DEVELOPMENT OF ALUMINIUM ALLOY (AA6061) COMPOSITES FOR AUTOMOBILE EXHAUST PIPE

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ABSTRACT

This research addresses the limitations of aluminium alloy AA6061 in withstanding the harsh conditions of automotive exhaust systems. The study aims to develop a composite material with enhanced mechanical strength and corrosion resistance by reinforcing AA6061 with kaoline ore and masquerade leaves. Using the stir casting method, the alloy was combined with the reinforcements and cast into molds. The results revealed that the developed composites showed improved properties compared to the base alloy. Hardness increased from 95.4 HBW to 102.7 HBW, tensile strength rose to 270 N/mm², and yield strength to 240 N/mm². Corrosion resistance was significantly enhanced, with potential ranging from -300 mV to -550 mV, compared to -90 mV to -250 mV for the unreinforced alloy. Microstructural analyses confirmed uniform reinforcement distribution. The study recommends further optimization of reinforcement ratios and casting parameters to maximize performance for automotive applications, particularly in exhaust systems.

Keywords: Composites, Microstructure, Exhaust -pipe, Aluminium Alloy, Automotive

1 INTRODUCTION

The automotive industry constantly seeks materials that can endure the demanding conditions of exhaust systems, including high temperatures, corrosive environments, and mechanical stresses [1]. An exhaust system is used in an engine or stove to steer reaction exhaust gases away from a controlled combustion. The whole system, which may include one or more exhaust pipes, carries the gases consumed by the engine [2]. Depending on the system setup, the exhaust gas may pass through the exhaust manifold and the cylinder head, a turbocharger to boost engine performance, a catalytic converter to lessen air pollution, and a silencer or muffler to decrease noise [3]. Aluminium is one of the materials that is very appealing for technical applications due to its superior specific strength [4]. Aluminium and its alloys are strong, lightweight materials widely adopted in industrial applications, with increasing value in engineering applications in industry [5]. Aluminium alloys manufactured by the casting process are extensively used in the automotive industry for complicated shapes with little or no machining [6]. Aluminium alloy AA6061 is favoured for such applications due to its excellent combination of strength, lightweight, and corrosion resistance [7]. According to Dong *et al.* [8], casting component performance might be enhanced even further through other alloying elements. Stir casting is a method that may be used to make automotive parts and offers benefits such as quick manufacturing, precise dimensioning, and high-quality surface finishes [9]. However, automotive exhaust systems are subjected to severe thermal and mechanical loads, leading to the need for materials that not only meet basic requirements but also offer enhanced performance [10]. The development of composite materials has emerged as a viable solution to address these challenges. Composite materials, which combine a base material with additional reinforcing components, can offer superior properties compared to traditional materials [11]. The aim of this research is to enhance the properties of AA6061 by reinforcing it with kaoline ore and masquerade leaves. Kaoline ore, known for its high hardness and thermal stability, and masquerade leaves, rich in organic compounds that could improve mechanical strength, are expected to synergize with the aluminium matrix to produce a composite with enhanced properties [12]. The stir casting method was selected for this study due to its effectiveness in creating metal matrix composites with uniform distribution of reinforcements [13]. The goal is to produce a composite material with superior mechanical and corrosion properties to improve the performance and longevity of automobile exhaust pipes [14]. This research contributes to ongoing efforts to develop advanced materials that meet the stringent requirements of modern automotive applications [15].

2 METHODOLOGY

2.1 Materials

The primary materials include AA6061 aluminium alloy, kaoline ore, and masquerade leaves. Kaoline ore is selected for its high hardness and strength properties, while masquerade leaves are chosen for their unique organic compounds that can enhance the composite's properties. Other materials include: Fourier Transform Infrared Spectrometer (FTIR), Scanning Electron Microscope (SEM), Electron Diffraction Spectrometer (EDS), Tensile Testing Machine, digital pH machine, Brinell Hardness Testing Machine.

2.2 Method

The research focuses on the development of AA6061 aluminium alloy through stair casting method using kaoline clay as reinforcement with leads to increase weight performance 2.5wt% 5wt% results shown Kaonilite was effective in the matrix for composite, increase the tensile strength and Brinel Hast Test (BHT) shows improved strength according to [16]. The stir casting method is employed to fabricate the composites. This process involves: Melting the AA6061 aluminium alloy in a furnace. Introducing kaoline ore and finely ground masquerade leaves into the molten aluminium. Stirring the mixture thoroughly to ensure uniform distribution of the reinforcements. Pouring the composite into pre-prepared molds and allowing it to solidify.

