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Study of Aluminum Based Composite Fabricated by Friction Stir Processing

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Abstract:

Friction stir processing (FSP) is a solid-state procedure that enhances microstructures and mechanical characteristics over traditional manufacturing techniques. By passing a rotating pin through the workpiece, the machined area experiences localised frictional heating, softening the material and refining various material properties, typically resulting from the grain refinement of the softened metal. FSP Friction stir process was advanced from friction stir welding (FSW) technology, and both FSW process and FSP process use the same process principle of operation. In this research work, the impact of process parameters such as speed, feed, angle of inclination, and number of passes is analysed over mechanical and microstructural attributes of Al2014 plate reinforced with TiB_2 nanoparticles (60-90 nanometres). Vickers hardness measurements, and Optical, scan electron microscopy, together with grain analysis, are executed on multiple regions of the machined cross-sections to demonstrate the condition of the machined material properties.

Keywords: Friction stir processing, Al2014, TiB_2 nanoparticles, Mechanical, FSW.

1. Introduction

Friction stir processing is known as solid state technique for changing the characteristics of a metal by localised plastic deformation. FSP operates by inserting a rotating tool into a slot loaded with reinforcement powder and then spinning the tool along on the interface. The tool's friction heats the materials around the rotating- pin of the FSP tool to temperatures below the melting point of the base metal. Friction stir processing is a solid- state technique that is used for the purpose of creating surface composites. In comparison to the traditional liquid state processing technique, An aluminium-copper alloy AA2014 that can be heated due to its better ductility and huge strength to weight-ratio, is wide uses in the aerospace, defence, and military industries as well as in heavy forgings, extruded forgings for aircraft, and wheels, among other things. However, the application of AA2014 in industry is restricted because of its poor hardness and low wear resistance. To get around the restrictions, several researchers have offered various techniques. The MMC (Metal Matrix Composite) of aluminium metal with various materials utilised as reinforcement materials has been determined to be the optimum approach for this purpose. (Tiwari et al., 2021)

In order to achieve the necessary qualities, a metal matrix composite (MMC) is made up of at least two components: a matrix (often an alloy) and a reinforcement (hard ceramic particles). The mechanical-characteristics of the material produced with mixing high-strength, high-modulus refractory particles (such as silicon carbide and aluminium oxide) with a ductile metal matrix lie somewhere between those of the alloy matrix and those of the ceramic reinforcement.

2. Principle of FSP

The FSP friction stir process procedure is a straightforward one that involves plunging a rotating tool with shoulder &pin into the workpiece and then moving in the appropriate direction. The tool pin can have a wide variety of profiles, including cylindrical, square, triangular, hexagonal, tapered taper, threaded taper, and many more. The tools main two significant uses are to heat and distort that materials of the workpiece. The spinning pin or probe deforms or swirls the resonally heated material while heating is predominantly produced by friction between surfaces of rotating arm and the work piece. The material is heated, which causes it to soften and flow around the revolving pin before filling the tool's hollow at the rear. The resulting composite's characteristics are determined by predetermined factors like rotational speed, tool angle, feed rate, axial force, depth of immersion, etc. FSP process results in the considerable microstructural refinement, densification, and homogeneity of treated zone by intensive plastic deformation of material, material mixing, and heat exposure of the processed zone. The creation of fine-grained structural and surface composites, the alteration of material microstructures, and the synthesis of composites have all been accomplished with success using the FSP approach.

