The Peerian Journal
Open Access | Peer Reviewed
Volume 9, August, 2022. ISSN (E): 2788-0303
Website: www.peerianjournal.com Email: editor@peerianjournal.com

Verification of the effect of adding nano-silicon oxide on the quality of friction stirs welding of AC-51300 aluminum Nano Composite

Mamoon A A Al-Jaafari
(University of Al-Mustansiriya,
Eng. College, baghdad)

Abstract: This work aims to study the addition of different proportions of silicon oxide to aluminum alloys that are difficult to weld, and to show the results obtained to increase the strength and quality of the weld joint using friction stirs welding.

Keywords: friction stirs welding, AC-51300 aluminum, silicon oxide, Nano Composite, Nano

Introduction: Aluminum is considered one of the most important metals that are relied upon in the modern industry because it possesses physical properties that help in reliability for its high performance in many fields. Acidic, alkaline or saline', therefore it is preferred for use in transportation, pipelines, building structures, power transmission poles and household appliances.[1-4] Nanomaterials are of performance importance because they can change many properties of materials in addition to their microscopic structure, as these particles usually contain 106 atoms or less. . One of the most important properties of nanoparticles is that the surface properties of the particles overcome the volumetric properties of the material, that is, the properties of the material when it reaches the nano scale will change and thus depends on its size, and it is also noted that the percentage of surface atoms of the material becomes very important when the size of the material approaches the nano scale , a property of nanoparticles is that they can be suspended inside a liquid for the buoyancy or immersion of a volumetric substance in the liquid, which leads to the process of using them being additive To the metal fuses of aluminum leads to the overall success of the process of adding nano materials to aluminum alloys.[5][6][7][8]

Verma et al studied a new solid-state welding technique used for joining, especially aluminum alloys. Friction fusion welding (FS) has many advantages over traditional fusion welding techniques. This study described the effects of tool pin profiles, feed rates, tool tilt angles, welding velocities, and the mechanical and metallic behavior of FS welded joints. As well as friction stir welding of like and dissimilar aluminum alloys (AA), optimization techniques, welding defects, and fatigue behavior of FS welded joints. [9]

Wang et al studied spool tool stir welding (BT-FSW) is a different kind from conventional friction stir welding (FSW). By adding shoulders instead of rigid counter-anvils, it may be used to weld curved and enclosed sections with other materials to preserve packaging, expanding the potential use of FSW in many industries with special or precise requirements. (BT-FSW) has many advantages. The strengths of the prevailing FSW model, and the most important differences between the two methods are honing the presence of defects in the root, balanced heat supply for full welding, balanced heat supply, and low rigidity requirements for machines and devices, and these points lead to opening up several unpredictable areas of use at the moment., But there are variables that the study recommended taking into consideration in the future, such as the high cost of implementing this process, as well as the life span of the equipment and the complexity of the techniques used in the new types of BT-FSW. This study describes the progress of: coil tool design and production, the weld zone crystal structure and general mechanical properties, the temperature ranges used, and the prioritization of factors affecting the quality of BT-FSW. [10]

Cabibbo et al investigated the (FSW) which is wider in the case of solid state bonding technology for lightweight sheet and plate products. Join via this technique is saving the energy, relatively widely used as well as environmentally friendly. They deliberate this type of welding as a technology in high-precision technical fields in metal alloys as well as ultra-strong titanium alloys. As a result of the physical properties obtained on it in the welding joint, they investigated the crystalline and microstructural lattice that resulted from FSW bonding in the solid state. As well as several mechanical properties, this bonding technology has been further developed with the need to expand the fields of application of FSW, expand possible alloying systems and improve the resulting mechanical properties. The researchers focused on two modified FSW technologies applicable to aluminum alloy sheets. Both sides of the AA6082 aluminum alloy tempering plate were friction stir-welded (DS-FSW). The other AA5754 aluminum plates were FSW with an innovative approach that slightly deviates the weld pin from the center line of the joint. [11]

