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MANUFACTURING HIGH STRENGTH ALUMINUM MATRIX COMPOSITES BY FRICTION STIR PROCESSING

CHANDANKAR VINOD KUMAR M.
RESEARCH SCHOLAR, SUNRISE UNIVERSITY, ALWAR RAJASTHAN

DR. DEEPAK DALAL
RESEARCH SUPERVISOR, SUNRISE UNIVERSITY, ALWAR RAJASTHAN

ABSTRACT

MMCs are remarkable due to their many advantageous characteristics, such as their high strength-to-density ratio, fatigue resistance, wear resistance, higher electrical and thermal conductivities, transverse stiffness, radiation resistance, low creep rate, and so on. MMCs found extensive usage in fields requiring improved material qualities, such as the aerospace and marine sectors, because to their high stiffness-to-weight ratios and corrosion resistance, respectively. Researchers are now interested in the production of Aluminum Matrix Composites (AMCs) using ceramic reinforcements. Hybrid metal matrix composites may be made by combining several reinforcements with an aluminum alloy matrix. The AMCs' set of properties react in a variety of ways, making it impossible to use conventional welding processes. The material being welded does not melt and recast during the Friction Stir Welding (FSW) process, making it a promising new solid state joining technique.

KEYWORDS: Metal matrix composites, friction stir processing, shape memory alloys, microstructure defects, homogeneous distribution

INTRODUCTION

By creating coalescence at temperatures below the melting point of the base materials, friction stir welding is a solid-state welding method. As a spinning tool is moved over the joint interface, friction and heat are created, and the plasticized material flows back and forth along the tool's surface (Nandan et al. 2008; Dawes and Thomas 1996). The pliable material was extruded, and the stir zone was created, as a result of the friction stir welding tool's rotating and transverse motion. The creation of the stir zone is affected by the material flow performance while the tool is spinning. Researchers have put in much time and energy into understanding the effects of the most important process parameters in friction stir welding on the flow behavior of the material and the mechanical qualities of the welded joint. Several academics have focused on learning how to choose the best friction stir settings and how to understand the impact of process factors on the weld qualities.

Several different types of vehicles and airplanes employ the aluminum alloy AA7075. The production of surface composites is a process that may be used to enhance the surface characteristics of these alloys, which now show signs of being subpar. While making surface composites, ceramic particles are stirred casted into the material first. Nevertheless, there are constraints inherent to this approach, such as the need for perfect particle dispersion across the grain boundary in ceramics. In recent years, surface composites have been manufactured using Friction Stir processing, a noble, environmentally friendly method. In order to create super plastic alloys of aluminum with consistent grain distribution, Mishra et al. (1999) refined the friction stir welding technology to create friction stir processing. Afterwards, the metal is plastically deformed to strengthen the grain boundaries, and the alloy is forced to flow into grooves for friction stir processing, where it solidifies.

To meet this need, a new field of composites was developed to accommodate the materials' complicated features. Although casting alloys and other liquid-state processing methods were formerly used to prepare composites, a shift to solid-state alloying was necessitated by the need for improved surface qualities. Before the ceramic particle is developed inside the matrix of the material by the in situ formation technique by the chemical reactions between the raw materials for the production of ceramics, the solid state processing is performed by liquid phase deposition of the ceramic particle to ensure the effective control over the grain size in the surface composites. Subsequently, Mishra et al. at The Welding Institute of Technology in the United Kingdom invented the technology of friction stir processing, which evolved from friction stir welding, to create aluminum alloys with super plasticity, ultra-fine grain size, and high grain boundary orientation. Friction stir processing evolved quickly over time, eventually being split into two distinct categories: in-volume friction stir processing and Surface friction Stir processing. Similar techniques for depositing the ceramic particle were also developed. Nowadays, this is accomplished by taking a groove or drilling a series of holes throughout the workpiece and filling them with a ceramic powder.

