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Fabrication and Characterization of Aluminium Matrix Composite Reinforced with Limestone Powder

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ABSTRACT: The aim of work is deals with the fabrication, characterization and mechanical investigation in the effect of change in mechanical properties of aluminium metal matrix composites when limestone powder (LS) is added to it. Stir casting is the method is used to fabricate aluminium metal matrix composites reinforced with limestone powder in different weight fractions of 2.5, 5, 7.5, 10 and 12.5%. The dry sliding wear behavior of composites is studied by using Pin-On-Disc wear and friction testing machine. Mechanical properties of such as the hardness are studied and compared the obtained results with the results of unreinforced aluminium alloy. The composite with 10%LS exhibited better mechanical and tribological properties as compared to other

KEYWORDS: Metal matrix composites; Limestone powder; Mechanical properties; Wear properties

I. INTRODUCTION

In the past 40 years, the researchers and design experts have perceived their research to emphasis on finding lightweight, environmental friendly, low-cost, high quality, and good performance materials. In accordance with this trend, MMCs have been attracting growing interest among researchers and industrialists. Metal Matrix Composites (MMCs) are finding increased applications in the fields of automobile, aerospace, defence, marine, sports, and recreation industries due to their improved properties such as high specific modulus, specific strength, good wear resistance and damping capability. MMCs consists of a metal matrix(Al, Mg, Ti, Cu etc.) and a ceramic phase (carbides, oxides) or metal phase (Mo, Pb, W etc). The attributes of MMCs include alterations in mechanical behaviour (e.g., tensile and compressive properties, hardness, wear resistance, and Tribology) a change, primarily induced by the reinforced filler phase[1]–[3].

In addition, the cost of ceramic reinforcement materials is high and this is a major problem especially for developing countries. However, by the replacing of secondary reinforcements with Limestone powder reduces the cost, because they are readily available and these have lower density of the composites. In the recent days, the use of rock waste such as Limestone power (LSP) as a reinforcement, in the manufacturing of composites is gaining more importance. The advantages of using rock wastes are less cost and often lower densities when compared to the ceramic reinforcements. So far lot of research has been done on the limitations and potentials of the use of industrial wastes as reinforcements. The results of LSP reinforced composites revealed that there is some improvement in mechanical properties and tribological properties. While composites have already proven their worth as weight-saving Materials, the current challenge is to make them cost effective. The efforts to produce economically attractive composite components have resulted in several innovative Manufacturing techniques currently being used in the composites industry[4], [5].

The literature survey is carried out as a part of the thesis work to have an overview of the production processes, properties and wear behaviour of metal matrix composites. Composite structures have shown universally a savings of at least 20% over metal counterparts and a lower operational and maintenance cost. As the data on the service life of composite structures is becoming available, it can be safely said that they are durable, maintain dimensional integrity, resist fatigue loading, and are easily maintainable and repairable. Composites will continue to find new applications, but the large-scale growth in the marketplace for these materials will require less costly processing methods and the prospect of recycling will have to be solved. It has been reported that the energy consumed when aluminium is recycled is only about 5% of that required in the primary production of aluminium.

Kumar [5] used the marble dust powder as a possible reinforcement in the AlCuNi alloy. The marble dust was varied in the proportion of 3, 4, 9, and 12 % in the matrix material. It was reported by authors that, lower amounts of marble dust particles improved the tensile strength and hardness of the aluminium composite. With higher percentages (12%), the marble dust particles tend to agglomerate which in result decreased the mechanical properties. Ramesh et al. [6] used the quarry dust particles to fabricate an AMC with the help of a stir casting method. Quarry dust in weight percentages of 5, 7.5, and 10 was used and the prepared composite was investigated to determine the effects of quarry dust particles on the mechanical properties. The properties such as strength, hardness, and wear resistance increased with the addition of quarry dust particles was reported by the authors. Rajak et al. [7] proposed a copper-marble dust composite as a bearing material. Different Copper composites with marble dust (1.5, 3, 4.5 and 6 wt.%) particles were prepared using the stir casting in a vacuum. It was reported by authors that, marble dust enhanced the mechanical properties of the copper composite. The marble dust particles reduced the porosity in the composite and improved the bond strength between the matrix materials.