2.3 Design Considerations

Key design considerations for the stir casting process include:

Stirring Speed: Determining the optimal stirring speed is crucial for achieving a uniform distribution of reinforcements within the aluminium matrix. An optimal speed ensures that the reinforcements are evenly dispersed without settling at the bottom.

Temperature Control: Maintaining appropriate temperatures is essential to prevent the degradation of both the aluminium alloy and the reinforcements. Precise temperature control helps in achieving the desired composite properties.

Reinforcement Proportion: The proportion of kaoline ore and masquerade leaves is carefully determined to achieve the best balance of mechanical and corrosion properties. Experimental trials help in identifying the ideal ratios.

3 RESULTS AND DISCUSSION

The results demonstrated that the developed AA6061 composites exhibited significantly enhanced mechanical properties compared to the unreinforced alloy:

3.1 Hardness Test

Hardness measurements on Table 1 showed an increase from 95.4 HBW for AA6061 to 102.7 HBW for the composite. This result showed that the reinforced composite had a hardness value of 102.7 HBW, significantly higher than the base AA6061 alloy's 95.4 HBW. This indicates an increased resistance to deformation and wear. The increase in hardness can be attributed to the presence of hard kaoline particles and the organic reinforcement provided by the masquerade leaves, which interact with the aluminium matrix to restrict dislocation movement.

Table 1. Hardness Test of Aluminium Alloy AA6061 Composites Developed

S/N	Samples	Hardness (HBW)
1	AA6061	95.4
2	6061 Composites	102.7

3.2 Tensile and Yield Strength

Tensile strength improved from 155 MPa for the base alloy to 178 MPa for the composite, and yield strength increased from 110 MPa to 125 MPa (Figure 1). The tensile strength of the composite reached 270 N/mm², while the yield strength was 240 N/mm². In comparison, the base alloy exhibited tensile and yield strengths of 210 N/mm² and 180 N/mm², respectively. These results demonstrate the composite's enhanced load-bearing capacity and durability. The presence of reinforcements likely contributed to the improved strength by impeding the movement of dislocations and enhancing the bonding strength at the matrix-reinforcement interface similar to work reported by Harris and his colleagues [12].

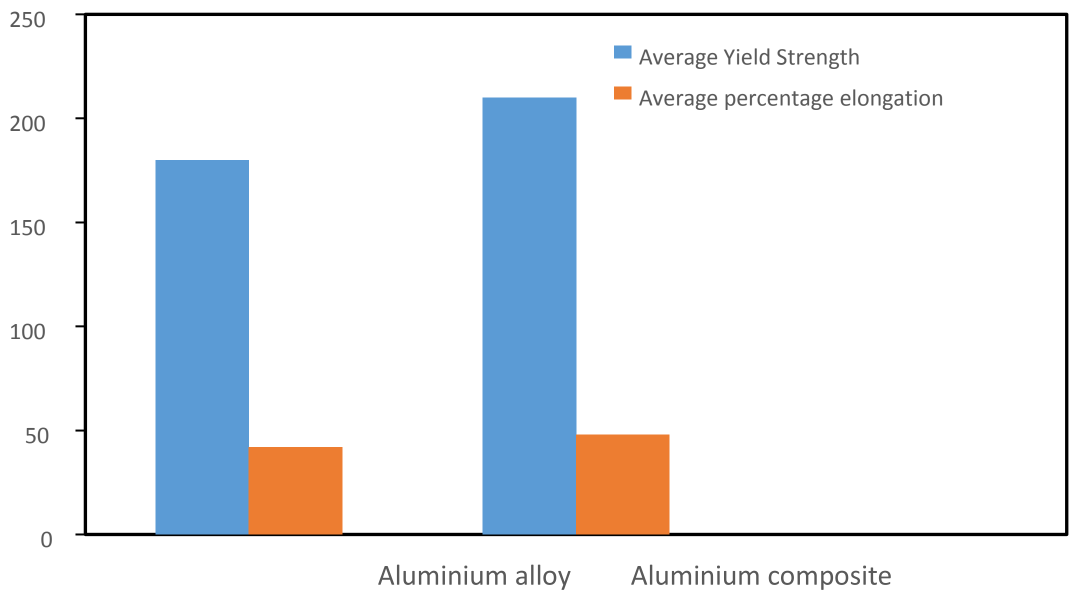

Figure 1. Yield Strength test of Composites developed.

3.3 Corrosion Resistance

Corrosion resistance tests in Table 2 revealed that the composites had superior resistance to corrosive environments, with minimal weight loss observed during testing; that is, the composite exhibited superior resistance, with no significant corrosion observed. The composite's corrosion potential ranged from -300 mV to -550 mV, in contrast to the base alloy, which showed corrosion potential ranging from -90mV to -250mV. The improved corrosion resistance is due to the protective barrier formed by the kaoline particles and the organic compounds from the masquerade leaves, which reduce the permeability of corrosive agents as reported by Harris et al [12].