Yu et al steadied the Dynamic recrystallization (DRX) and Structural trans formations in the crystal lattice throughout this type of welding decisive the quality of the crystal lattice as well as the mechanical properties of the weld joint. They applied the (M. C.) technique to obtain a numerical simulation model of (DRX) during this type of welding of aluminum alloys. A suitable DRX nucleation model was chosen for Monte Carlo simulation and the relationship calibration in real time with a Monte Carlo simulation step. It numerically predicts the transient evolution and final distribution of weld grain structure. The calculated grain size in the weld block area corresponds well to the experimentally measured area. It’s analyzed by combining the results of F.E. simulations and M. C. simulations with the results of electron backscattering diffraction characteristics [12]

Tanaka et al deliberate the formation of inter-metallic compounds (IMCs) through fusion of (FSW) of Steel and Aluminum. These compounds may be a serious problem because these IMCs can decrease the bond strength between the two weld joints. They investigated the reasons behind the unusual phase growth of IMC that appeared in the various FSWs between aluminum and steel alloys. The temperature was verified during the welding process, and the phase changes in the microstructure of the weld joint material were verified using the results of the sub-crystalline structure. The first stage of growth in the IMC was observed directly after contact of a rotating probe with steel, and the instant stage started in the shoulder area of the instrument on the steel plate subjected to significant downward pressure. The readings indicated that the temperature under the instrument's shoulder was higher than that of the instrument's probe. Moreover, it is found that the two steps of IMC growth and growth rates can be expressed by equations based on metal diffusion and measured temperature. The IMC grows rapidly on contact between the steel plate and the probe or shoulder, and this contact must be controlled in order to curb the growth of the IMC. This strategy and proposed formulas for forecasting the growth potential of IMC may help improve the strength of welds in the fabrication of lightweight materials in the automotive

The Peerian Journal
Open Access | Peer Reviewed
Volume 9, August, 2022. ISSN (E): 2788-0303
Website: www.peerianjournal.com Email: editor@peerianjournal.com

and aerospace industries. [13]

Su et al studied the polygonal profile process in aluminum (FSW), but it is reasonably efficient because the thermo mechanical properties are affected by different numbers of rivets. We use a 3D computational fluid dynamics (CFD) model to gain insight into all aspects of the effect of polygonal profiles to the heat generation mode As a result of the contact friction process at the interface between the tool and the work piece and the volumetric viscous dissipation near the tool. They had been using this method to measure temperature distribution, heat generation and heat loads. As well as different shoulder diameters, horizontal welding speeds, and tool rotation velocities of this process for various tools. Then they performed a quantitative analysis of variables such as the number of revolutions, torque, cross-sectional area resulting from full contact and the standard was compared with the experimental results to show the applicability of the current numerical models. Methods have been developed to improve the number of flats by determining the parallel and perpendicular torque factors in the flat area. The effects of both shoulder diameter and welding speed may be considered insignificant the reliability of the improved results will be screw life and welding conditions. [15]

Khajeh et al studied the effects of (FSW) coefficients on the crystal structure and physical properties of copper/ aluminum alloy 2024. FSW at rotational speed 950 rpm and linear lateral velocity gave best ethics of tensile strength = 140 MPa, ductility = 5 %, and the electrical resistance is in the order of ≈ 33 nm. The W/V ratio, which represents the amount of heat introduced into the FSW 85 mm/min, had a significant effect on the properties of the joint. Large amounts of brittle metal compounds Al4Cu9 and Al2Cu (IMC) were obtained with W/V > (W/V) and W/V. (W/V) More contact defects were formed compared to the optimal case. IMCS and voids at suboptimal junctions were responsible for the low strength, ductility, and high electrical resistance. In addition, the mechanism of microstructure formation in the induction region is discussed in detail.[16]

Maji et al used frictional welding and processing to bond composites and aluminum alloys, to make aluminum matrix compounds. , the friction stir plates have distinctly altered microstructure regions and may make a big difference in mechanical properties and require heat treatment to achieve the organization of the crystal lattice. This researchers' work demonstrates the latest heat treatment technology for FSW/FSPed aluminum alloys. They study the effects of heat treatment time and temperature on microscopic phenomena, mechanical properties, and condition of the sediments resulting from different heat treatment processes. [17]

In this study, the effect of adding silicon oxide nanoparticles on the established weld joint will be investigated and the influence of this addition on the physical properties will be investigate.

