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Al6061 Alloy Based Metal Matrix Composite Materials

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Abstract*: The utilization of aluminum alloys has significantly increased in recent years, particularly in the automobile industry, due to their low weight, density, coefficient of thermal expansion, and high strength and wear resistance. Among the materials of interest in Tribology, aluminum metal matrix composites have garnered significant attention for both practical and fundamental reasons. These composites have found numerous applications in manufacturing various components of automotive engines. Compound workpieces are developed by combining the advantageous properties of different materials. Composite materials are widely used in both domestic and industrial production. The reduction of weight and wear in rapidly moving parts of automobile engines, such as crankshafts and connecting rods, is a primary objective. This review paper examines recent advancements in composite technology, performance behavior, and the analysis of metal matrix composites. The paper specifically focuses on composites made by combining aluminum with non-metal materials, highlighting their mechanical properties and fabrication techniques*..

Keywords: aluminium alloys, boron carbide, fabrication technique, MMC

I. INTRODUCTION

In recent years, specific strength, weight, and cost have become important parameters in material selection for many industrial applications. This review paper focuses on discussing the relevance of these parameters. Before delving into the review section, it is essential to understand the distinction between composites and metal matrix composites (MMCs). Composites are composed of different materials, while MMCs involve mixing non-metal materials with a base material. The review paper primarily focuses on MMCs, with aluminum alloy being the predominant base material, along with additives such as silicon carbide, graphite, boron carbide, silicon nitride, silicon carbide, and others. A review of Aluminium Al7075 metal Matrix composites with different reinforced particles with varying weight percentages and sizes are fabricated by different casting process. The prepared materials samples were examined to find out properties like physical strength, mechanical strength, morphological study and tribological properties results evaluated, studied and discussed here.

II. LITERATURE REVIEW

Rama Rao et al[1]. Examined that Aluminum alloy-boron carbide composites were fabricated using liquid metallurgy techniques, incorporating different weight fractions of the particulate (2.5%, 5%, and 7.5%). X-ray diffraction studies were conducted to identify the phases present in boron carbide, while microstructure analysis was performed using SEM. The composites were characterized using hardness and compression tests. The results indicated that an increase in the amount of boron carbide led to a decrease in the density of the composites, but an increase in hardness. Additionally, the compressive strength of the composites showed an increase with higher weight percentages of boron carbide.

B. Raviet al [2]. Found in their study that a homogeneous AA6061/B4C composite was successfully produced using the Stir Casting setup. The Scanning Electron

Microscopic (SEM) study confirmed the presence of B4C particles within the composite, with uniform and well-distributed grain boundary thickening throughout the matrix. The Rockwell hardness of the composites exhibited an increase from 50.4 HRB to 64 HRB as the weight percentage of B4C particles increased. However, the inclusion of B4C reinforcement resulted in a reduction in the impact strength of the Aluminum Matrix Composites (AMCs) from 0.22 J/mm2 to 0.11 J/mm2.

Sampath Boopathi et al [3]. In their studyan Aluminum alloy (Al6061) surface composite reinforced with B4C was fabricated using Friction Stir Processing (FSP) and subsequently characterized for its tensile strength and wear properties. The research findings indicated that the volume percentage of B4C and the rotating speed were critical factors affecting the tensile strength and wear resistance of the composite.

Nagender Kumar Chandlaetal [4].In their study observed, from physical characterization that the theoretical and experimental density of Al-6061 alloy increased with an increase in SiC, Al2O3, and Fe2O3, while it decreased with BA, B4C, and CSA. Among the various features studied, porosity percentage demonstrated a direct relationship with the weight percentage of reinforcements. However, the inclusion of lightweight reinforcements such as B4C, Gr, FA, BA, and CSA was considered the most beneficial in reducing the density of Al-6061 composites while minimizing porosity percentage.

Tessera Alemneh Wubienehet al[5]. In their experimental study aimed at preparing an Al-6061 metal matrix composite reinforced with glass powder using the stir-casting technique. The effect of the glass particles on the bonding properties of Al-6061 was investigated because of its impact on the mechanical properties of the composites. The micro-structural analysis using optical-microscope showed good bonding of the reinforcement with the matrix material. It was evident that waste glass powder is a low-cost material that can be used as reinforcement in metal matrix of aluminum with improved mechanical properties. It was conclude that aluminum alloy with reinforcement of powder glass improves properties of the base alloy especially mechanical properties with their excellent quality of hardness and tensile strength of the composite.

