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Experimental Investigation of Changes in Micro Structure of FSW in AA6061/Sic/Coconut Shell Ash MMC's.

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Abstract:

Modern Metal Matrix Composites are made of getting much attraction in the automobile, aerospace applications. Research is going in an organic reinforcement material such as flyash, Rice husk and redmud. Coconut shell ash a natural material available very easily.Aluminium matrix composites (AMCs)6mm thick plates made with coconut shell ash (7.5 Wt%) and AA6061/SiC (10 Wt%) butts were Friction stir welded (FSW)utilised in this project. The characteristics of the specimens are examined with optical and scanning electron microscopes. The weld's microstructure displays specific sections, such as the zone impacted by heat (HAZ), the region affected by both thermal and mechanical factors (TMAZ), the original metal structure (BM or base metal), and the area where the material is transformed during welding (NZ or nugget zone).The nugget area displays a uniform dispersion of coconut ash and SiC particles. The rotational force from the Friction Stir Welding (FSW) tool causes the breakage of various grains found in the original Aluminum Matrix Composites (AMCs). The addition of ash from coconut shells particles successfully reduced the parent AMCs contain phases that resemble needles. The nugget zone is more difficult than the previous zones.

Keywords: *FSW, Reinforcement Material, Coconut Shell Ash, AMC'S,Scanning Electron Microscopes.*

1. Introduction

The qualities that are sought for certain applications under different service conditions cannot be produced by conventional materials. When reinforcements are added to an aluminium matrix, a material called an aluminium matrix composite (AMC) is created. This material is superior than unreinforced alloys in terms of mechanical characteristics, strength, and wear resistance [1]. These composites are used in the manufacture of several components used in commerce and industry [2]. AMCs are constructed with a number of reinforcements, including as Silicon dioxide (SiO2), aluminum nitride (AlN), boron carbide (B_4C), titanium dioxide (TiO_2), titanium carbide (TiC), titanium diboride (TiB_2), and zirconium diboride (ZrB_2). The price of reinforcements and the sluggish advancement of connecting technology, the general application of AMCs is constrained [3]. Researchers tried to weld AMCs together using conventional methods, and they observed a variety of flaws, including cracks, pores, and the due to a powerful chemical interaction between the matrix and reinforcing material during melting, brittle intermetallic structures might emerge [4-5]. Such issues were absent from the FSW-created joints [6–8]. At the UK's Welding Institute (TWI), the FSW energy-efficient solid-state master joining technology was created in 1991. [9]. In order to weld two workpieces together, A non-consumable tool is designed to go along the length of the weld line while rotating at a modest spindle speed. The parent material close to the junction becomes softer as a result of the heat produced by the tool and workpiece rubbing against one other. This feature allows FSW welds to provide a uniform dispersion of reinforcing particles, which results in higher mechanical characteristics. When the tool advances, Plasticized substance shifts from the tool's front to back side, causing the joint to form in the plastic state. [10].

Interest in composites employing affordable, low-density reinforcements has increased. When coal is burnt in thermal power plants, fly ash is created and a readily accessible, low-cost reinforcing material, was one of the AMCs explored by researchers who used a range of reinforcements [12]. Aluminum/fly ash composites are frequently utilised in the production of brake rotors, valve covers, manifolds, casings, shrouds, valve covers and engine blocks for automobiles [13]. Coconut shell ash particles can be added to composite materials to improve their density and give them more strength, stiffness, and wear resistance [14]. Following a thorough assessment of the literature, it is concluded that more research has to be done on the combined characteristics AMCs of AA6061/SiC/coconut ash connected by FSW. This study aimed to conduct friction stir welding on a composite material comprising AA6061, SiC, and coconut shell ash (7.5 wt%) to analyze the hardness and microstructure of the welded joints[21].