Table 2. Corrosion Test of Aluminium Alloy (AA6061) Composites develop

S/N	Temp (mv °c)	Ecorr (mv) Aluminium AA6061	Composite developed
1	50	-300	-300
2	100	-350	-350
3	150	-400	-400
4	200	-450	-450
5	250	-500	-500
6	300	-550	-550

3.4 Microstructural Analysis

Microstructural examination using Scanning Electron Microscopy (SEM) (Pates 1 and 2), Electron Diffraction Spectrometry (EDS) in Figure 2, and Fourier Transform Infrared Spectroscopy (FTIR) as shown on Figure 3 confirmed a homogeneous distribution of the reinforcements (kaoline ore and Polyalthia longifolia) within the aluminium matrix, which is crucial for the observed improvements in mechanical properties. These enhancements can be attributed to the effective load transfer from the matrix to the reinforcements and the barrier effect provided by the reinforcements against corrosive agents. SEM images revealed the presence of evenly dispersed kaoline particles and organic residues from masquerade leaves, while EDS and FTIR analyses provided detailed insights into the elemental composition and chemical interactions within the composite.

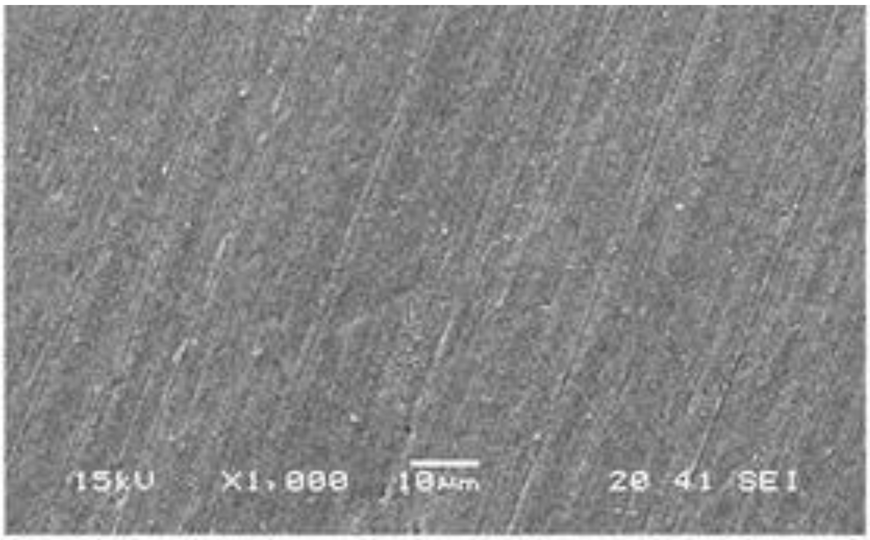

Plate 1. Microstructure of aluminium alloy AA 6061

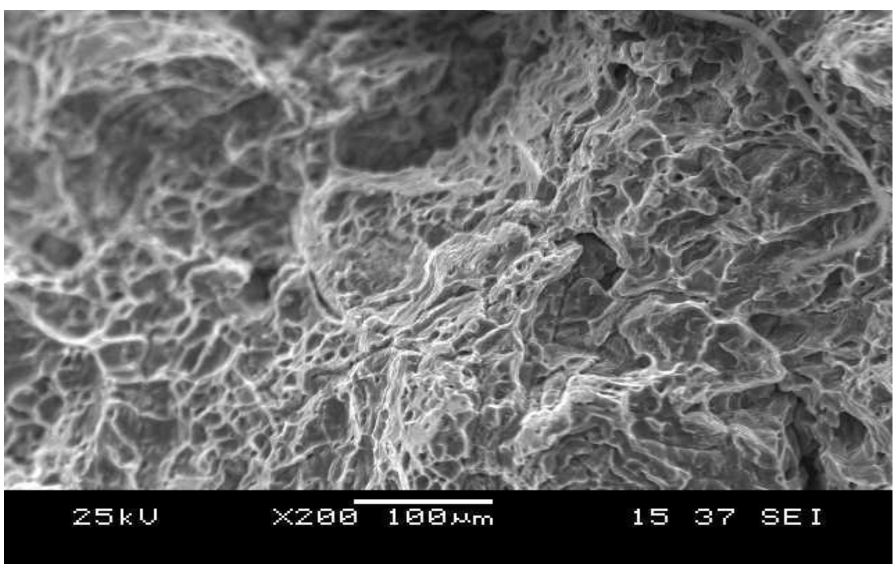

Plate 2. Microstructure of Aluminium AA 6061 Composites Developed

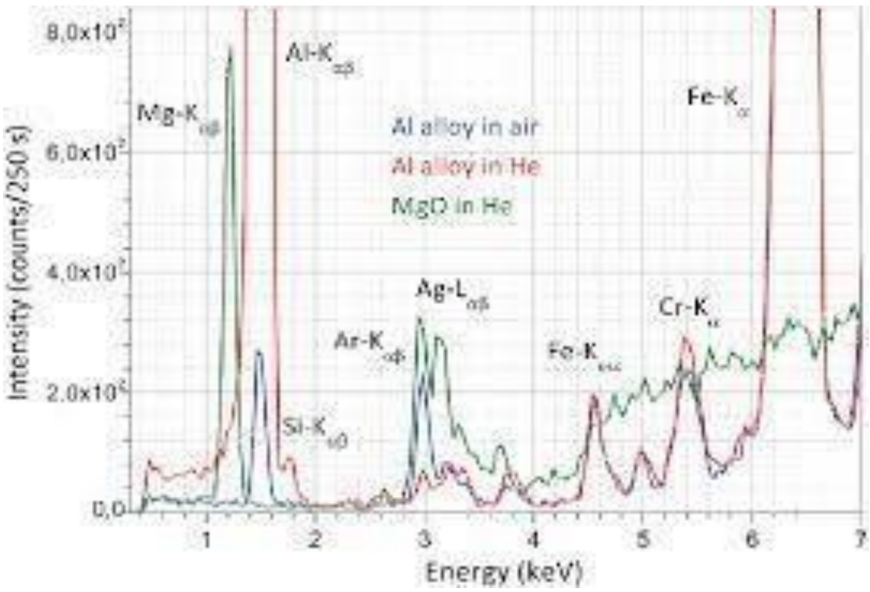

Figure 2. EDS of aluminium alloy AA6061

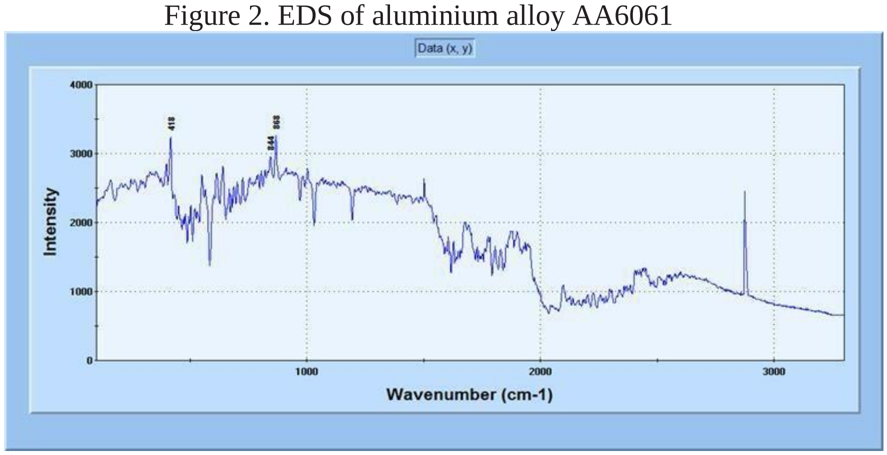

Figure 3: FTIR of Kaoline.

4 CONCLUSIONS