Alaneme et al. [8] manufactured Al-Mg-Si alloy from two-step stir casting method with groundnut shell ash and SiC to examine microstructural and mechanical properties, the author showed that ultimate tensile strength (UTS) and fracture toughness of the composite increased but hardness and strength decreased. Carlos [9] studied the hot deformation and wear resistance of powder metallurgy aluminium metal matrix composites. It was found that the addition of Al₂O₃ and Al₄C₃ increases the hardness and compressive strength. The addition of Al₄C₃ improved the wear resistance of the MMC. Lokanadham and subbaiah[4] prepared Al-Si-Mg/ lime stone dust composites with varying weight % of 4. They studied on mechanical, tribological and micro structural properties of composites. They revealed that with increasing wt. % of LSP increased properties of composites up to 12% then declines.

In this study, the Al-LS power composites are prepared with stir casting route by variation of weight % of LS (i.e. 2.5%). The Al-LS composite are prepared Al-base (A), Al-2.5%LS (B), Al-5%LS (C), Al-7.5%LS (D), Al-10%LS (E), and Al-12.5%LS (F). The evolution of mechanical, physical and tribological examination has been carried in this study.

II. FABRICATION AND METHODOLOGY

The Al-LS power composites are prepared with stir casting route. The matrix Al-Si cut into small pieces and pre-heated in a muffle furnace. After the pre-heating, base matrix shifted to melting furnace at raised to a temperature of 650 °C. Based on the calculation, the LS powder added to molten metal and stirred. The process is the same for making all the composites. The preparation and fabrication of composites are explained elsewhere[10], [11]. The harness of Al-LS composite tested using “B” Scale with load 100 kgf or 980.7 N and 1.588 mm diameter ball indenter is used Dry sliding wear tests for different number of specimens was conducted by using a pin-on- disc machine (Model: Wear & Friction Monitor TR-20) supplied by Magnum. The pin samples were 30 mm in length and 8mm in diameter. All the materials are tested at a constant load of 30N; speed of 1.5m/s and at a sliding distance of 1500m. The wear rate has calculated from the height loss technique and expressed in terms of wear volume loss per unit sliding distance. Coefficient of friction calculated by considering the friction forces.

III. EXPERIMENTAL RESULTS

Figure 1 shows the increase of hardness value of all composites compared with the pure aluminium material. However, composite E (10%LSP) exhibited better hardness and tensile strength as compared to other materials. The hardness of composite has been increased by 6.83%, 5.64%, 8.57%, and 4.43% for 5%, 7.5%, 10%, and 12.5% of LSP respectively as compared to base metal (Al-Si). The hardness of composite increased due to the following reasons (i) the hard phase ceramic compounds in LSP particulates (ii) homogeneous distribution of LSP into the composite (iii) Presence of alkali earth metal such as CaO and MgO in LSP. The tensile strength increased with increase in weight fraction of LSP particle up to 7.5% then decreases, as shown in Figure 1. The density of composite decreased by 1.45%, 3.56%, 5.57%, and 6.87% for 5%, 7.5%, 10% and 12.5% of LSP respectively as compared to Al-Si, shown in Figure 2. However, decrease in elongation noticed in Figure 2 that with increase in addition of LSP particles. The tensile strength increases with intend to increase in weight fraction of LSP particle, even as the elongation decrease with an increase in the addition of LSP particles.