LITREATURE REVIEW

Vivek Kumar Jain (2021) By altering the substrate's microstructure and reinforcing the surface with hard-particles, the hardness, tensile strength, corrosion and wear resistance may be improved via friction stir processing (FSP). This research conducts a comprehensive review of the existing literature on FSP method and its impact on the various classes of aluminum-based metal matrix composites (AMMCs). Different reinforcements and their impact on AMMCs are also discussed. This paper's goal is to summarize the impacts of different operating circumstances and FSP parameters on the microstructure and final characteristics of surface composites fabricated using FSPed AMMCs. It was found that mechanical characteristics, corrosion resistance, and wear resistance all increased. By performing multi-pass FSP with quick cooling, fine grains ranging in size from 100 nm to 400 nm were achieved in an AA7075-T6 matrix. Compared to cast AA7075, AA7075/9 wt% TiB_2 SCs have improved UTS by 237 percentage points, hardness by 246 percentage points, and wear rate by 47 percentage points. This review paper contains substantial information about AMMCs that can be useful to new researchers working in the field of FSP.

KarthikAdiga (2021) Composites have shown their importance in the aviation industry due to their advantageous properties, such as high strength and stiffness with low density. Because to its high specific strength, higher wear resistance, and decreased thermal expansion, aluminum metal matrix composites (AMMC) are used in the automotive, aerospace, and marine sectors. To make matters worse, intermetallics and undesirable phases tend to develop during the high-temperature liquid-phase manufacturing of composites. This new method of composite production, called Friction Stir Processing (FSP), uses a temperature much below the melting point of the matrix to provide excellent grain refinement. It has been widely reported that AMMC made by the FSP technique has improved mechanical, microstructural, and tribological characteristics. Particle distribution is shown to be most affected by FSP characteristics such tool rotational and traversal speeds. Tensile strength, hardness, wear and corrosion resistance are only some of the qualities that are known to be affected by FSP techniques, with the extent of these changes depending heavily on the processing and tool settings. In this study, we explore the processes of reinforcement behind these transformations. Shape memory alloys, high entropy alloys, MAX phase materials, and intermetallics as reinforcing material are only some of the cutting-edge engineering materials covered. Researchers focusing on the FSP approach to produce AMMC can greatly benefit from this summary of the difficulties and potential gains that they face.

RajkumarDuhan (2021) This study presents the results of microscopic and mechanical studies of friction stir applied to the production of higher polymers. The robust processing method known as contact stir preparation (FSP) has a number of desirable characteristics. They include low heat generation, a large plastic flow, the achievement of very fine micro in the stirred zone, and the healing of faults and castings defects. FSP allows for localized adjustments to a building's characteristics. It's a method for adjusting the mechanical properties of a substance by swirling it while a tool moves across its contact with the substance. The purpose of this research was to determine whether or not the surface mechanical qualities of metal matrix composites manufactured using stir casting might be enhanced. Metal matrix materials were filled with a hybrid hardening filler made of carbides (SiC) and aluminates (Al_2O_3) with a particle capacity of 200 m, or 5% by weight. FSP has been used to hone down on and scale down recommendations for composite materials' faces. Microstructural tests probing grain size changes revealed a drastic decrease in grain size, from 84 m to 7 m. Three different tool rotation speeds and three different linear tool movements were tested as process parameters. The testing findings were used to identify the best parameters for producing the proposed composite material with the desired fine grain size, high hardness, high tensile strength, and low wear.

Gupta, M.K. (2020) When it comes to practical use, the qualities of a material's or component's surface often outweigh those of the bulk. Surface qualities are the primary determinants of a material's hardness, wear, and corrosion resistance. The lengthened durability of many parts may be attributed to their enhanced surface characteristics. Friction stir welding is a relatively new solid-state processing technology. In this research, we looked at how the friction stir technique may be used to create composite surfaces using an aluminum matrix. It was also documented how the surface qualities changed as a result of changing the parameters of the friction stir process, the tool design, the reinforcing, and the reinforcement procedures.

