



Experimental Investigation Into Mechanical And Microstructural Properties Of Aluminium 7075 Metal Matrix Composites Reinforced With Silicon Carbide And Nickel

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Abstract: This study focuses on the development and characterization of a novel aluminium-based metal matrix composite (MMC) by reinforcing Aluminium 7075 with varying weight percentages of Silicon Carbide (SiC) and a constant amount of Nickel powder. The primary objective is to enhance the mechanical properties, specifically tensile strength and hardness, to meet the demanding requirements of high-stress engineering applications in the automotive and aerospace sectors. Three composite variations were fabricated using the stir casting method with SiC concentrations of 4%, 8%, and 12%, while maintaining Nickel content at 0.5%. Mechanical characterization involved Brinell hardness testing and tensile testing using a Universal Testing Machine (UTM), complemented by microstructural analysis via optical microscopy. The results demonstrate that increasing the SiC content significantly improves both hardness and tensile strength. The 12% SiC composite exhibited the highest tensile strength of 151.249 N/mm² and a significant improvement in hardness compared to pure aluminium. Microstructural examination confirmed a uniform distribution of reinforcement particles within the Al 7075 matrix, validating the effectiveness of the stir casting process.

Index Terms— Aluminium 7075, Silicon Carbide, Stir Casting, Metal Matrix Composite, Hardness, Tensile Strength.

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1. Introduction

Aluminium alloys are widely utilized across various industrial sectors, most notably in aerospace and automotive engineering, due to their exceptional strength-to-weight ratio and versatility [1][3]. Among these, Aluminium 7075 (AA7075) stands out as an ultra-high-strength alloy, primarily alloyed with zinc (5.1–6.1%), magnesium (2.1–2.9%), and copper (1.2–2.0%) [8]. Its high strength (510 to 572 MPa) and low density (2.81 g/cc) make it ideal for structural components subjected to high stress [7][9]. However, the increasing demand for materials that offer even greater wear resistance and mechanical performance has led to the development of Metal Matrix Composites (MMCs).

Silicon Carbide (SiC) is a preferred reinforcement material for aluminium matrices due to its diamond-like hardness, high thermal conductivity, and superior resistance to wear and chemical corrosion [11]. The addition of SiC particles into the Al 7075 matrix aims to combine the ductility of the aluminium alloy with the high stiffness and strength of the ceramic reinforcement. Furthermore, Nickel is incorporated into the composite to provide additional strength and longevity, given its high melting point and resistance to oxidation. This paper investigates the influence of varying SiC content (4%, 8%, and 12%) on the mechanical and microstructural properties of Al 7075-SiC-Ni composites produced via the stir casting technique.

2. Literature Review

The development of Al-SiC composites has been a subject of extensive research due to their potential in replacing traditional monolithic alloys. Pawar and Utpat [1] explored the development of aluminium-based SiC composites for spur gear applications, emphasizing the improvement in mechanical properties. Similarly, Kumar et al. [2][6] reviewed the wear characteristics of aluminium SiC reinforced with basalt fibers, noting that the addition of ceramic particles significantly enhances wear resistance.

Nuruzzaman and Kamaruzaman [3][7] investigated the processing and mechanical properties of Al-SiC composites, highlighting the challenges in achieving uniform particle distribution. Neelima et al. [4][8] conducted mechanical characterization of Al-SiC composites, providing data on the correlation between reinforcement volume fraction and tensile strength. Rahman [5][9] further validated that Al-SiC composites offer enhanced physio-mechanical properties compared to unreinforced alloys. These studies collectively suggest that while the addition of SiC improves strength and hardness, the fabrication process, particularly the stir casting parameters, plays a crucial role in determining the final properties of the composite.

3. Gaps Identified

While previous research has extensively covered the general properties of Al-SiC composites, there is limited literature specifically addressing the synergistic effect of Nickel additions alongside Silicon Carbide in an Aluminium 7075 matrix. Most studies focus on binary Al-SiC systems or different aluminium series (such as 6xxx). Furthermore, there is a need for a detailed comparative analysis of mechanical performance across a specific range of SiC weight percentages (4% to 12%) using the cost-effective stir casting method to determine the optimal reinforcement level for high-stress automotive components like shafts and power-transmitting units.

4. Methodology

The fabrication of the Al 7075-SiC-Ni composite was carried out using the stir casting process, selected for its versatility and cost-effectiveness in producing large components.

4.1 Stir Casting Process

The base matrix, Aluminium 7075, was melted in a furnace at temperatures ranging from 700°C to 750°C. Once the metal reached a molten state, reinforcement particles—Silicon Carbide (varying at 4%, 8%, and 12% by weight) and Nickel powder (fixed at 0.5% by weight)—were introduced. A mechanical stirrer was employed to create a vortex, ensuring the uniform dispersion of the reinforcement particles throughout the molten matrix. The composite melt was then poured into prepared moulds and allowed to solidify.

4.2 Specimen Preparation and Testing

The cast specimens were sectioned and machined to meet ASTM standards for mechanical testing.

Hardness Testing: Conducted using a Brinell Hardness Machine. An indenter was applied with a controlled force, and the diameter of the resulting imprint was measured to calculate the hardness value.

Tensile Testing: Performed using a Universal Testing Machine (UTM). Parameters such as ultimate tensile strength (UTS), ultimate load, and elongation were recorded for each composition.

Microstructural Analysis: Specimens were ground, polished, and etched for examination under an optical microscope at magnifications of 100X and 200X to evaluate the grain structure and particle distribution.

5. Results and Discussion

5.1 Chemical Composition

Chemical analysis confirmed the composition of the developed composite, showing a primary aluminium content between 81.39% and 82.81%, with the presence of silicon, magnesium, zinc, and the added reinforcements.

5.2 Hardness Analysis

The hardness tests revealed a significant increase in material resistance with the addition of reinforcements. The average hardness of the Al 7075-SiC-Ni composite was measured at 78.2 HB, which is a marked improvement over the 68.4 HB recorded for pure aluminium. This increase is attributed to the presence of hard SiC particles which act as barriers to dislocation movement within the matrix.

5.3 Tensile Properties

The tensile strength of the composite demonstrated a clear upward trend with increasing SiC content. The experimental data for the three compositions is summarized in Table 1.

Table 1: Tensile Test Results for Al 7075-SiC-Ni Composites

The 12% SiC reinforcement yielded the highest tensile strength (151.249 N/mm²), indicating that the load-bearing capacity of the alloy improves as the ceramic reinforcement phase increases.

5.4 Microstructural Examination

Optical microscopy at 100X and 200X magnifications confirmed that the Silicon Carbide particles were evenly distributed throughout the Aluminium 7075 matrix. The absence of significant clustering or porosity suggests that the stir casting parameters (stirring speed and temperature) were effectively controlled. The uniform distribution is a key factor in the observed enhancement of mechanical properties.

6. Conclusion

The experimental investigation into Al 7075-SiC-Ni composites concludes the following:

Stir casting is an effective and viable method for producing Al 7075 composites with uniform reinforcement distribution.

The addition of Silicon Carbide and Nickel significantly enhances the hardness of the base alloy, increasing it from 68.4 HB to 78.2 HB.

Tensile strength increases proportionally with Silicon Carbide content, reaching a maximum of 151.249 N/mm² at 12% SiC.

The developed composite, particularly with 12% SiC, is highly suitable for high-stress applications in the automotive and aerospace industries, such as shafts and structural components, where improved strength and wear resistance are critical.

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