SunaAvcıo˘glu et al [6]. investigated that the presented sol-gel approach offers an improved method for synthesizing boron carbide powders with different morphological features, eliminating the need for catalytic elements. By optimizing the thermal decomposition duration of the polyol-based polymeric gel, high-purity polyhedral-equiaxed boron carbide particles were successfully obtained through heat treatment. The synthesized powders showed no residual carbon-based phases, as confirmed by XRD patterns. The study revealed that extending the thermal decomposition duration from 2 hours to 4 hours resulted in a morphological transition from polyhedral-equiaxed particles to nano/micro fibers. The electrochemical performance analysis indicated that particle morphology significantly influenced the performance of boron carbide electrodes. The symmetric device composed of electrodes with polyhedral-equiaxed morphology exhibited excellent cycling performance and rapid ion transport, demonstrating approximately ten times higher specific capacitance compared to the device with fiber electrodes. Furthermore, an asymmetric configuration further improved the power density and cycling stability of the device, indicating a synergistic effect between the two morphologies.

Gurpreet Singh et al [7]. Found out in their study that aluminium possesses numerous distinct and attractive characteristics when combined with different elements. It is important to understand the differences between the various available alloys and their specific performance and weldability characteristics. The aspect ratio plays a significant role in determining the choice of material for a given application. Furthermore, aluminium can be designed to create special shapes due to its superior extrudability. It can be demonstrated that aluminium alloys are capable of meeting the requirements of any job.

K Kaviyarasanet al[8]. In their experimental study an Aluminium metal matrix composite was fabricated using Al6061 as the matrix and Al2O3 as the reinforcement through the stir casting technique. The ceramic content was varied in three different compositions: 0%, 3%, and 6% by weight. After the preparation of the specimens, the composite underwent several tests. Firstly, it was observed that the micro-hardness of the composite increased with an increase in the alumina content in the matrix. Additionally, the compressive strength of the composite also exhibited an increase with higher Al2O3 content. Furthermore, the corrosion properties of the composite showed a steady improvement. However, it was noted that the impact strength of the composite decreased with an increase in the weight of alumina.

Şener Karabulutetal[9]. In their study found that the B4C particles were uniformly distributed within the matrix, and as the weight fraction of the reinforcement increased, the fracture toughness decreased while the hardness increased. Among the specimens measured, the composite material with 10 wt.% B4C exhibited the best fracture toughness, while Al6061/5 wt.% B4C showed the highest tensile and transverse rupture strength. For milling tests, the study utilized the Taguchi mixed-orthogonal-array L16 (44×21) to examine the influence of B4C content on surface quality and energy consumption under different cutting parameters, such as dry- and compressed-air cooling, using an uncoated carbide insert. It was observed that at higher milling speeds and lower cutting feed rates, excellent surface quality was achieved across all composite materials. Furthermore, the surface finish improved with an increase in B4C content within the matrix. However, when cooling with compressed air, power consumption and surface roughness increased.

N. Poornachandiran et al [10]. In their investigation of the aluminium metal matrix composites (AMMCs), the Al6061 aluminium alloy was taken as a base metal and reinforcement of Silicon carbide (SiC), Boron carbide (B4C) were used to improve the mechanical properties of the material. The material composite was prepared by various compositions in the stir casting process and their mechanical properties were investigated. The density analyses were made in which it was found that the lightweight material achieved a better wear resistance. The aluminium metal matrix composites (AMMCs) of Al6061 with 4% of SiC and 4% of B4C is comparatively given better results in high flexural strength and a better bending properties material than the other composition of the materials with high impact load carries the material.

Poorna Chandra et al [11]. Their research findings suggested several important conclusions. Firstly, there is a direct relationship between the hardness of the composite and the percentage of red mud, with an increase in red mud leading to an increase in hardness. Secondly, as the red mud content increases, the density of the composite material decreases. Thirdly, the Stir casting method proves effective in achieving a uniform distribution of the reinforcement, as observed through SEM images. Fourthly, an increase in cutting speed results in a decrease in the cutting force acting on the cutting tool. However, a higher feed rate per revolution leads to an increase in the cutting force. Furthermore, during machining, when the percentage of reinforcement in the composites reaches 6%, there is a higher cutting force acting on the cutting tool. The lowest cutting force is observed at a feed rate of 0.08 mm/revolution. Finally, built-up edge formation is observed during the machining of aluminum alloy and its composites, although the intensity of built-up edge formation is comparatively lower when machining composite materials.