EXPERIMENTAL PROCEDURE

The manufactured stir cast rectangular plates had dimensions of 100 mm by 100 mm by 10 mm. The manufactured stir cast plates were first sliced to a thickness of 6 mm using a power hacksaw machine. Figure 1 depicts the milling process that was used to reduce the plates to the specified dimensions (100 mm x 50 mm x 6 mm - Based on the literature review). Grinding and emery polishing were used to get rid of burrs and make the edges smooth and flat. The specimens were cleaned before friction stir welding was performed so that no surface contaminants would affect the results.

Figure 2 depicts the positioning and firm clamping of the test plates to the backing plate using mechanical clamps to prevent the plates from rising during welding, a necessary step in the fabrication of square friction stir welded butt joints utilizing a single pass. The base plate was secured to the workstation with clamps. After positioning the test plates, a non-consumable square-profiled tool was progressively inserted into their faying surfaces while being turned clockwise until the shoulder of the welding tool made contact with the plates' top surfaces.

Figure 1 Plates prepared for friction stir welding from stir casting (100 mm X 50 mm X 6 mm size)

Figure 2 Test plated clamped to the backing plate during friction stir welding process

The spinning tool was given just enough time to stop moving before preheating the material and starting the plastic flow at the junction line. The weld traverse then began with a vertical downward force applied to the tool shoulder. The welding was done in a direction that was perpendicular to the rolling. The pliable substance was moved from the blade's cutting edge to its backside. The welding rod was moved along the joint line until the end of the weld was reached. After the weld was complete, the spinning tool was pulled from the plate, leaving a key hole. The friction stir welding specimen is depicted in Figure 3, which is a schematic. Figures 4 and 5 depicted the usual friction stir welded plate and friction stir welded butt junction plate examples, respectively.

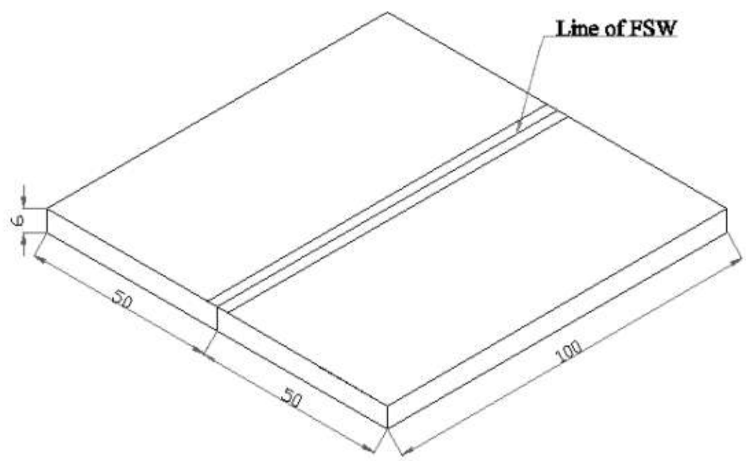
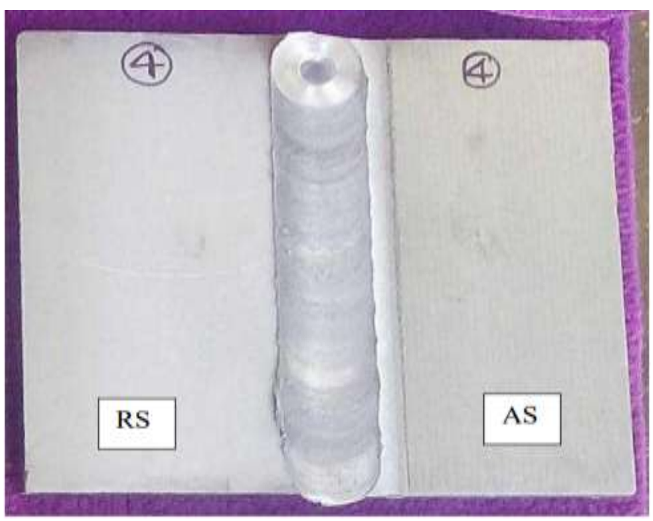


Figure 3 Schematic diagram of the friction stir welding Joint.