Base Metal Alloys; EN AC-51300 is a metal base Aluminum alloy its composition is prepared for casting. The properties mentioned are suitable for the manufactured condition (without heat treatment or chemical treatment). 51300 is the EN numerical designation for this substance. AIMg5 is the chemical designation EN having a moderate melting temperature among Euronorm (EN) cast, it has a moderately low thermal conductivity and a moderately low tensile strength. Table number one shows the main properties of the aluminum ingot used to conduct tests and practical results compared to the approved standard results

The Peerian Journal
Open Access | Peer Reviewed
Volume 9, August, 2022.
ISSN (E): 2788-0303
Website: www.peerianjournal.com
Email: editor@peerianjournal.com

Table no. 1 the main properties of the aluminum ingot.

No.	Properties	Units	Standard [19]	Actual
1	Tensile Strength: Yield (Proof)	MPa	110	110
2	Tensile Strength: Ultimate (UTS)	MPa	190	190
3	Shear Modulus	GPa	25	24
4	Poisson's Ratio	--	0.33	0.33
5	Elongation at Break	%	3.7	3.4
6	Elastic (Young's, Tensile) Modulus	Gpa	67	66
7	Brinell Hardness	--	65	63
8	Density	g/cm^3	2.70	2.70
9	Melting Onset (Solidus)	^oC	600	600
10	Melting Completion (Liquids)	^oC	640	640

Table number two shows the basic elements included in the above-mentioned alloy, which is considered one of the alloys rich in both magnesium and manganese, as well as it is considered almost balanced in the presence of the rest of the alloying elements included in most aluminum alloys.

Table no.2 Chemical composition

Elements	Standard [19]	Actual	Elements	Standard [19]	Actual
Magnesium (Mg)	4.5 - 6.5	4.90	Manganese (Mn)	0.0-0.45	0.22
Copper (Cu)	0.0- 0.1	0.05	Zinc (Zn)	0.0-0.1	0.1
Titanium (Ti)	0.0-0.2	0.10	Iron (Fe)	0.0-0.55	0.40
Silicon (Si)	0.0-0.55	0.33	Residuals	0.0-0.15	0.10

Aluminum 91.4 to 95.6, all rates is % weight. Domains represent what is acceptable under approved standards

Nano Material; The silicon oxide (called silica) nanomaterial s a solid and colorless crystalline was chosen because it is one of the materials with good mix ability with metal alloys, especially aluminum alloys. The silicon element is one of the supporting elements for the formation of the second phase in aluminum alloys, which promises to add it as well as to strengthen the basic alloy supporting the welding joint and improving the mechanical properties It and also to the heat affected area, Table No. three shows some physical properties of silicon oxide.[20]

Table No. 3 the physical properties of silicon oxide.

No.	Properties	Amount	Units
1	density	2.63	g/cm^3
2	molar mass	60.08	g/mol.
3	crystal structure	--	Quartz
4	melting point	1712	^oC
5	boiling point	2229	^oC

The Peerian Journal
Open Access | Peer Reviewed
Volume 9, August, 2022.
ISSN (E): 2788-0303
Website: www.peerianjournal.com
Email: editor@peerianjournal.com

Preparation Method ; Stir casting is one of the most effective methods of producing nano-reinforced aluminum alloys and the most reliable in obtaining uniform results for the crystal lattice distribution of the final product in which materials (mainly metal alloys and metal matrix compounds) are formed by melting metals and pouring them into metal molds of suitable shapes. for the ultimate purpose[21][22] .Samples were prepared by bringing a base alloy subject to the required basic specifications, then cutting them into cubes with a side length between 1 – 1.5 centimeter, then washing them with sodium stearate several times, then washing them with ethyl alcohol and leaving them to dry after washing with distilled water. This process is followed by the process of introducing the pieces into the oven with stirring up to 670 degrees Celsius, after which the reinforcing materials are gradually added.[23][24] For more information, you can review other places.[25][26]

Welding Process;on the friction welding process done in this work , a milling machine was used Type (GE 43-A) and rotational speed of 900 revolutions per minute, a linear speed of 40 mm per minute, and Tilt Angle (angle of inclination) of 4 degrees were used. The rotational direction is clock wise .all these parameters are constant for all experiments.[27]