Study of Coconut Shell Ash:

By blending multiple distinct materials, a composite material can be formed, exhibiting mechanical properties that surpass those of its individual components. The composite material typically undergoes two key stages: reinforcement and a matrix [22] The matrix component in a metal matrix composite consists of a metal or metal alloy, and the reinforcement can take the form of fibers, whiskers, or particles. Metal matrix composites exhibit remarkable mechanical properties and high electrical conductivity. A composite containing more than two distinct materials is commonly known as a hybrid composite. [22]. Because of its advantageous characteristics, such as lightweight, affordability, excellent heat conductivity, and stiffness, aluminum matrix composites find extensive applications. They are utilized across various sectors, including manufacturing, thermal, marine, and automotive industries. Given its abundance as the most prevalent substance on Earth, aluminum is employed in diverse products including vessels, aircraft, automobiles, electrical cables, and household objects[24]. Sarayu Jagadesh, T. Nithyanandhan, K. Rohith, C.G. Sidharath, and C. Sachinundertook a study on the physical characteristics of a composite material, combining aluminum and metal matrix, with varying proportions of B_4C and CSA as strengthening components. The study concentrated on evaluating the mechanical behavior of a hybrid composite using varying levels of B_4C and coconut shell ash as strengthening agents. When compared to Al6061, the findings indicated a slight decline in hardness and a reduction in the tensile strength of the composite [23]. Yawas, D.S., Madakson, P.B., and Apasi, Aconducted a metallurgical analysis with the objective of investigating the characteristics of CSA. The concentration of ash derived from coconut shells wasdetermined to be 2.05g/cm3, suggesting its potential use in manufacturing lightweight components for MMCs with excellent thermal properties [24]. P. Lakshmi Kanthan and Dr. B. Prabu conducted a study focusing on the creation and assessment of the mechanical and tribological properties of the alloy comprising Al6061 and Coconut Shell Ash (CSA). The composite material, specifically with a 6% CSA reinforcement, demonstrated superior tensile strength, increased hardness, and reduced wear. The increased tensile strength and hardness can be ascribed to the presence of ceramic particles and metal oxides within the reinforcing element, in conjunction with the CSA particles being in close proximity to dislocations when subjected to a load. This event is responsible for the initial enhancement in both tensile strength and hardness, as well as the initial decrease in wear observed at lower concentrations of CSA (up to 6%) in the composite materials[25].

2. Experimental procedure

AA6061 is cast using CSA:

The coconut shell, a form of agricultural residue abundant in tropical countries such as India, is under further investigation as a prospective biofuel resource. There is a possibility of combining it with aluminum to enhance strength and decrease density, leveraging the robust qualities of the shell.

The versatile AA6061 aluminum alloy is extensively utilized due to its outstanding material characteristics. It stands out as the matrix of choice for crafting aluminum matrix composites (AMC). Numerous studies indicate that enhancing the reinforcement content enhances the mechanical and tribological features of these composites. Furthermore, hybrid composites demonstrate superior material properties compared to composites with a single type of reinforcement. Notably, industrial and agricultural remnants find application in the evolution of composite materials blending various elements.

The stir casting technique was employed for manufacturing AMC materials, incorporating diverse weight ratios of coconut shell ash (5%, 7.5%, and 10%), while maintaining a fixed weight proportion of 10% for SiC. Vickers hardness tests were conducted on AMCs with varying coconut shell ash percentages, revealing that the composition containing 7.5 weight percent of coconut shell ash exhibited the highest Vickers hardness (106 Hv). The final outcome is recognized as a combination of AA6061 alloy with silicon carbide (10 wt%) and coconut shell ash (7.5 wt%). These metal composites are selected as the substance for friction stir welding. The welding procedure entails utilizing plates that are 5 mm thick, 60 mm wide, and 100 mm long to create the welded connections.

Fig:1 Coconut shell Ash Powder

Fig:2 AA6061+CSA for FSW

Preparation of Reinforcement

In order to prevent the production of charcoal, which could potentially catch fire during the stirring casting method is employed to facilitate the complete conversion of coconut shells into ash., dried coconut shells are incinerated in an open-air environment to yield coconut shell ash. This ash is then sifted to acquire particles smaller than 150 micrometers.

Table 1: Composition of AA6061

Elements	Magnesium	Silicon	Fe	Copper	Titanium
Wt in %	1.06	0.61	0.15	0.30	0.01
Chromium	Zinc	Manganese	Others	AI	
0.015	0.22	0.50	0.05	remaining	

Table 2: Elements of Coconut shell Ash

Elements	CaO	K_2O	Fe_2O_3	Al_2O_3
Wt in %	0.56	0.51	12.5	15.5
MnO	Al	Na_2O	Si_2O	MgO
0.23	0.25	0.44	45.0	16.3

Figure 3 depicts the FSW tool that is used to attach the plates. It has a straight tapering cylindrical form with basic regular geometry, a 4.5 mm probe length, a 6 mm root diameter, and a 2 mm tip diameter. Figure 4 depicts the dimensions of the tool.