RS – Retreating side AS – Advancing side

Figure 4 Typical friction stir welded plate

Figure 5 Samples of friction stir welded butt joint plates

4.4.1 Identifying the Range of Friction Stir Welding Process Parameters

Axial force, welding speed, and tool rotational speed were all tested in the first round of testing for friction stir welding. It was determined what range of friction stir welding process parameters could be achieved by doing trial runs on a 6 mm thick stir cast Al 6063 hybrid composite. Table 1 displays the process settings currently in use. This study draws on a wide range of previous research to.

Table 1 The friction stir welding process parameters

S.No	Process Parameter	Range
1.	Tool Rotational speed (rpm)	800,900,1000,1100 and 1200
2.	Welding speed (mm/min)	20,30,40,50,and 60
3.	Axial force (kN)	6,8,10,12 and 14

4.5 SPECIMEN PREPARATION AND TESTING

4.5.1 Microstructure Analysis

Samples from the welded joint were utilized to produce the specimen, which was then examined under a microscope to disclose the material's microstructure. The specimens went through a series of procedures including sectioning, grinding, polishing, and etching to get ready for study. At first, a band saw was used to make a traverse cut through the specimen. The stir zone, the thermo mechanically affected zone, the heat affected zone, and the base metal must all be present in the cut samples. Smoother edges were achieved by utilizing a grinding machine, and the scratches and abrasions were removed by polishing the specimen on a polishing wheel with progressively finer grades of silicon carbide paper. The samples were polished, and then etched to reveal the microstructure more clearly, including the grain sizes. Keller's reagent was used to etch the samples, and it was made by mixing 1.5 percent Hydrochloric acid with 2.5 percent Nitric acid in 95 percent distilled water. After a thorough cleaning, the engraved specimens were dried using an electric drier. Using a metallurgical microscope and a scanning electron microscope, we analyzed the friction stir welded specimen along its various zones.

Ultimate Tensile Strength

As an acceptance test for material specifications, tensile testing is widely used to determine a material's strength. Tensile tests were utilized to determine the specimen's strength in this investigation. Tensile specimens were manufactured using the ASTM E8M 04 standard, and their dimensions are shown in Figure 6. The specimens were made from a friction stir welded stir cast Al 6063 hybrid composite. Fractional stir welding is seen in Figure 7, where a tensile specimen is removed from the component. Universal testing equipment shown in Figure 8; friction stir welded Al 6063 hybrid composite specimens shown in Figure 9. The ultimate tensile strength was determined when the specimen was gripped and an increasing force was applied under computer control. For the sake of reliability, three samples were evaluated, and the average ultimate tensile strength was used in the calculations.