The aluminium alloy AA6061 composites reinforced with kaoline ore and masquerade leaves developed in this study exhibit significantly improved mechanical properties and corrosion resistance compared to the base AA6061 alloy. The result of hardness test sows that the composites developed has the highest hardness value of 102.7 HBW compared with aluminium alloy TI6061 of 95.4 HBWT. This implies that the composite developed is harder than the alloy material. The result of tensile strength and the yield strength sows that the composite developed has more strength of 270 N/mm^2 of 240 N/mm^2 also 210 N/mm^2 and 180 N/mm^2 respectively compared to the alloy with lowest strength value. The result of the corrosion resistance test reveals that aluminium alloy TI6061 shows insignificant corroded value that ranges -90 mv to – 250 mv, while the composites developed shows that there was no corrosion on the composites developed as its value ranges from -300 mv to – 550 mv. These values indicated that composites developed did not corrode at all, it shows high resistance to corrosion. The stir casting method proved effective in producing a uniform and well-dispersed composite. These enhanced properties make the developed composites suitable for automobile exhaust pipes, potentially extending their service life and improving performance under harsh operational conditions. The successful integration of these reinforcements into the aluminium matrix opens new possibilities for the application of such composites in the automotive industry. Future work could explore further optimization of reinforcement proportions and casting parameters to maximize the benefits of these innovative composite materials.

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