Fig:3straight tapered cylindrical tool used for experiment

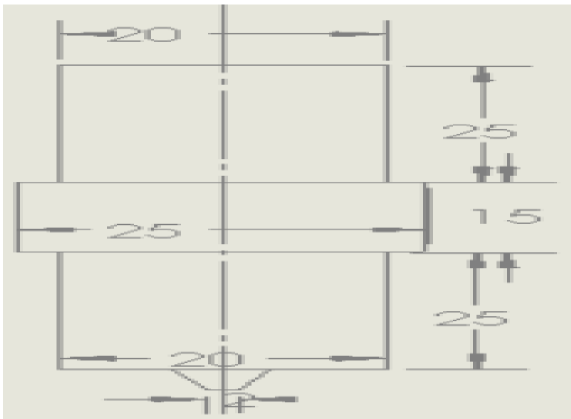


Fig:4Geometry of the Tool used for experiment

Friction stir welding was performed using a 5-ton ETA stir welder. The welding process included setting the tool speed to 1400 rpm, maintaining a traverse speed of 50 mm/min, and utilizing a tool tilt angle of 20 degrees.Derived from the findings on hardness obtained during the preliminary inquiries, These FSW process parameters' values were chosen. Figures 3 and 4 respectively depict the AMCs' crown appearance after FSW welding and the FSW setup. Cuts were made in the joints where the specimens were welded that ran transverse to the weld line. After being polished using diamond paste, the specimens that were sliced underwent etching using Keller's solution. Afterward, an examination of the microstructures in the welded joints was conducted employing both optical microscopy (OM) and scanning electron microscopy (SEM).The hardness of the specimen was assessed at the center of the weld using a Vickers microhardness tester.

Fig:5 Final AMC jointFig:6Arrangement for experimentation

3. Findings and Analysis:

3.1 Examination of the Microstructure in Friction Stir Welding Connections

The AA6061/SiC/coconut shell ash AMCs plates were successfully butted together in one pass finished by FSW. The weld joint's surface was smooth, and Figure 4 shows how the AMCs' welded surfaces appear. Due to the FSW tool's stirring action, semicircular structures resembling onion rings were created on the weld surface. The AMCs' welding area did not have any noticeable faults, such as reinforcement segregation or porosity, in contrast to AMCs connectedusing standard fusion welding procedures.