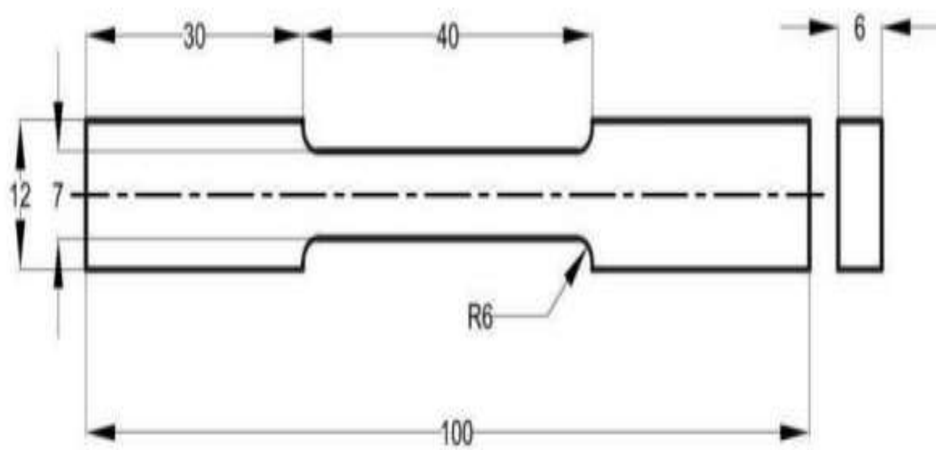


Figure 6 Dimension of tensile specimen

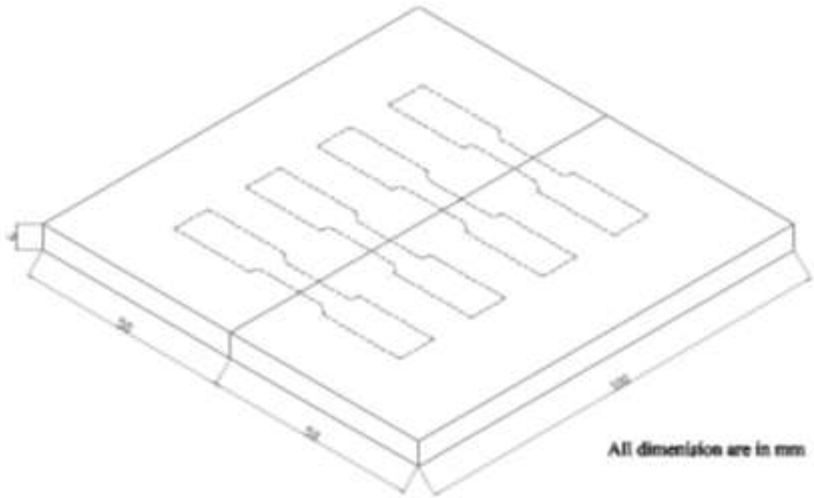


Figure 7 Extraction of tensile specimen from friction stir welded joints

Figure 8 Universal testing machine.

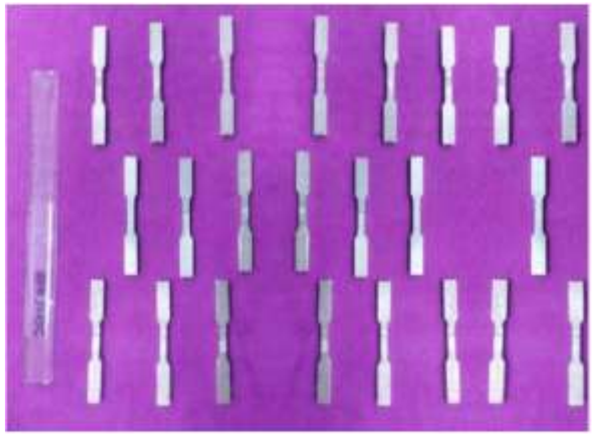


Figure 9 Tensile specimen prepared from friction stir welded joints

Micro Hardness

Little components, thin portions, etc., are often tested using the micro hardness method. The following method was used in the production of the welded specimen in order to determine its hardness. Standard metallurgical practices were used to get the dimensions given in Figure 10 for the specimens, and then they were etched so micro hardness testing could be done in places such the stir zone, the thermos mechanical affected zone, the heat affected zone, and the base metal.

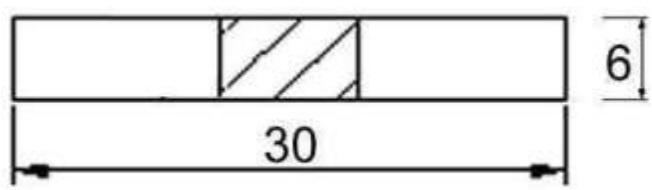


Figure 10 Dimensions of macro/microstructure and microhardness specimen.

CONCLUSION

In this chapter, you will learn how to set up an experiment, perform the technique, and create a finished product using friction stir welding on an Al 6063 hybrid composite. The parameters of the friction stir welding process were investigated via a series of experiments. The testing and preparation of specimens followed established protocols.

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