Results are Discussion; The standard tensile test was chosen because it gives a clear picture on a set of criteria, Tensile evaluated are, tensile strain at failure, ultimate tensile_stress, yield stress and elongation.[28] Table No. 4 shows the tensile test properties of Aluminum alloys with different ratios of silicon oxide. And figure no. 1 shows ultimate tensile stress and yield stress (5%) vs. different nano material ratios

Table No. 4 the tensile test properties of Aluminum alloys with silicon oxide

No.	Material	Ultimate stress (MPa)	Yield stress (MPa)	Elongation %
1	As received	190.0	110.0	3.4
2	AA/0.5wt.%SiO_2	199.31	115.39	5.1
3	AA/1.0wt.%SiO_2	208.63	120.79	6.2
4	AA/1.5wt.%SiO_2	219.64	126.16	7.1
5	AA/2.0wt.%SiO_2	226.95	130.39	8.2

The Peerian Journal
Open Access | Peer Reviewed
Volume 9, August, 2022.
Website: www.peerianjournal.com
ISSN (E): 2788-0303
Email: editor@peerianjournal.com

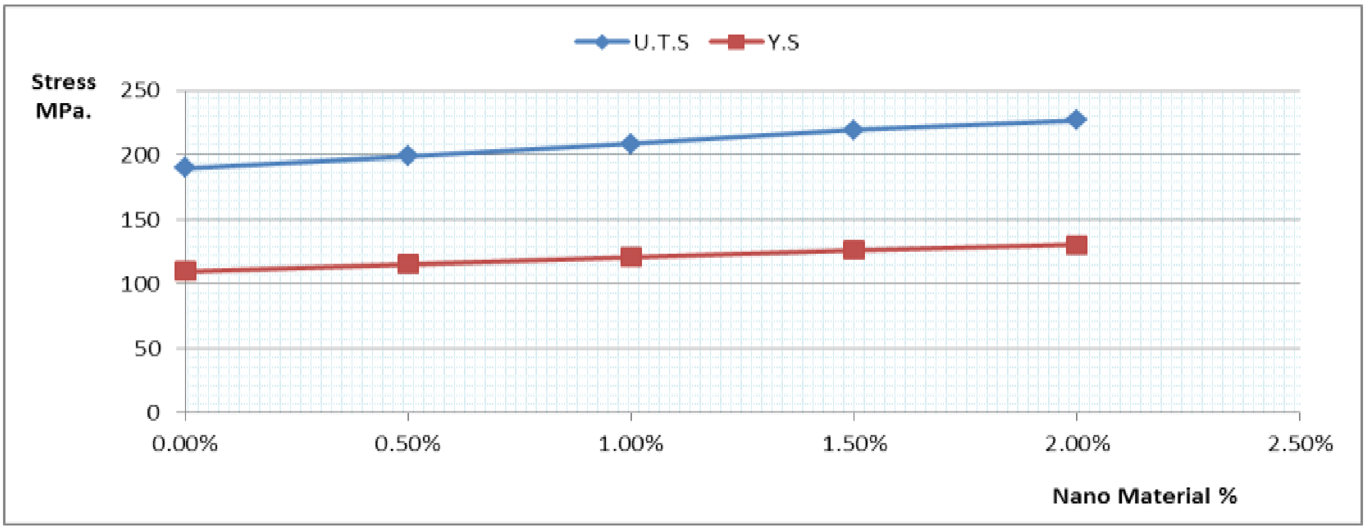

Figure no. 1 ultimate tensile stress and yield stress (5%) vs. different nano material ratios

From Table No. 4 and Figure No. one it appears that the weld joints are getting stronger as the percentage of silicon oxide increases. This could be due to several reasons, the priority of which is the increase in the rate of dislocations and the intensity of dislocations, which is a major reason for stopping the growth of microscopic cracks in each of the two stages of generation Or the growth of cracks, thus increasing the strength of the weld joint mainly. The abundance of silicon during the melting process and available from the nano-material can lead to an improvement in the mechanical properties of the welding area and the adjacent area, which is the thermally affected area, and this leads to an increase in the strength of the weld [29].