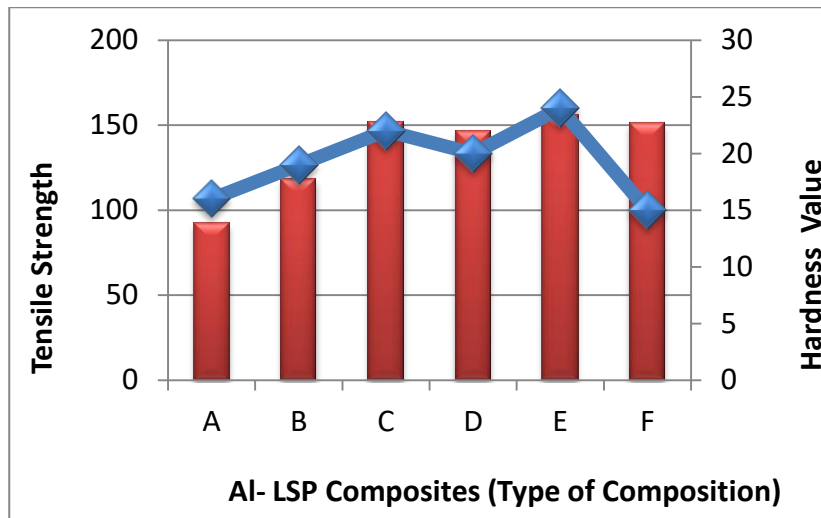


Fig. 1. Mechanical Properties of Al-LSP composites (a) BHN (b) TS

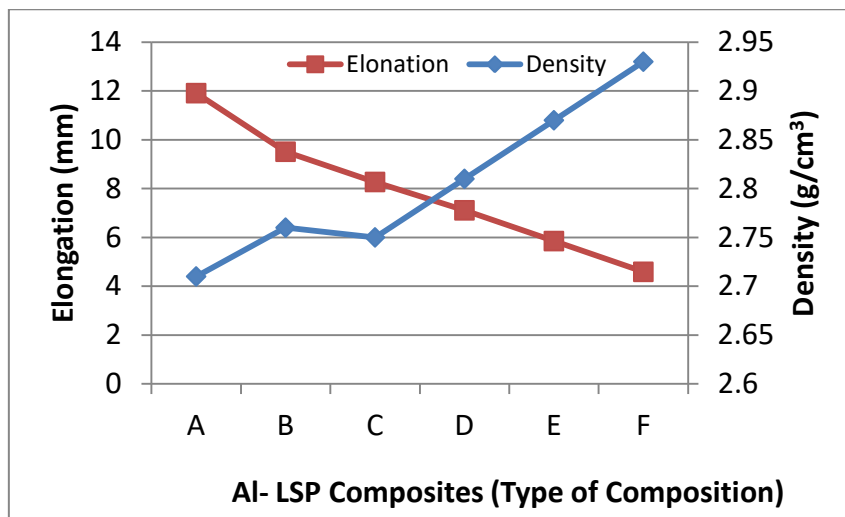
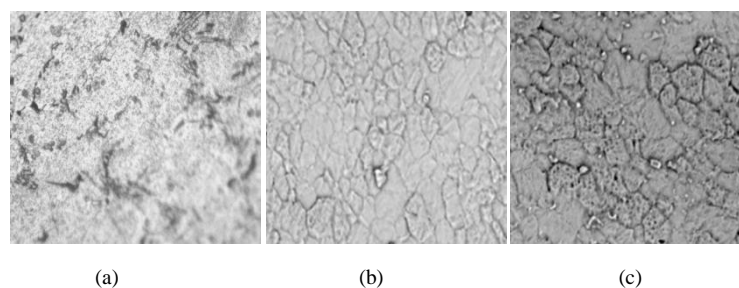


Fig. 2. Physical Properties of Al-LSP composite (a) Elongation (b) density

Figure 3 (a-f) shows the optical micrographs of the composites. They revealed a clear interface for intimate bonding. They did not show any interfacial reaction products. Reinforcing particles well distributed in the aluminium matrix. In addition, while increasing of % of LS observed grain size decreasing. This occurs due to the homogeneous distribution of particles in all combination of the composites. It emerged that the composite surface layer has well attached to the alloy substrate without any defect formation and that the particles well dispersed in the surface layer of the composite mixing area.