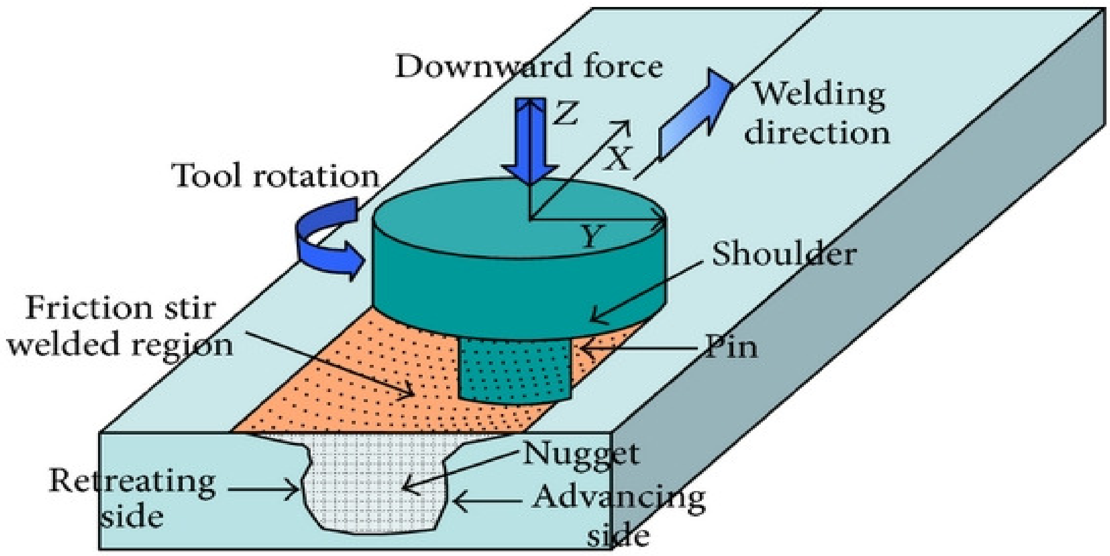


Fig 2 Schematic diagram of FSP processing

2.1 SELECTION OF ALUMINIUM ALLOY FOR THIS STUDY

Al 2014 was the base metal we used in this study to examine the FSP procedure. Al2014 is a common flat rolled sheet alloy with the following composition: 3.9% copper, 1.2% silicon, 0.8 Mg, and 0.7 Fe. used in situations where extreme strength/hardness is required, such as those involving use at high temperatures. Large forgings, sheets, and injection molded parts are used specifically for heavy vehicle chassis and suspension system, tanks, wheels, and important structural parts. Aluminum is now utilised in a wide range of applications where a combination of light weight and high-strength is necessary. The aerospace and automotive sectors demand a high strength to weight ratios. Fuel efficiency and prices has improved as a result of this ongoing competition to decrease weight without sacrificing overall strength. To reduce weight in this area, numerous aluminium alloys are the subject of research. One such aluminium alloy is Al2014. These are copper and aluminium alloys.

3. Experimental Procedure

3.1 Milling machine and Fixture design

Due to the unavailability of specialized friction processing machines, a CNC milling machine with variable rotation and linear speed was used. The machine was set up to be suitable for the job. The machine was equipped with a welding tool, support plate and fixtures that are suitable for FSP. The milling machine used in this study is an 808d Milling and Turning multi-axis CNC machine with a Siemens control unit. (Ali et al., 2020b; Huang et al., 2018b) The clamping system and CNC milling machine should be added as shown in Figure 4.11 and Figure 4.12

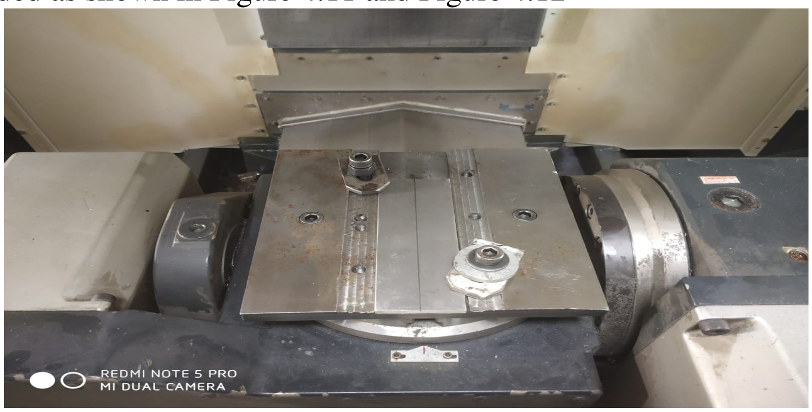


Figure 3.1 Fixture Plate

Figure 3.1.1 Multi Axis CNC Milling Machine

3.2 Tool design and specifications

Friction welding tools were designed and manufactured from H13 type tool steel. The tool steel was designed as follows, shoulder diameter: 16 mm, pin diameter: 5 mm and its height: 3.5 mm, which is slightly less than the sheet thickness (6 mm). The specifications of these tools are shown in Figure 4.13. (Bauri et al., 2011b; Sethi et al., 2019b)