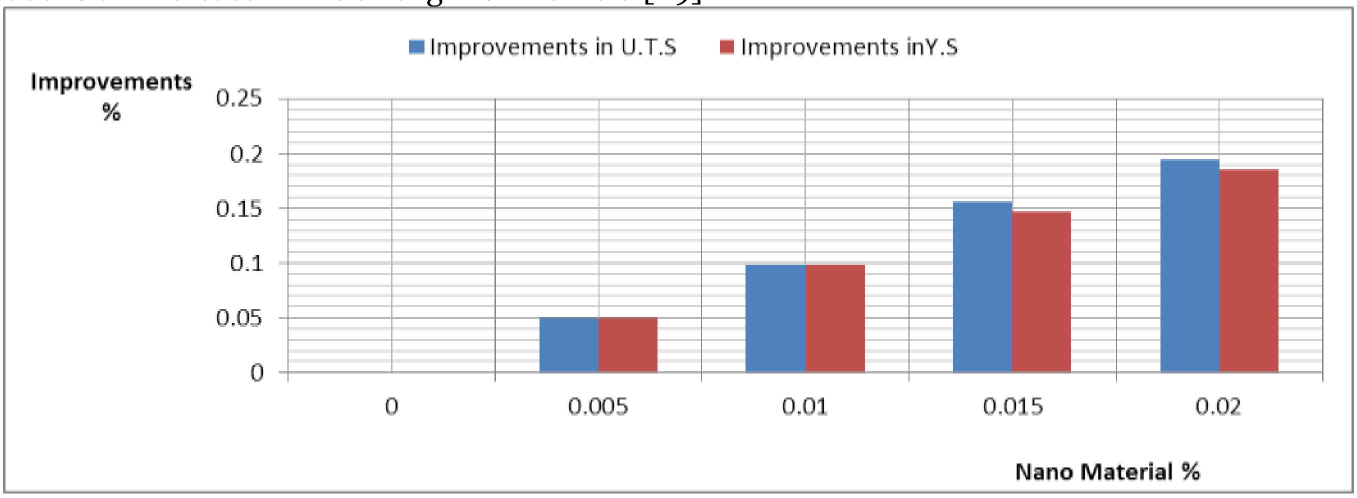

Figure no. 2 Improvements ultimate tensile stress and yield stress (5%) vs. different nano material ratios

Figure three shows the effect of adding different percentages of silicon oxide on the elongation, and from it it turns out that by increasing the nanomaterial, the elongation property of the weld joint increases.