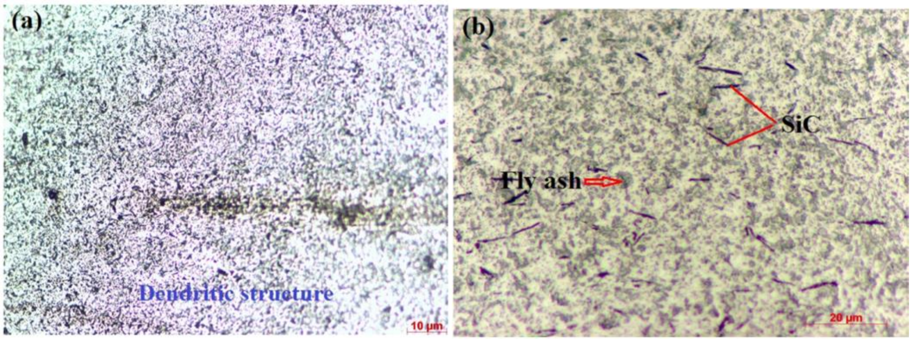


Fig: 5 a) Micro structure of AA6061 Fig: b) AMC before FSW

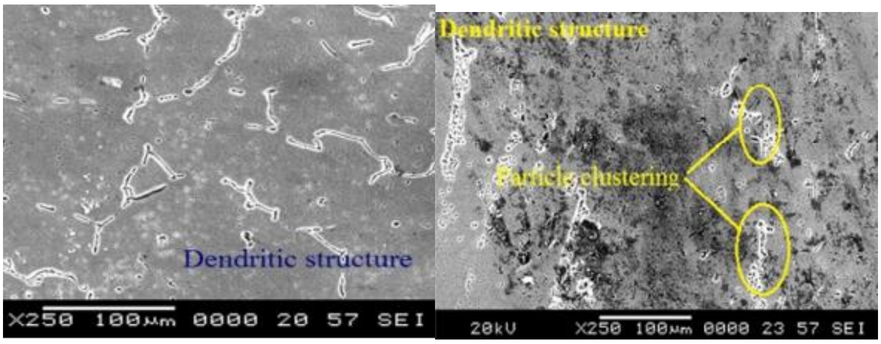
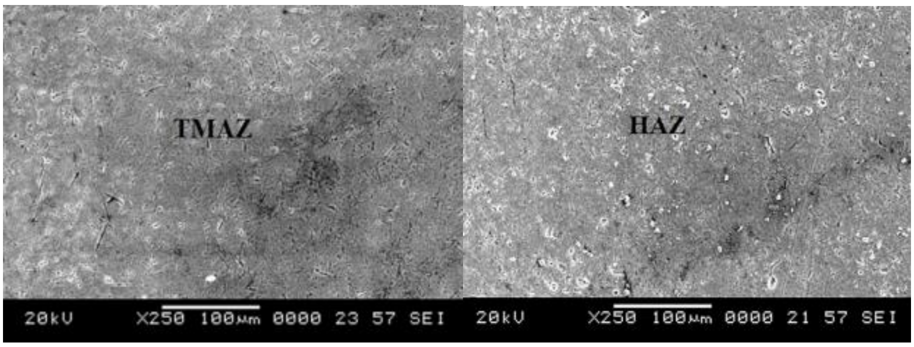


Fig. 6a) SEM images ofAA6061 (b) SEM image of AMCs

Figures 5(a) and 6(a) respectively exhibit Scanning electron and optical photomicrographs of the matrix material AA6061, both of which demonstrate the existence dendritic in nature. Figure 5(b) shows a photomicrograph taken prior to friction stir welding of AA6061/SiC/Coconut shell ash AMCs. This image showed the formation of SiC particles added to the matrix material resulted in needle-like formations, which is undesirable since it reduces the AMCs' mechanical characteristics[18].Additionally, it demonstrated the presence of inhomogeneous reinforcement dispersion, particularly in cluster form, including SiC and coconut shell ash particles. Figure 6(b) shows SEM micrographs of parent AMCs prior to FSW, which unmistakably demonstrate the existence of clusters via the cooling process used during stir casting, of reinforcing particles in dendric form. Following FSW, the AMCs' SEM photo micrographs showed that there were four separate zones: when combined heat and tool pressure create deformation; The areas affected encompass those influenced by elevated temperatures, commonly referred to as the heat-affected zone (HAZ), the central welding region referred to as the nugget zone (NZ), and the zone influenced by both heat and mechanical forces, termed the thermo-mechanically affected zone (TMAZ), where deformation is solely attributed to heat. The basic metal (BM) is resistant to deformation caused by either heat or tool pressure, representing the area where the workpiece undergoes the most significant deformation.



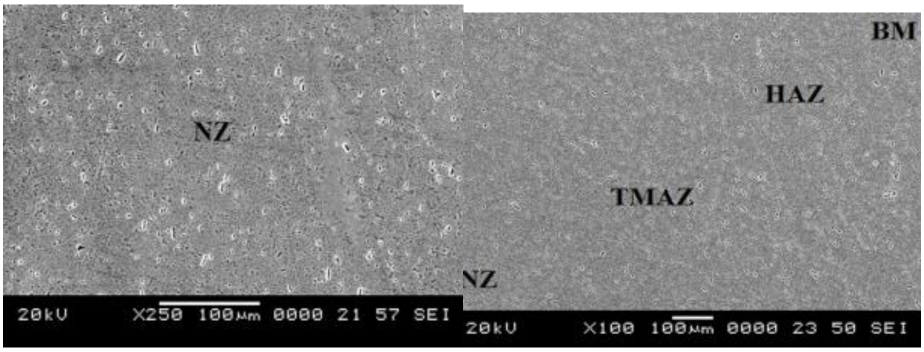


Figure 7 displays scanning electron microscope (SEM) images depicting a) region affected by thermomechanical processes (TMAZ), b) zone influenced by heat (HAZ), c) nugget zone (NZ), and d) all the welded zones.