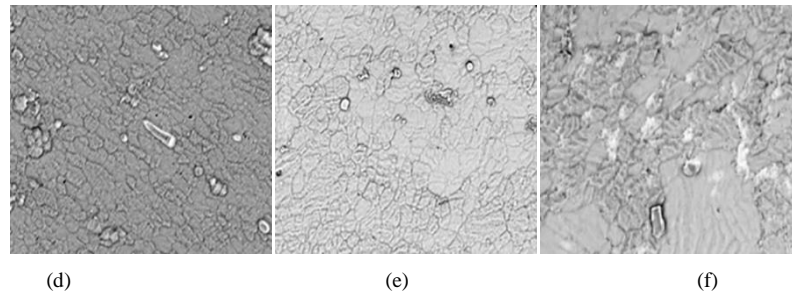


Fig. 3. Microstructures of Al-LSP composites (a) Al-Si base (b) Al-2.5%LS (c) Al-5%LS (d) Al-7.5%LS (e), Al-10%LS and (f) Al-12.5%LS.

All the materials shown in Figure 34 tested at a constant load of 30N; speed of 1.5m/s and at a sliding distance of 1500m. Figure 4 revealed that wear of composite increased with increasing % of LSP. It can be observed composite (E) exhibited least and material (A) exhibited highest wear. Similarly, frictional forces exhibited highest for composite (D).

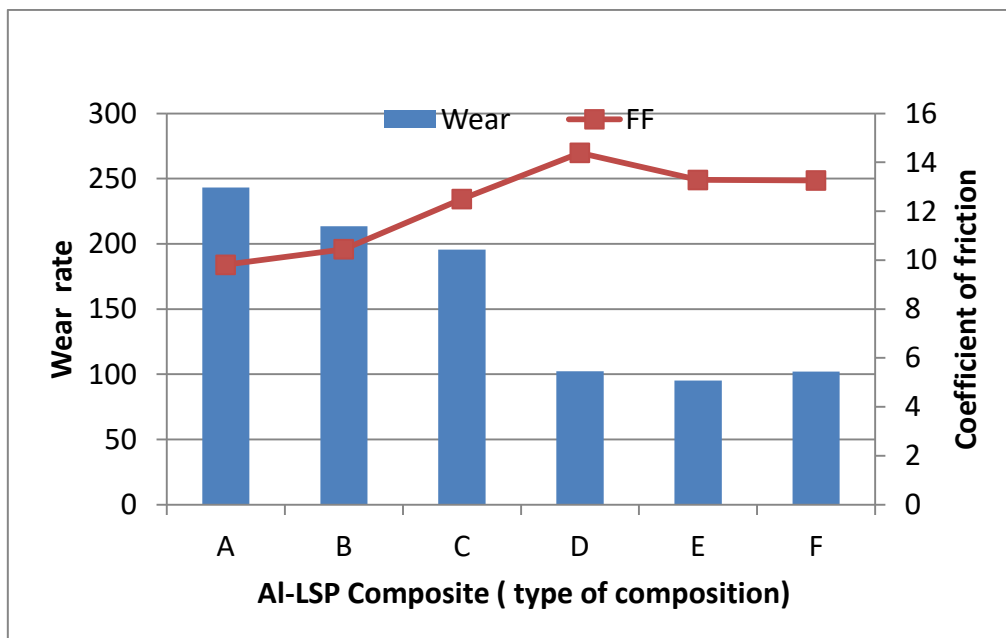


Fig. 4. Tribological performance of Al-LSP composites (a) wear (b) frictional force

Figure 5 revealed that the composite (E) shows better wear resistance than other composites. Generally, the wear rate has increased with the increase in load at constant rpm. LSP composites also have an increasing trend of wear with applied load due to deformation generation of cracks within the oxide film that may act as a three-body wear on removal of the particles increasing the wear rate drastically at high loads. The addition of LSP acts as a barrier to the movement of dislocations and thereby increases hardness of the composite. Thus, addition of LSP particles to the aluminium melt significantly increases its abrasive wear resistance. The improvement in wear resistance is due to the hard constituent present in LSP particles.

