

“EXPERIMENTAL INVESTIGATION AND CHARACTERIZATION OF 6061 T6 ALUMINIUM ALLOYS METAL MATRIX COMPOSITES THROUGH FRICTION STIR PROCESSING”

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Abstract - The demand of aerospace industries has stimulated research focused on improving the properties of aluminium alloys through innovative processing methods. Friction Stir Processing (FSP) is an advanced solid-state method for the fabrication and improvement of the surface and bulk characteristics of Metal Matrix Composites (MMCs). Friction Stir Processing is utilized to manufacture and analyze 6061-T6. This research examines the microstructural development and mechanical improvement of Al6061-T6 aluminum alloy augmented with SiC nanoparticles through a Friction Stir Processing (FSP) method. OM demonstrated that the addition of SiC nanoparticles induced a notable Zener pinning effect, hindering grain boundary migration during dynamic recrystallization.

1.1 INTRODUCTION

The fabrication of metal matrix composites (MMC) has garnered significant attention owing to their unique mechanical characteristics, including lightweight, exceptional wear resistance, and elevated elastic modulus. FSP is an innovative method for the treatment of solid-state metals. FSP is a technique for generating surface composites and altering microstructural characteristics. FSP achieves localized and significant grain refinement and microstructural modification, resulting in enhanced mechanical properties of the treated area [1]. fabricated via the liquid metallurgical method, exceeded those of pure AA6061. Inadequate waste management adversely affects human health. Besides its visual deficiencies, waste exacerbates climate change by contaminating the atmosphere, damaging aquatic ecosystems upon disposal, and depleting the ozone layer during incineration. This research aims to develop a functional composite material with enhanced properties utilizing SiC. Silicon Carbide (SiC) as an agent of reinforcement in Aluminum Metal Matrix Composites (AMMCs) is one of the most effective materials engineering advancements, bridging metals' ductility and ceramics' strength. Al6061 and other 6XXX series aluminum

alloys are popular for their low density and corrosion resistance, but they lack hardness and wear resistance for heavy-duty industrial applications

1.2 Categorization of composite materials:

Composites are classified as fibers, whiskers, and particulates based on the reinforcement phases utilized. In certain studies, Intermetallic-Matrix Composites (IMCs) are classified separately from Metal Matrix Composites (MMCs).

1.3 Fabrication techniques for metal matrix composites:

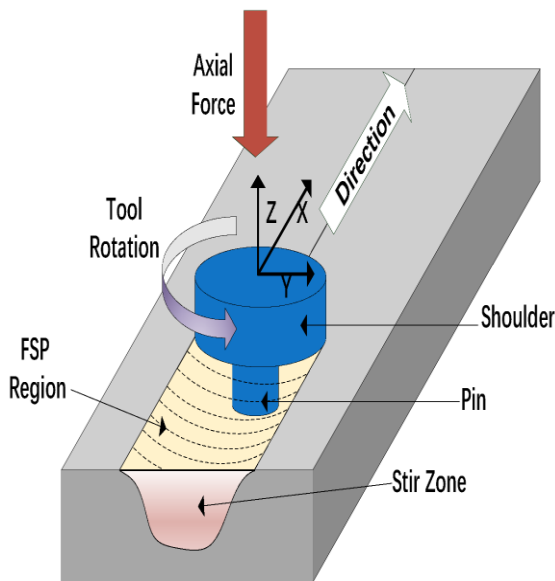
It can be fabricated using stir casting, powder metallurgy, or various chemical and thermal methods. However, in these procedures, composite creation occurs throughout the entirety of the volume. The friction stir process and laser cladding techniques can be employed to produce surface metal matrix composites of restricted thickness.

1.4 Principle of FSP

The core principle of FSP relies on plastic deformation at elevated temperatures. The rotating shoulder produces the majority of heat from frictional contact with the surface, whereas the pin facilitates the stirring and mixing of the softened material below the surface.

As the tool traverses forward:

- The material in front of the tool undergoes plastic deformation and is conveyed around the rotating pin.
- The pliable substance experiences significant shear deformation.



2. LITERATURE REVIEW

Metal matrix composites are good for surface-interacting components. Friction stir procedure is a potential method for making surface metal matrix composites. Some automotive, aerospace, naval, and other industries use surface metal matrix composites. Surface composites are employed in various fields because of their wear resistance, hardness, corrosion resistance, strength, and ductility. Friction stir procedure is superior for making surface composites with MMC to hide constituent properties [12].

According to multiple researchers, FSP has the potential to enhance mechanical and metallurgical properties through plastic deformation, grain refinement, dynamic recrystallization, and tool rotation. Tool rotational speed, traversal speed, and tilt angle are the main process parameters of FSP. Plunge depth, pin diameter, pin length, shoulder diameter, and other similar parameters have little bearing. By optimizing the combination of FSP parameters, homogeneous microstructure was achieved in processed magnesium AZ31B alloy, and this was after investigating the impact of critical process factors on the forming-limits, microstructure, and texture of the alloy. A significant material processing technology, FSP has a homogenous small microstructure and a strong basal texture [14].