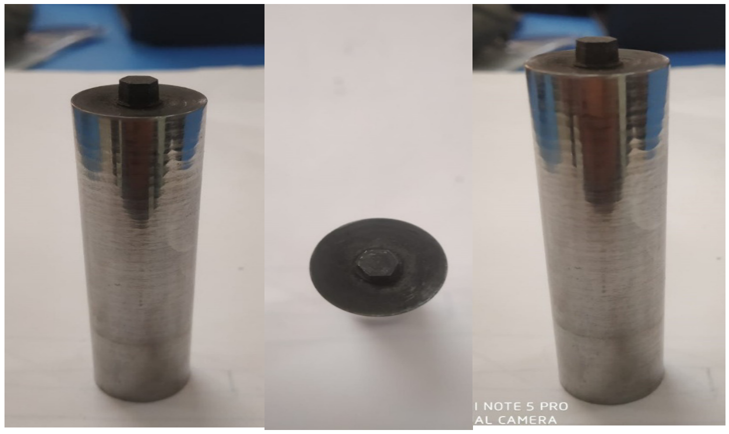


Figure 3.2 FSP Tool

4. FSP processing procedure

The FSP process was carried out on aluminum alloys (AA2014 T6) as shown in the following steps:-

4.4.3.1 Immersion step

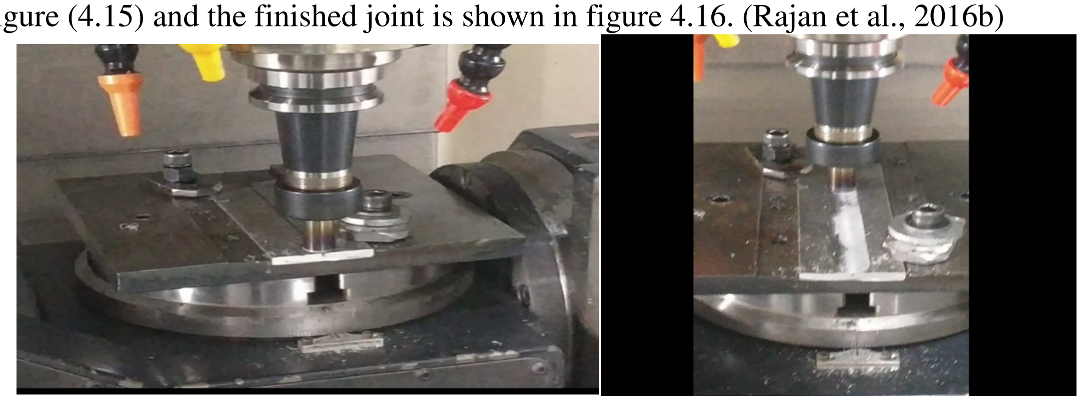
In this step, the spindle was placed in the centre and rotated at its specified rotation (rpm). The machine table was gradually raised vertically until the tool insert sank 0.1 mm into the plate surfaces, then the spindle was rotated in position for 30 seconds (dwell time) to preheat the plates prior to welding. (Patil et al., 2021b).

4.4.3.2 Mixing and welding steps

In this step, the plate mixing process was carried out, where the machine table moved forward for the welding speed with a certain linear speed (mm/min) to make the welding process. (Patil et al., 2021b).

4.4.3.3 Inserting the step of the welding tool

This step started when the center point of the tool reached the given weld length, so the forward movement stopped and the tool was lifted from the sample leaving the hole at the end of the weld as shown in figure (4.15) and the finished joint is shown in figure 4.16. (Rajan et al., 2016b)



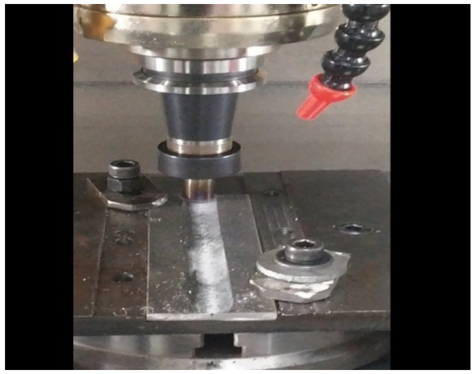


Figure 4.14-4.16 Friction Stir Welding Steps: step1: Plunging step, step2: Stirring step and step3: Retracting step.

5. TESTING OF STIRRED ZONE

In order to investigate mechanical properties of the processedzone before and after heat treatment and to evaluate the effect of heat treatments on these properties, several tests have been conducted.

i. Tensile test

Tensile test specimens were manufactured by using CNC wire cut with geometry in accordance with the specifications given in the ASTM standardE8/E8M-09for sub-size specimens as shown in Figure (4.18).Such that the processed nugget was positioned in the middle of the specimen gage length (transverse specimen). Tensile test was carried out to determine the tensile properties of the processed zone at all process parameters.(R et al., 2018b; Rao et al., 2021b)