The coefficient of friction (Shown in Figure 5) exhibited least for composite (B) compared to other. The coefficient of friction decreases with increasing sliding distance up to 1.5 km and thereafter it started increasing. Sliding distance exceeding 1.5 km, the heat generation will be more and this may attribute delamination and thermal cracks on the sliding surface, hence the coefficient of friction started increasing.

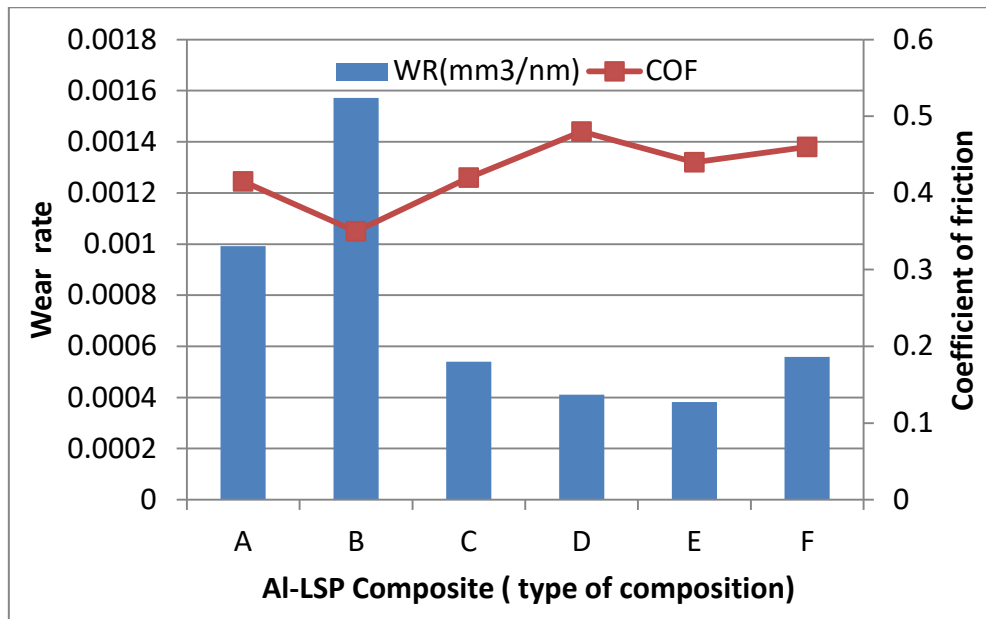


Fig. 5. Wear behavior of Al-LSP composite (a) Wear rate (b) coefficient of friction

V. CONCLUSION

The present work on preparation of Al-LSP metal matrix composite by stir casting and evaluation of mechanical properties has led to following conclusions:

- The hardness is gradually increasing by adding Limestone powder. In this project, the hardness number is more at composition of Aluminium (90%) and Limestone powder (10%).
- Aluminium metal matrix hybrid composites reinforced with limestone powder are fabricated by stir casting route. The composites are made at three different weight fraction reinforcements for hardness measurement and wear testing.
- The micro structural studies revealed that there is a uniform distribution of Limestone powder particles and non-uniform distribution LSP particles in the metal matrix composites.
- Hardness and wear resistance increases as the weight fraction of reinforcements increases. The increase in mechanical and wear resistance properties are high at higher weight fractions of reinforcements.
- The density of composite decreased by 1.45%, 3.56%, 5.57%, and 6.87% for 5%, 7.5%, 10% and 12.5% of LSP respectively as compared to Al-Si.
- Reinforcing particles well distributed in the aluminium matrix. In addition, while increasing of % of LSP observed grain size decreasing. This occurs due to the homogeneous distribution of particles in all combination of the composites.
- Wear of composite increased with increasing % of LSP. It can be observed composite (E) exhibited least and material (A) exhibited highest wear. Similarly, frictional forces exhibited highest for composite (D).
- The evaluated results in this work are useful in the fields of automobile and aerospace applications. In addition, the results provided in this work can act as a base for the utilization of industrial waste such as limestone powder for the development of composites.

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