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Microstructure and Hardness Characteristics of Friction Stir-welded Brass Plate

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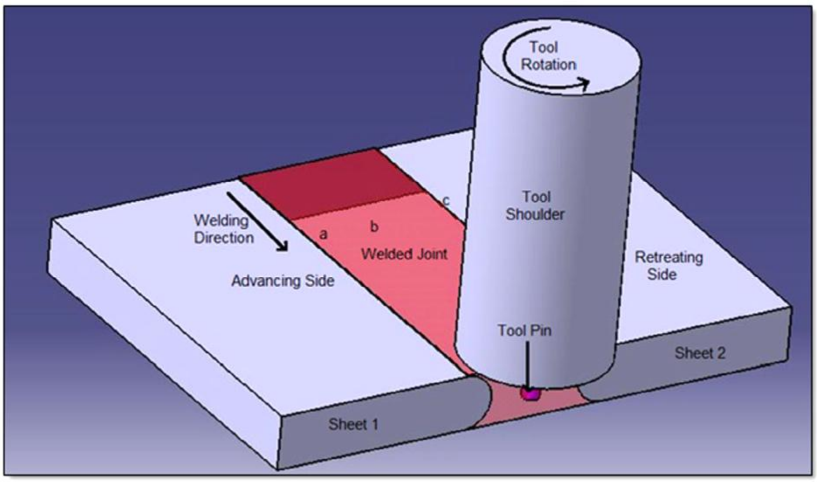
ABSTRACT

The current study examined the suitability of friction stir welding for the joining of 6 mm thick brass plates. The tool rotational rates used for the friction stir welding technique were 455 and 715 rpm. A smooth, defect-free weld zone was seen with a greater tool rotational speed, but a noticeable fracture formed in the weld zone with a lower tool rational speed. Grain size gradually decreased from the source metal to the stir zone through the heat impact zone and thermomechanical influenced zone, according to microstructure study. Because of its finely recrystallized grains, the stir zone displayed a greater hardness than the base metal.

Keywords: Brass, tool rotation speed, microstructure, micro hardness, and friction stir welding (FSW).

INTRODUCTION

One of the crucial procedures utilized in the industrial sector to join disparate parts to create a structural entity is welding. Coalescence of the materials is achieved via heating them to the welding temperature, either in combination with or without the use of pressure, and with or without the use of filler metal [1]. There are two types of welding processes: fusion welding and non-fusion welding. The material at the junction is heated to a molten condition and allowed to solidify in fusion welding. By applying pressure at temperatures lower than the melting point of the base material, the non-fusion welding technique joins materials by plastic deformation. The main advantages of non-fusion welding are that no filler metal is needed and the joining occurs without fusing at the interface. Welding flaws resulting from solidification are reduced since there isn't any liquid or molten phase at the junction [2]. The Welding Institute (TWI) created the non-fusion welding technique known as friction stir welding (FSW).



Arrangement of FSW process

This method involves driving a non-consumable tool at a fast speed along the region that has to be connected while it rotates. The tool has a specifically constructed pin and shoulder. The plasticized material at the contact is then connected after it generates frictional heat and softens but does not melt the substance [3]. In order to produce extremely homogenous welds, FSW offers high levels of repeatability, accurate external process control, and simplicity of handling. Little waste or contamination is produced during the welding process, and no specific sample preparation is needed [4]. Friction stir welding of 2024-T351 aluminum rolled sheet with a 7 mm thickness was done by Sutton et al. To describe the segregated, banded microstructure, they used quantitative energy dispersive X-ray, hardness, and metallurgical analyses. The findings showed that it is possible to alter the friction stir weld process parameters to enhance a variety of material qualities, including fracture resistance, and change the weld microstructure [5].

The microstructure and mechanical characteristics of friction stir-welded SAF2507 super duplex stainless steel were examined by Sato et al. Test plates measuring 300 mm in length and 100 mm in breadth were made. Solid polycrystalline cubic boron nitride (PCBN) was used in the fabrication of the FSW tool. Using dynamic recrystallization, FSW greatly refines the ferrite and austenite phases. The hardness and strength in the stir zone are increased by the smaller ferrite and austenite grains that are produced [6]. Zhang et al. used a polycrystalline cubic boron nitride tool to apply friction stir welding on commercial quality titanium.