Sener Karabulut et al[12]. Investigated and found out in their study that the B4C-reinforced laminated FGM demonstrated the highest ballistic protection, achieving a penetration depth of 14 mm at an impact speed of 664.25 m/s. In comparison, the impact speeds for SiC- and Al2O3-reinforced FGMs were 500.88 m/s and 435.23 m/s, respectively. These findings highlight the favorable mechanical properties and ballistic resistance of B4C-reinforced FGMs, suggesting their potential use in applications requiring enhanced strength and protection.

MadevaNagaral et al [13]. Investigated and found out in their study that the inclusion of SiC particles in the Al6061 matrix led to an increase in both theoretical and experimental densities of the resulting composites, Al6061-6, 9, and 12 weight percentages of SiC. Furthermore, the micro hardness, ultimate tensile strength (UTS), and yield strength (YS) of the SiC reinforced composites demonstrated an improvement, albeit with a slight decrease in ductility. SEM analysis of the tensile fractured surfaces revealed different fracture mechanisms between the base alloy (Al6061) and the produced composites. These findings demonstrate the successful synthesis of Al6061-SiC composites using the stir-cast technique and highlight the improved mechanical properties of the SiC reinforced composites, which can have potential applications in industries requiring enhanced strength and performance.

A. Chinnamahammad Bhasha et al [14]. In their investigation they successfully employed the stir casting process to prepare aluminum matrix composites with different weight percentages of TiC and RHA. The addition of TiC and RHA reinforcements significantly improved the mechanical properties of the PHAMCs compared to the base sample under tempered conditions. The experimental study yielded several important findings. Firstly, the addition of reinforcements led to a decrease in the percentage of elongation and impact strength, resulting in reductions of up to 28.52% and 29.91%, respectively. Secondly, PHAMCs developed with 7% weight fractions demonstrated a decrease in density by 3.88% compared to unreinforced aluminum 6061. Thirdly, the incorporation of 7 wt% reinforcement led to significant improvements in the ultimate tensile strength, yield strength, and Micro Vickers hardness of the PHAMCs, with increases of 31%, 17.1%, and 18%, respectively. However, when the reinforcement content exceeded 7 wt%, there was a decline in the mechanical properties such as tensile strength, impact energy, hardness, and density of the PHAMCs. Lastly, microstructural analysis revealed the presence of agglomerations and increased porosity with the addition of RHA. The fractured surface exhibited a mixed mode of failure, including reinforcement fracture, dimples, and micro-cracks. These observations contribute to a deeper understanding of the behavior and characteristics of the PHAMCs, informing future research and potential applications in industries requiring enhanced mechanical properties.

P. K. Jayashree et al [15]. In their investigation stir casting was employed to prepare Al6061 specimens with 6 wt.% silicon carbide (SiC) particles for tensile and impact tests. These specimens were later subjected to TIG welding at different current levels (150 A, 170 A, and 200 A) using an AC source. The test results indicated that as the TIG welding current increased, the Al-SiC MMC exhibited a decrease in peak load and percentage elongation. The impact strength of the specimens was investigated, with the specimen welded at 150 A displaying significantly higher impact strength compared to those welded at 170 A and 200 A. The 150 A specimen showed a 40% increase in impact strength compared to non-welded impact specimens. Ductile striations and finer dimple formations were more prevalent in this specimen. In contrast, the impact specimens welded at 170 A and 200 A exhibited lower impact strength, with a decrease of 22.2%. SEM images unveiled shallow dimples, continuous river patterns, and shearing planes, indicating a mixed mode of quasi-cleavage fracture

III. CONCLUSION

From literature review of composites of Aluminium alloy Al6061 reinforced with various materials such as boron carbide, silicon carbide, alumina, glass powder, and red mud. The studies indicate that the addition of these reinforcements generally leads to improvements in hardness, tensile strength, and wear resistance of the composites. The choice of reinforcement, its weight percentage, and the fabrication technique all play crucial roles in determining the final properties of the composites

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