3. Base Material for Composite

Based on the above discussion and literature review, the Al-6061-T6 alloy has been chosen as the basis matrix metal for the current study. Table 4.1 displays the chemical composition of the alloy and table 4.2 show mechanical properties. This is a hot-rolled, artificially aged, and solution-hardened aluminum alloy. This alloy has silicon and magnesium as the principal alloying elements in aluminum. The characteristics of the Al-6061-T6 alloy are enumerated as follows:

- (a) Moderate strength accompanied by ductility.
- b) Exceptional resistance to corrosion.
- c) Excellent formability in the plastic state.
- d) Excellent machinability.
- e) Moderate fatigue resistance.
- f) Excellent wettability with ceramic materials

Table 3.1 Chemical composition of base materials

Component	Al	Mg	Si	Fe	Cu	Zn	Ti	Mn	Cr
Amount (Wt %)	Balance	0.8-1.1	0.4-0.9	Max. 0.6	0.15-0.42	Max. 0.27	Max. 0.14	Max. 0.16	0.04-0.36

Table 3.2 Mechanical Properties of AA6061 T6

Properties	Ultimate Tensile Strength	Yield Strength	Elongation	Hardness	Density	Modulus of Elasticity	Thermal Conductivity
6061-T6	309 MPa	281 MPa	7-11%	96 Hv	2710 g/cm ³	67.8 GPa	168 W/m K

Universal Tensile Strength Test

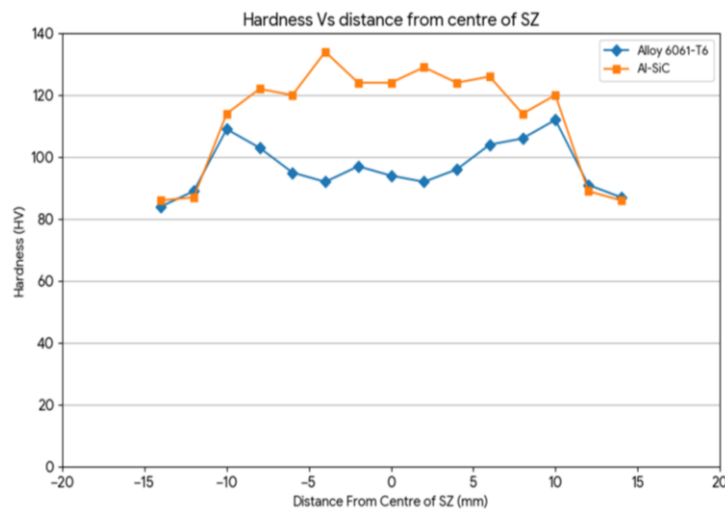
The ultimate stress a material can endure in a tensile test prior to plastic deformation is referred to as its tensile strength. Tensile testing entails exerting a consistent strain on both ends of the specimen. This inquiry used a Uniaxial Tensile Test (UTM) conducted by Tinius Olsen H50KS. The processed material was utilized to fabricate test specimens standardized per ASTM E8 requirements for tensile testing (Figure 3.5). This apparatus can measure elongation percentage, yield tensile strength, and ultimate tensile strength.

4.1 Visual Assessment

Figure 4.1 (a and b) illustrates the morphologies surface of the AA6061 T6 Al alloy FSPed Sample with and Without SiC nano particles. This is a comprehensive study of the microstructural results for Friction Stir Processed (FSP) Al 6061-T6 and Al 6061-T6 + SiC nanocomposite samples based on optical micrographs. Figure 4.1 (a) shows the base alloy after friction stir processing without reinforcements. Long, "pancake-shaped" grains are seen in the micrograph. This indicates a material that has undergone significant plastic deformation but may retain some directional alignment from rolling or the FSP tool route.

4.2 Microhardness Test:

To assess hardness, the Vickers micro-indentation machine was employed to create indentations in the transverse direction of the weld, maintaining a 1mm interval between each subsequent indentation. Each sample, encased in a phenolic resin mold, was individually secured in the vice. The indentation load was sustained at 500 kg-f with a dwell period of 10 seconds each indentation.



5.1 Conclusions

Friction stir processing was successfully used to create a SiC-reinforced Al-6061-based surface composite. Several tests, such as micro-hardness, tensile, optical microscopy, and SEM, were carried out on manufactured samples in compliance with the recommended procedures. The study's main conclusions are as follows.

1. Friction stir processing can be employed as an innovative method for grain refinement, resulting in enhanced mechanical, and metallurgical properties.

2. The incorporation of SiC nanoparticles led to a significant enhancement in mechanical performance. The Ultimate Tensile Strength (UTS) augmented by roughly 31%, escalating from 351 MPa in the base alloy to 460 MPa in the processed nanocomposite.
3. The integration of ceramic reinforcements resulted in a significant enhancement in Vickers hardness, rising from 89 HV to 132 HV. The 48% increase is ascribed to the presence of hard SiC particles and the consequent grain refinement.

6.1 References

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