Higher hardness than base material was discovered as a result of the creation of a fine grain structure surrounded by serrated grain boundaries in the stir zone [7]. Using a computerized numerical control machine, Muhammad Tehyo et al. examined the impact of friction stir welding settings on the microstructure and mechanical characteristics of friction stir welded butt joints of different aluminum alloy sheets between Semi-Solid Metal (SSM) 356-T6 and AA6061-T651. Six welding speeds (20, 50, 80, 120, 160, and 200 mm/min) and tool rotation rates (1750 and 2000 rpm) are the two primary parameters taken into account.

Tensile, hardness, and microstructure tests are used to assess the outcomes. A welded specimen created at a tool rotation speed of 2000 rpm correlated with a welding speed of 80 mm/min had a maximum tensile strength of 206.3 MPa. The tensile strength of a tool grows with tool rotation speed up to a certain point; beyond that point, the tensile strength decreases [8]. The literature unequivocally shows that the FSW procedure can be successfully applied to the joining of engineered materials.

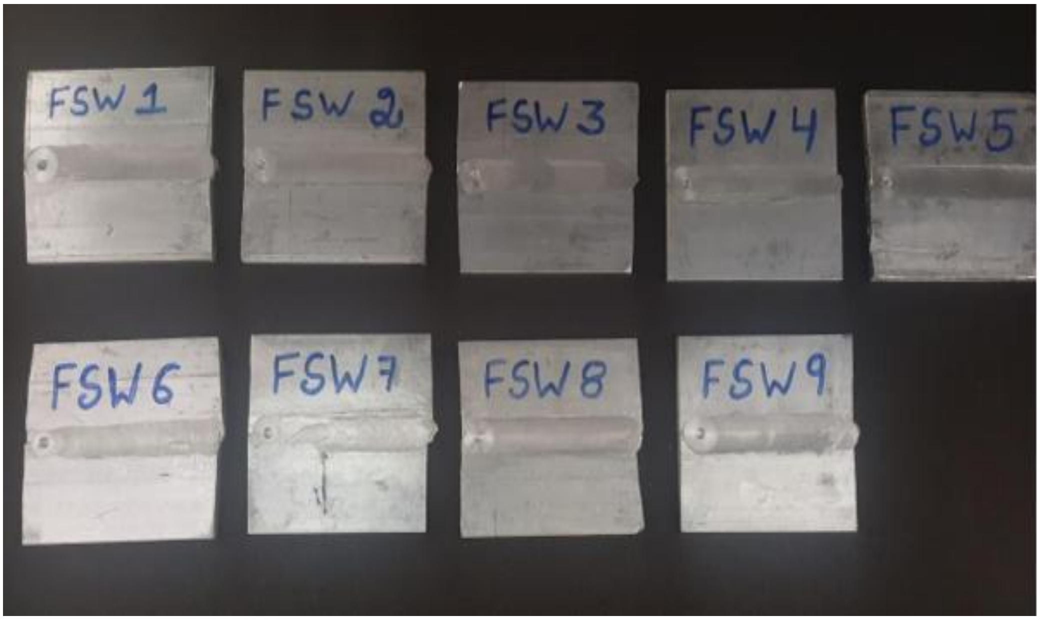
Because of their excellent electrical and thermal conductivity, great strength, and strong resistance to corrosion, brass materials are frequently employed in technical applications. Due to its high heat diffusivity—roughly 10–100 times greater than that of many steels and nickel alloys—brass is typically difficult to fuse using traditional fusion welding techniques. As far as we know, brass materials are alloys of copper (Cu) and zinc (Zn).

For instance, in TIG welding, the temperature during the welding process approaches 4200°C in the cathode (the electrode) and around 3200°C in the anode (the work piece). These temperatures are higher than the melting and boiling points of zinc (419/907°C) and copper (1083/2590°C). Furthermore, the melting point of zinc oxide, which results from the evaporation of zinc, is 1970°C. Because of this, copper and zinc may evaporate from the work piece during welding.