The TMAZ, a zone that has been thermally and plastically damaged, is a zone that is close to the nugget zone.HAZ and TMAZ together form the transition zone. In TMAZ and NZ, different grain sizes were seen.According to Figure 7(b), dendritic structure refinement in HAZ was seen as a result of exposure to heat produced by the rubbing of a revolving tool against the work surface during plastic deformation. Figure 7(a) also shows that elongated coarse grains are formed in TMAZ because there is less plastic deformation and recrystallization there than in NZ [15]. However, Since the FSW tool stirs the material, causing dynamic recrystallization and allowing the flow of plasticized material, the NZ of the FSW-welded AMCs. Figure 7(c) depicts the complete transformation of grains, transitioning from the initial AMCs to the FSW-welded AMCs. This highlights the emergence of finely structured and equiaxed grains[16]. Due to the severe distortion generated by the tool's swirling action, SiC needles were successfully broken in NZ [11]. At the same time, SiC and coconut shell ash clusters vanished in NZ and the particles were spread evenly. The major cause of this is the development of strain fields surrounding the coconut shell ash particles when the hot weld zone cools. Furthermore, since the grain sizes of the HAZ and BM are similar, there is little variation in their microstructures. It is easy to see where the NZ and TMAZ borders are. The nugget zone's microstructure showed clear evidence of joints without flaws bypreventing the development of flaws such porosity, fracture formation, and segregation that are present in joints made using traditional welding techniques[20]. The FSW tool's heat doesn't support any interactions between the matrix and the reinforcing material. The reinforcing particles are redistributed because to the increased the FSW tool created plastic strain.The number of nucleation sites is increased by the reinforcing particles, which causes the grain size of the aluminium matrix to decrease [17].

3.2 Evaluation of the hardness of welded joints

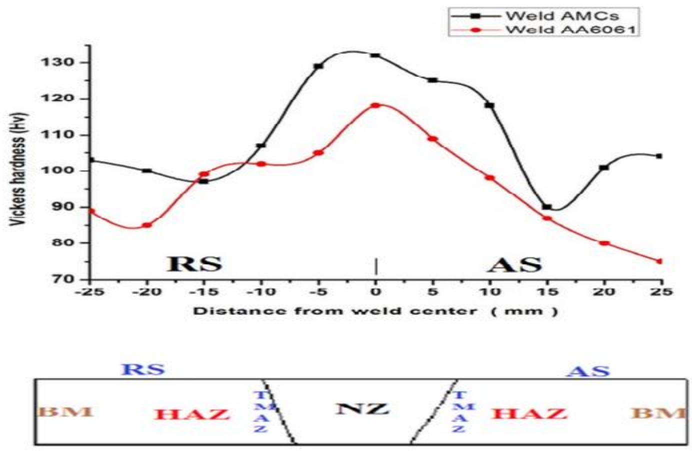


Fig:8 Graph depicting the relationship between hardness and distance from the weld's center

The Figure 8 demonstrates the hardness values of plates made of AA6061 and AMCs that have been welded using FSW, covering the range from the central region of the weld to its outer edges. Remarkably, the hardness levels of FSW-welded AMCs exceed those of AA6061 welded using FSW, consistently observed across various zones of the FSW. This difference is highlighted in Figure 8.Because the advancing side's (AS) hardness levels were lower than the retreating side's (RS), Figure 8 demonstrates that the graph grew asymmetrical further out from the weld centre. The primary factor contributing to this difference is the amount of plastic deformation occurring on both sides of the joint[19].Because RS is subject to less plastic fatigue than AS, which results the temperature at the weld nugget on the AS is higher with greater deformation heat is higher than on the RS.The hardness of AS is lower than that of RS because of the coarsening and precipitate dissolving brought on by the higher temperature, according to Chaitanya et al. [4] discovered asymmetrical micro hardness profiles for AA7039 that were welded by FSW on either side of the joint, starting from the weld centre. NZ has the greatest Vickers hardness readings, with TMAZ, HAZ, and BM following closely after.

4. Conclusions:

FSW may be utilised to combine with AA6061/10wt%SiC/(7.5wt%) casted AMCs effectively in this experiment.The results of the evaluation of the welds' microstructure and hardness are summarised below.

- The AA6061/SiC/coconut shell Four distinct zones may be found in the microstructures of ash AMCs: The original composite material (base metal), the area affected by heat, the zone impacted by thermomechanical forces, and the central nugget region.
- The nugget zone is evenly covered with coconut shell Ash and SiC particles are diffused, as are clusters, and the dangerous needle-like SiC structure that was a feature of the parent AMCs was completelyeliminated by use of the FSW tool's spinning motion.
- Studies on Vickers hardness show that the nugget zone of FSW displays higher hardness than other zones of FSW because of the disintegration of reinforcing particles and the creation of tiny grains.

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