflicting financial or personal interests that would have affected the findings of the research.

REFERENCES

1. Kumar SD and Kumar SS. Investigation of Mechanical Behavior of friction-stir welded joints of AA6063 with AA5083 AL Alloy. Mechanics&Mechanical Engineering, July 2019; Vol. 23 Issue 1, p59-63. https://doi.10.2478/mme-2019-0008.
2. Oosterkamp A, Djapic Oosterkamp L, and Nordeide A. 'Kissing Bond' Phenomena in Solid-State Welds of Al Alloys. Welding journal. August 2004; 83 (8)-225S. Corpus ID: 138620222
3. Prashanth B, Shravan Kumar K and Prakash D. Tensile Strength and Hardness Test on Friction-Stir Welded Aluminium 6061-T6 and 5083-H111-O Alloys. IJSDR. January 2017; Volume 2, Issue 1. ISSN: 2455-2631.
4. Hai, T., Ali, M. A., Dhahad, H. A., Alizadeh, A. A., Sharma, A., Almojil, S. F., ... & Wang, D. (2023). Optimal design and transient simulation next to environmental consideration of net-zero energy buildings with green hydrogen production and energy storage system. Fuel, 336, 127126.
5. Bodukuri A K, et.al A. Comparison of Aluminum Alloy 5083 properties on TIGW and FSW Processes. Materials Today Procedings. January 2017; Volume 4, Issue 9 ISSN:10197-10201. https://doi.org/10.1016/j.matpr.2017.06.347
6. Hirani T, et al. Influence of friction stir-welding parameters on grain size and formability in 5083 Al alloy. Mat. Sc. & Engg. May 2007; 456(1-2):344-349.

https://doi.org/10.1016/j.msea.2006.12.079
7. Sharma, A., Sharma, K., Islam, A., & Roy, D. (2020). Effect of welding parameters on automated robotic arc welding process. Materials Today: Proceedings, 26, 2363-2367.
8. G. Çam. Friction-Stir welded structural materials: beyond Al-alloys. International Materials Reviews. January 2011; Volume 56, - Issue 1. https://doi.org/10.1179/095066010X12777205875750.
9. Kumar, R., Pandey, A. K., Samykano, M., Mishra, Y. N., Mohan, R. V., Sharma, K., & Tyagi, V. V. (2022). Effect of surfactant on functionalized multi-walled carbon nano tubes enhanced salt hydrate phase change material. Journal of Energy Storage, 55, 105654.
10. Suri A. An Improved FSW Tool for Joining Commercial Aluminum Plates. Procedia Materials Science. 6 (2014) 1857 – 1864. https://doi.org/10.1016/j.mspro.2014.07.216.
11. Sharma, A., Chaturvedi, R., Sharma, K., & Saraswat, M. (2022). Force evaluation and machining parameter optimization in milling of aluminium burr composite based on response surface method. Advances in Materials and Processing Technologies, 8(4), 4073-4094.
12. Bisadi H et al. The influences of rotational and welding speeds on microstructures and mechanical properties of friction-stir welded Al5083 and commercially pure copper sheets lap joints. Materials & Design. January 2013; Volume 43, , Pages 80-88. https://doi.org/10.1016/j.matdes.2012.06.029. Retrieved on 07-08-2023.
13. Chaturvedi, R., Sharma, A., Sharma, K., & Saraswat, M. (2022). Tribological behaviour of multi-walled carbon nanotubes reinforced AA 7075 nano-composites. Advances in Materials and Processing Technologies, 8(4), 4743-4755.
14. Derazkola HA and Elyasi M. The influence of process parameters in friction-stir welding of Al-Mg alloy and polycarbonate. Journal of Manufacturing Processes. October 2018; Volume 35, Pages 88-98. https://doi.org/10.1016/j.jmapro.2018.07.021.
15. Liu, Z., Zhanguo, S. U., Abed, A. M., Chaturvedi, R., Feyzbaxsh, M., & Salavat, A. K. (2022). A comparative thermodynamic and exergoeconomic scrutiny of four geothermal systems with various configurations of TEG and HDH unit implementations. Applied Thermal Engineering, 216, 119094.