More zinc evaporates than copper because zinc has a lower boiling temperature [9]. To get around the issues with fusion welding, a new technique for welding brass must be used. Since FSW is a solid-state method, its application to the joining of brass materials may be advantageous in terms of the development of the microstructure and mechanical characteristics with reduced flaws. Very little study has been done and very few attempts have been made to investigate the weld ability of FSW for copper alloys. This study looked at whether or not FSW could be used to connect brass plates that were 6 mm thick.

Experimental

A 6 mm thick brass plate was used as the foundation material. Table 1 displays the base material's composition. To get rid of any debris on the plate surface, acetone was used to clean the samples' surfaces.



After surface cleaning, straight filing was done on the sides of the brass plates to ensure exact face-to-face contact at the weld connection. H13 was used as the instrument material. The tool material was purchased in a somewhat annealed condition. Every single machining operation was carried out by a lathe machine.

Fig. 1 displays the dimensions of the tool. The tool was machined, then quench-hardened and tempered to a 54–56 HRC hardness. A customized milling machine was used to perform the friction stir welding technique. Initially, the milling machine table was where the work holding device was installed. Then, in order to withstand the forces applied by the tool throughout the procedure, two brass plates were firmly attached to the table using clamping plates. The tool rotational rates used for the friction stir welding technique were 455 and 715 rpm.

A specimen was made from the sample after it was joined in order to evaluate the weld joint's microstructure. The sample was ground using silicon carbide sheets with 190, 230, 410, 610, 810, and 1210 grits in order. Specimen was completely cleaned and dried following each polishing session. Using a revolving disc polisher with 0.3 µm levitated alumina, the final polishing was completed. The specimen was completely cleaned, dried, and etched using an etchant containing ferric chloride. The specimen's microstructure was investigated with an inverted metallurgical microscope. A micro-hardness tester was used to measure the sample's hardness.

Table 1. Thermo-physical properties of mold and cast materials.

Elements	**Cu**	**Zn**	**Fe**	**Nickel**	**Pb**
Weight %	55.44	39.99	0.51	0.774	3.32

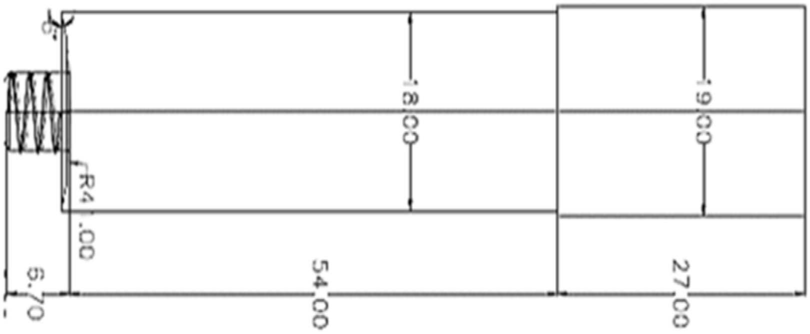
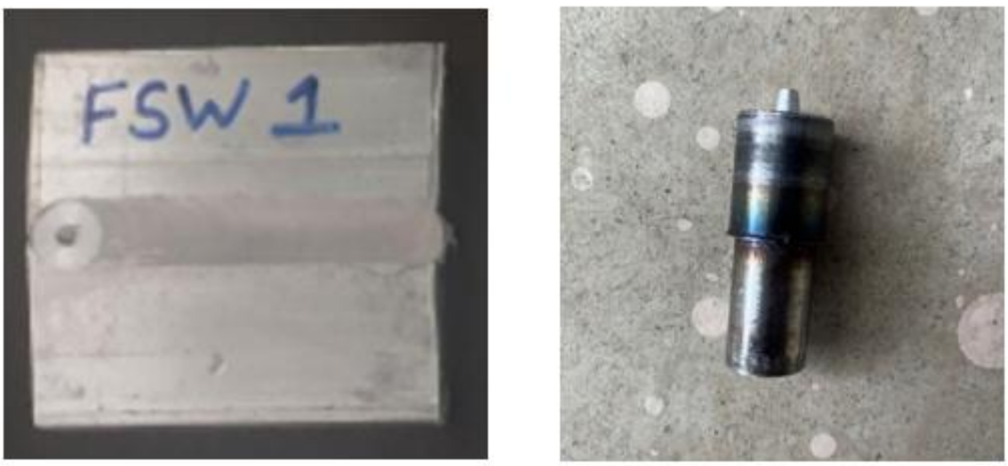