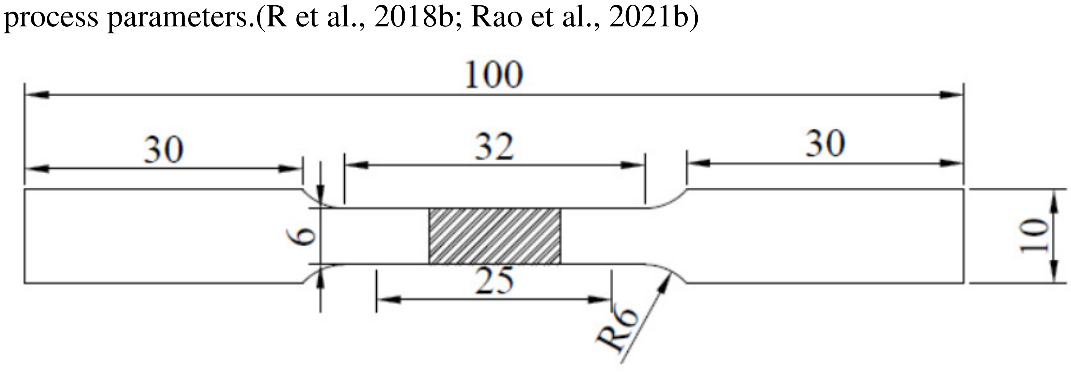


Figure 5 ASTM standardE8/E8M-09 for sub-size specimens

Figure 5.1 Universal Testing Machine

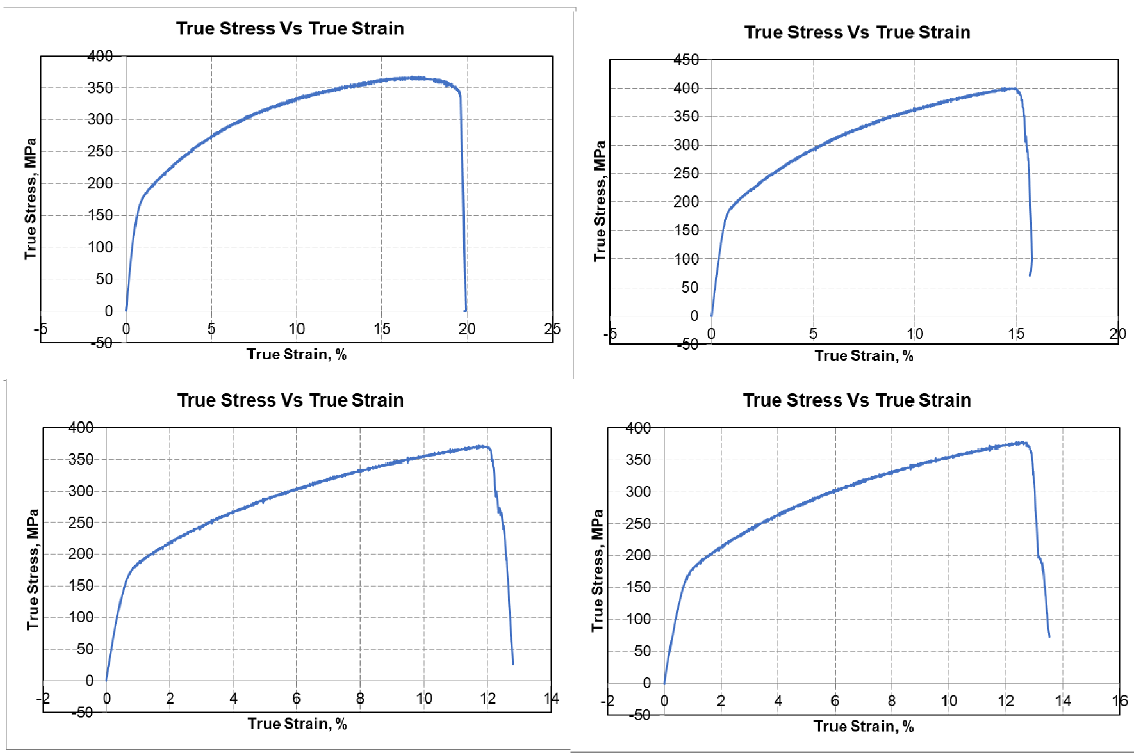


Figure 5.2 True stress strain curve for different experiments

TABLE 5.1 TENSILE STRENGTH TEST RESULT

Experiment no.	RPM	TRANSVERSE SPEED	TILT ANGLE	UTS MPa
1	700	40	1	365

2	700	70	2	407
3	700	100	3	401
4	1000	40	2	390
5	1000	70	3	368
6	1000	100	1	372
7	1300	40	3	364
8	1300	70	1	378
9	1300	100	2	427
BASE METAL	-	-	-	414

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