ISSN (E): 2788-0303
Email: editor@peerianjournal.com

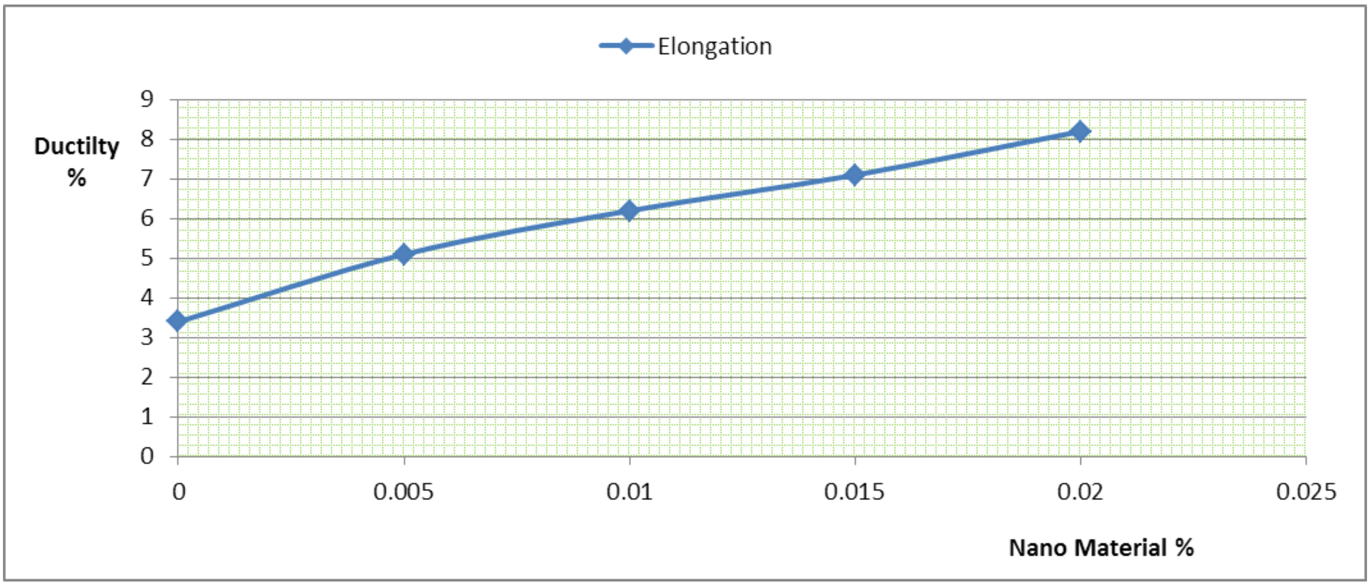

Figure -3 shows the effect of adding different wt. of silicon oxide on the elongation

4. Conclusion

A package of conclusions can be obtained from the work done above:

- The highest tensile strength borne by the material witnessed a remarkable improvement by adding the reinforced nano materials, and the highest result was at 2w.t%.

- It was noted that there is a tendency towards improvement of yield stress in most of the samples, and the main improvement percentage was in 2 wt. %.

As for the ductility, the largest change was in the case of q, which amounted to 2wt. %.

-Since the nano-material used is silicon Oxide and since the effect of the content of Mg, Si and Cr in EN AC-51300 on weld strength and brittleness, it became clear that the properties of the weld joint improved by increasing the additive

References

1. Mohammed, H.J., Mahmood, I.A. and Al-Jaafari, M.A., 2018. An Estimation Study on Fatigue transition Life of Nanocomposites Reinforced by AL2O3. *Association of Arab Universities Journal of Engineering Sciences*, *25*(4), pp.185-202.
2. Al-Jaafari, M.A., 2021, June. Study the Effects of Titanium Dioxide nano particles reinforcement on the mechanical properties of Aluminum Alloys composite. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1105, No. 1, p. 012062). IOP Publishing.
3. Al-Jaafari, M.A., 2021. Heat Treatments Effects on the Fatigue Behaviors of Aluminum Nano-Composite Alloys. *Iraqi Journal of Science*, pp.4397-4405.
4. Al-Alkawi Hussain Jasim Mohammed, Abthal Abd Al-Rasiaq & Mamoon A. A. Al-Jaafari, 2017 , "Effect of Cryogenic Treatments on Mechanical Properties of 7075 Aluminum Alloy Matrix/Al203 Particles Reinforced Composites". International Journal of Engineering Research and Modern Education.vol.2, no. 1,pp.143-149.

5. Al-Jafaari, M., 2017. Cryogenic treatment effect on fatigue behavior of 2024 and 7075 aluminum alloys with nano alumina composite material [Ph. D thesis]. University of Technology. *Mechanical Engineering Department*.
6. Ibraheem, I.F. and Al-Jaafari, M.A., 2021, June. Evaluation of photovoltaic potential application in urban environments using GIS-based method: the particular case of Baghdad/Iraq. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1105, No. 1, p. 012083). IOP Publishing.
7. Al-Jaafari, M.A., 2022. A comparative study using silicon carbide and zirconium dioxide nano material's to improve the mechanical properties of 6261AA. *Periodicals of Engineering and Natural Sciences (PEN)*, *10*(3), pp.323-333.
8. Al-Jaafari, M.A. and Ibraheem, I.F., 2022. Determination the groundwater effects on corrosion in Nano composite material Silicon-Carbide reinforced aluminum alloys in Baghdad Iraq. *Texas Journal of Engineering and Technology*, *10*, pp.33-39.
9. Verma, S., Kumar, V., Kumar, R. and Sidhu, R.S., 2021. Exploring the application domain of friction stir welding in aluminum and other alloys. *Materials Today: Proceedings*.
10. Wang, G.Q., Zhao, Y.H. and Tang, Y.Y., 2020. Research progress of bobbin tool friction stir welding of aluminum alloys: A review. *Acta Metallurgica Sinica (English Letters)*, *33*(1), pp.13-29.
11. Cabibbo, M., Forcellese, A., Santecchia, E., Paoletti, C., Spigarelli, S. and Simoncini, M., 2020. New approaches to friction stir welding of aluminum light-alloys. *Metals*, *10*(2), p.233.
12. Yu, P., Wu, C. and Shi, L., 2021. Analysis and characterization of dynamic recrystallization and grain structure evolution in friction stir welding of aluminum plates. Acta Materialia, 207, p.116692.
13. Tanaka, T., Nezu, M., Uchida, S. and Hirata, T., 2020. Mechanism of intermetallic compound formation during the dissimilar friction stir welding of aluminum and steel. Journal of Materials Science, 55(7), pp.3064-3072.
14. Fathi, J., Ebrahimzadeh, P., Farasati, R. and Teimouri, R., 2019. Friction stir welding of aluminum 6061-T6 in presence of watercooling: Analyzing mechanical properties and residual stress distribution. International Journal of Lightweight Materials and Manufacture, 2(2), pp.107-115.
15. Su, H. and Wu, C., 2021. Numerical simulation for the optimization of polygonal pin profiles in friction stir welding of aluminum. Acta Metallurgica Sinica (English Letters), 34(8), pp.1065-1078.
16. Khajeh, R., Jafarian, H.R., Seyedein, S.H., Jabraeili, R., Eivani, A.R., Park, N., Kim, Y. and Heidarzadeh, A., 2021. Microstructure, mechanical and electrical properties of dissimilar friction stir welded 2024 aluminum alloy and copper joints. Journal of Materials Research and Technology, 14, pp.1945-1957.
17. Maji, P., Nath, R.K., Karmakar, R., Paul, P., Meitei, R.B. and Ghosh, S.K., 2021. Effect of post processing heat treatment on friction stir welded/processed aluminum based alloys and composites. CIRP Journal of Manufacturing Science and Technology, 35, pp.96-105.
18. Sun, Y., Liu, W., Li, Y., Gong, W. and Ju, C., 2022. The Influence of Tool Shape on Plastic Metal Flow, Microstructure and Properties of Friction Stir Welded 2024 Aluminum Alloy Joints. Metals, 12(3), p.408.