Fig.1. Tool used for friction stir welding

RESULTS AND DISCUSSION

The photos of the friction stir welded samples at 455 and 715 rpm tool rotating speed are displayed in Fig 2. Visual inspections reveal that there is a fracture evident on the weld joint at 455 rpm and a smooth weld junction at 715 rpm tool rotating speed. An indicator of inadequate thermoplastic material flow during the stirring process is the formation of a crack on the weld joint at 455 rpm. This might be because the base material and spinning tool experienced incorrect friction as a result of the inadequate heat input.

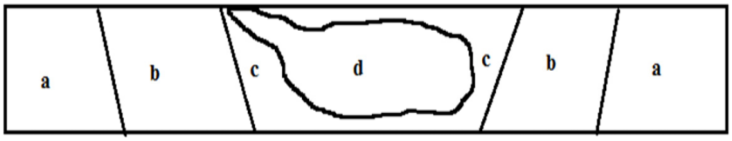
Conversely, a smooth weld connection at a tool rotating speed of 715 indicates that there is enough thermoplastic material flow inside the welding zone. The correct thermoplastic flow of material in the welding zone is made possible by the increased friction heat created between the FSW tool and base material due to the increased tool rotating speed. The findings suggest that in order to achieve a flawless weld union, the tool's rotating speed must be at its ideal level.



Work piece Tool

Fig.2. Photographs of the friction stir welded samples at the tool rotational speed of 455 and 715 rpm.

The friction stir welded sample was sliced perpendicular to the weld line at a tool rotating speed of 715 in order to study the evolution of the microstructure. The sample's microstructure examination reveals four unique regions: the parent metal, the heat affect zone, the thermomechanical influenced zone, and the stir zone. Figure 3 displays a schematic of the usual zones that were observed. The typical zones observed for the friction stir weld sample are shown in Fig. 3. These are base metal, heat affected zone, thermomechanical impacted zone, and stir zone.



The base metal's microstructure is seen in Fig. 4. It displays β phase and α dendritic phase with clean grain boundaries. This area is often not impacted by heat and is not distorted during FSW since it is far from the tool metal contact. The heat-affected zone's microstructure is displayed in Fig. 5. The HAZ microstructure has finer granules than the base metal microstructure. Despite not experiencing any plastic deformation, the material in this zone may be susceptible to heat cycling since it is located closer to the weld center region. This could have altered the HAZ's microstructure.

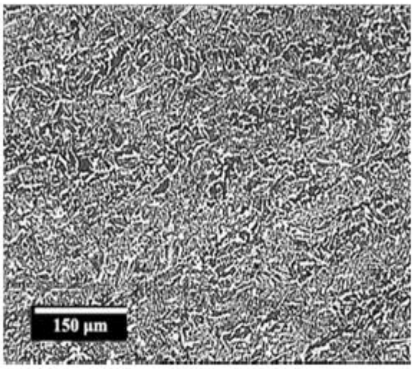


Fig.4. Microstructure of base metal

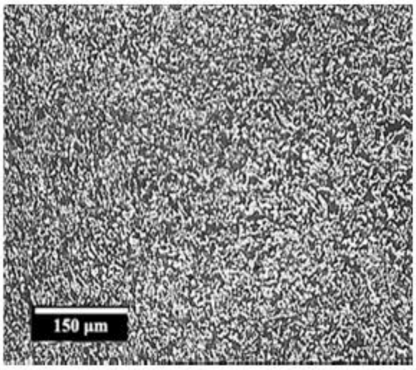


Fig.5. Microstructure of heat affected zone

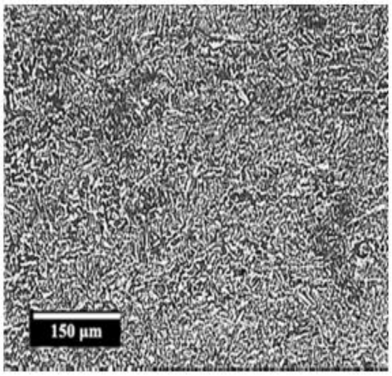


Fig.6. Microstructure of thermal affected zone

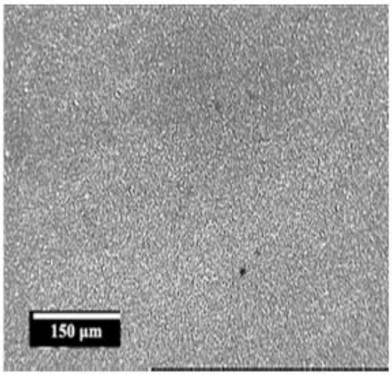


Fig.7. Microstructure of stir zone

CONCLUSIONS

The purpose of this investigation is to determine whether friction stir welding can be used to connect brass plates that are 6 mm thick. The creation of cracks in the weld zone was significantly impacted by the tool's rotation speed during friction stir welding. The creation of enough friction heat at the optimal tool speed results in a smooth, defect-free weld zone. Different base metal, HAZ, TMAZ, and stir zone zones were revealed by microstructure analysis. Grain size decrease is shown gradually by TMAZ, which moves from base metal to stir zone via HAZ. The presence of fine grains and greater hardness in the stir zone indicated the occurrence of dynamic recrystallization.

REFERENCES

[1]. Sunil Thakur, Kamal Kishore Thakur, Harmanjeet Singh 2017, “A review paper on abrasive wear and tribology of graphite”, Source of AGU Int. J. Eng. Technol, Volume 04, 62-69.

[2]. SR Chauhan, Sunil Thakur 2013, “Effects of particle size, particle loading and sliding distance on the friction and wear properties of cenosphere particulate filled vinylester composites”, Journal of Materials & Design , Elsevier, Volume 51, 398-408.

[3]. Santram Chauhan, Sunil Thakur 2012, “Effect of micro size cenosphere particles reinforcement on tribological characteristics of vinylester composites under dry sliding conditions”, Journal of Minerals and Materials Characterization and Engineering , Scientific Research Publishing, Volume 11, Issue 10, 938.

[4]. Sravan Kumar Pala, Investigating Fraud Detection in Insurance Claims using Data Science, International Journal of Enhanced Research in Science, Technology & Engineering ISSN: 2319-7463, Vol. 11 Issue 3, March-2022.

[5]. Goswami, MaloyJyoti. "Study on Implementing AI for Predictive Maintenance in Software Releases." International Journal of Research Radicals in Multidisciplinary Fields, ISSN: 2960-043X 1.2 (2022): 93-99.

[6]. Bharath Kumar. (2022). AI Implementation for Predictive Maintenance in Software Releases. International Journal of Research and Review Techniques, 1(1), 37–42. Retrieved from https://ijrrt.com/index.php/ijrrt/article/view/175

[7]. Sunil Thakur , Santram Chauhan, 2012, “Effect of micron and submicron size cenosphere particulate on mechanical and tribological characteristics of vinylester composites”, Journal of Proceedings of the Institution of Mechanical Engineers, Volume 228, Issue 04, 415-423.

[8]. Sunil Thakur , SR Chauhan, 2012, “Optimisation of cutting parameters using Taguchi design of experiment for titanium alloy (grade-5) on CNC turning centre”, International Journal of Machining and Machinability of Materials, Volume 12, Issue 04, 398-416.

[9]. Goswami, MaloyJyoti. "Leveraging AI for Cost Efficiency and Optimized Cloud Resource Management." International Journal of New Media Studies: International Peer Reviewed Scholarly Indexed Journal 7.1 (2020): 21-27.

[10]. Neha Yadav, Vivek Singh, “Probabilistic Modeling of Workload Patterns for Capacity Planning in Data Center Environments” (2022). International Journal of Business Management and Visuals, ISSN: 3006-2705, 5(1), 42-48. https://ijbmv.com/index.php/home/article/view/73

[11]. Chintala, Sathishkumar. "Explore the impact of emerging technologies such as AI, machine learning, and blockchain on transforming retail marketing strategies." Webology (ISSN: 1735-188X) 18.1 (2021).

[12]. Ayyalasomayajula, M., and S. Chintala. "Fast Parallelizable Cassava Plant Disease Detection using Ensemble Learning with Fine Tuned AmoebaNet and ResNeXt-101." Turkish Journal of Computer and Mathematics Education (TURCOMAT) 11.3 (2020): 3013-3023.