The Peerian Journal
Open Access | Peer Reviewed
Volume 9, August, 2022.
ISSN (E): 2788-0303
Website: www.peerianjournal.com
Email: editor@peerianjournal.com

19. https://www.makeitfrom.com/material-properties/EN-AC-51300-51300-F-AIMg5-Cast-Aluminum
20. https://nanografi.com/blog/sio2-nano-powder-properties-applications.
21. Balogun, O.A., Akinwande, A.A., Ogunsanya, O.A., Adემati, A.O., Adediran, A.A., Erinle, T.J. and Akinlabi, E.T., 2022. Central composite design and optimization of selected stir casting parameters on flexural strength and fracture toughness mTiO2p/Al 7075 composites. *Materials Today: Proceedings*.
22. Al-Jaafari, M.A., 2021. Study the effects of different size of Al2O3 nanoparticles on 6066AA and 7005AA composites on mechanical properties. *Materials Today: Proceedings*, *42*, pp.2909-2913.
23. Al-Jaafari, M.A., 2022. Investigated the effects of Different casting methods on the mechanical properties of 2014 Aluminum Alloy reinforced by Alumina. *Eurasian Journal of Engineering and Technology*, *8*, pp.43-50.
24. Mamoon, A. and Al-Jaafari, A., 2020, June. Fatigue behavior of aluminum SIC Nano composites material with different reinforcement ratio. In *IOP Conference Series: Materials Science and Engineering* (Vol. 870, No. 1, p. 012159). IOP Publishing.
25. Mohammed, A.A.H.J., Abd Al-Rasiaq, A. and Al-Jaafari, M.A., 2018. Studying the effect of Different wt% AL2O3 Nanoparticles of 2024Al Alloy/AL2O3 Composites on Mechanical Properties. *Al-Khwarizmi Engineering Journal*, *14*(2), pp.147-153.
26. Al-Rasiaq, A.A., 2017. Mechanical Properties of 7075 Aluminum Alloy Matrix/Al2O3 Particles Reinforced Composites. *Engineering and Technology Journal*, *35*(3 Part A).
27. Mahoney, M.W. and Mishra, R.S., 2007. *Friction stir welding and processing*. ASM International.
28. Adediran, A.A., Akinwande, A.A., Balogun, O.A., Adesina, O.S., Olayanju, A. and Mojisola, T., 2021. Evaluation of the properties of Al-6061 alloy reinforced with particulate waste glass. *Scientific African*, *12*, p.e00812.