[13]. MMTA SathishkumarChintala, “Optimizing predictive accuracy with gradient boosted trees infinancial forecasting” Turkish Journal of Computer and Mathematics Education (TURCOMAT) 10.3 (2019).

[14]. Chintala, S. "IoT and Cloud Computing: Enhancing Connectivity." International Journal of New Media Studies (IJNMS) 6.1 (2019): 18-25.

[15]. Robert W. Messler, Jr., Principles of Welding: Processes, Physics, Chemistry, and Metallurgy, first ed., Singapore, 1999.

[16]. R.S. Mishra, M. W. Mahoneyr, Friction Stir Welding and Processing, first ed., OH, 2007.

[17]. C. Yeni, S. Sayer, O. Ertugrul, M. Pakdil, Archives of Materials Science and Engineering, 34 (2008) 105-109.

[18]. Goswami, MaloyJyoti. "Study on Implementing AI for Predictive Maintenance in Software Releases." International Journal of Research Radicals in Multidisciplinary Fields, ISSN: 2960-043X 1.2 (2022): 93-99.

[19]. Bharath Kumar. (2022). Integration of AI and Neuroscience for Advancing Brain-Machine Interfaces: A Study. International Journal of New Media Studies: International Peer Reviewed Scholarly Indexed Journal, 9(1), 25–30. Retrieved from https://ijnms.com/index.php/ijnms/article/view/246

[20]. Sravan Kumar Pala, Use and Applications of Data Analytics in Human Resource Management and Talent Acquisition, International Journal of Enhanced Research in Management & Computer Applications ISSN: 2319-7463, Vol. 10 Issue 6, June-2021.

[21]. Pala, Sravan Kumar. "Databricks Analytics: Empowering Data Processing, Machine Learning and Real-Time Analytics." Machine Learning 10.1 (2021).

[22]. Goswami, MaloyJyoti. "Optimizing Product Lifecycle Management with AI: From Development to Deployment." International Journal of Business Management and Visuals, ISSN: 3006-2705 6.1 (2023): 36-42.

[23]. Vivek Singh, NehaYadav. (2023). Optimizing Resource Allocation in Containerized Environments with AI-driven Performance Engineering. International Journal of Research Radicals in Multidisciplinary Fields, ISSN: 2960-043X, 2(2), 58–69. Retrieved from https://www.researchradicals.com/index.php/rr/article/view/83

[24]. Sravan Kumar Pala, "Synthesis, characterization and wound healing imitation of Fe3O4 magnetic nanoparticle grafted by natural products", Texas A&M University - Kingsville ProQuest Dissertations Publishing, 2014. 1572860.Available online at: https://www.proquest.com/openview/636d984c6e4a07d16be2960caa1f30c2/1?pq-origsite=gscholar&cbl=18750

[25]. M.A. Sutton, B. Yang, A.P. Reynolds, R. Taylor, Materials Science and Engineering A323 (2002) 160--166.

[26]. Y.S. Sato, T.W. Nelson, C.J. Sterling, R.J. Steel, C.-O. Peterson, Materials Science and Engineering A 397 (2005) 376--384.

[27]. Y. Zhang, Y. S. Sato, H. Kokawa, S. H. C. Park, S. Hirano, Materials Science and Engineering A 488 (2008) 25-30.

[28]. Sravan Kumar Pala, Improving Customer Experience in Banking using Big Data Insights, International Journal of Enhanced Research in Educational Development (IJERED), ISSN: 2319-7463, Vol. 8 Issue 5, September-October 2020.

[29]. Bharath Kumar. (2022). Challenges and Solutions for Integrating AI with Multi-Cloud Architectures. International Journal of Multidisciplinary Innovation and Research Methodology, ISSN: 2960-2068, 1(1), 71–77. Retrieved from https://ijmirm.com/index.php/ijmirm/article/view/76

[30]. M.Tehyo, P. Muangjunburee, A. Binraheem, S. Chuchom, N. Utamarat, Songklanakarin Journal of Science and Technology 34 (2012)415- 421.

[31]. C. Meran, Materials and Design 27 (2006) 719-726.