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Studies on Mechanical Properties of Al LM13-Al_2O_3 Composites

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ABSTRACT : *In this study, Al alloy LM13-Al_2O_3 composites were produced by stir casting method using Al_2O_3 powder as reinforce particles with 150 micron average diameter and Al alloy as the matrix metal. The melt composites were stired, then casted into a metallic mold. Different samples of 3, 6, 9 and 12 weight percent of Al_2O_3 were prepared. The casted composite specimens were machined as per test standards. Effects of weight percent of Al_2O_3 particles on hardness, tensile strength and compressive strength of prepared composites have been investigated. The microstructures of the composites were studied to know the dispersion of the Al_2O_3 particles in matrix. The highest tensile and compressive strengths were achieved in the specimen containing 9 weight percent of Al_2O_3, which shows an increase in comparison with the unreinforced Al alloy. It has been observed that addition of Al_2O_3 particles significantly improves hardness, tensile strength and compressive strength properties as compared with that of unreinforced matrix.*
Keywords *- Al_2O_3 particles, Al alloy composite, mechanical properties, Resistance furnace, stir casting.*

I. INTRODUCTION

The possibility of taking advantage of particular properties of the constituent materials to meet specific demands is the most important motivation for the development of composites. A composite is a material made with several different constituents intimately bonded. This definition is very large, and includes a lot of materials such as the Roman ways (constituted of different layers of stones, chalk and sand), wood, human body etc... A more restrictive definition is used by industries and materials scientists: a composite is a material that consists of constituents produced via a physical combination of pre-existing ingredient materials to obtain a new material with unique properties when compared to the monolithic material properties[1]. Industrial technology is growing at a very rapid rate and consequently there is an increasing demand and need for new materials. Particulate reinforced composites constitute a large portion of these new advanced materials [2]. Metal matrix composite (MMC's) is engineered combination of the metal (Matrix) and hard particle/ceramic (Reinforcement) to get tailored properties. MMC's are either in use or prototyping for the space shuttle, commercial airliners, electronic substrates, bicycles, automobiles, golf clubs, and a variety of other applications [3-4].

A good combination of high strength and ductility of the Aluminum based metal matrix composites (MMC's) have introduced the material to a wide area of possible advanced applications. In general stir casting of MMC's involves producing a melt of the selected matrix material, followed by introducing reinforcement material into the melt, obtaining a suitable dispersion through stirring. Its advantages lie in its simplicity, flexibility and applicability to large scale production. It is also attractive because, in principle this method suitable for engineering application in terms of production capacity and cost efficiency [5]. Aluminium is the most popular matrix for the metal matrix composites. Aluminium is quite attractive due to its low density, their capability to be strengthened by precipitation, good corrosion resistance, high thermal and high electrical conductivity and damping capacity. The demand for structural materials to be cost effective and also to provide high performance has resulted in continuous attempts to develop composites as serious competitors to the traditional engineering alloys [6]. In the recent years, usage of ceramic particle - reinforced metal matrix composites (MMC's) is steadily increasing because of their advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components [7].

Al alloy composites have the potential to replace other costlier material in many significant engineering applications. The requirements concerning safety and reliability are always increasing and therefore the mechanical properties are ever more crucial [8].

II. MATERIALS AND METHODOLOGY

In this study aluminium alloy LM13 used as a matrix material and Al_2O_3 of average 150 micron size as particulate reinforcement with different percentages (in wt.% 3, 6, 9 and 12) based on the variation in weight. The composites were prepared by using stir casting method. Cast iron permanent mould is used for processing composite castings. The melt composites were stirred, then casted into a metallic mold. Figure 1 shows the pouring and stirring of reinforcement in stir casting method. The test specimens of the composites are prepared according to ASTM standards. The chemical composition of matrix material LM13 alloy is shown in table 1. Alumina will give excellent hardness property when it is incorporated into the soft alloys, thereby making it better suited for applications where hardness is desirable. The table 2 shows different properties of reinforcement alumina.

Fig. 1: Pouring and stirring of reinforcement in stir casting method

Table 1: Al alloy LM13 Chemical Composition by Wt. %

Elements	Zn	Mg	Si	Ni	Fe	Mn	Al
Wt. %	0.5	1.4	12	1.5	1.0	0.5	Bal

Table 2: Properties of reinforcement alimina

Properties	**Al_2O_3**
UTS(MPa)	300
Density (g/cm^3)	3.75
Melting Temperature(°C)	2030
Compressive strength (MPa)	2000-4000

III. PROCEDURE FOR TESTING PREPARED COMPOSITES

The cast composites were machined and the specimen for the measurement of hardness as well as for mechanical behavior was prepared as per the ASTM standards. Micro vicker's hardness tester was used to measure the hardness. The mechanical properties were evaluated in Sri Raghavendra Material Testing Services, Banglore. The specimens prepared for hardness as well as tensile and compression test as shown in figure 2.

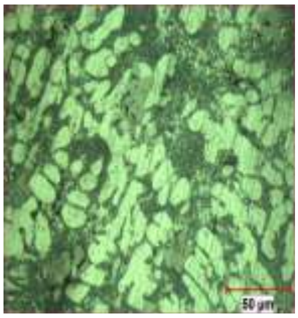
(a)Hardness test specimen (b) Tensile test specimen (c)Compression test specimen

Fig.2: Hardness, tensile and compression test specimens

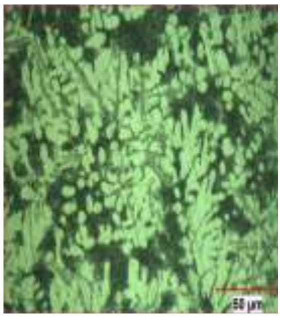
IV. RESULTS AND DISCUSSION

A. Microstructure Examination

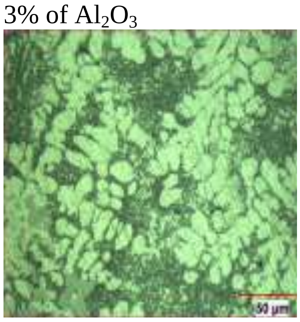
Microstructure is visualized with the help of optical microscope. The microstructure of the prepared composite for different weight percentage of reinforcement as shown in figure 3. These microstructures of the MMC's showing that the reinforcement particles are uniformly dispersed in the aluminium alloy matrix.



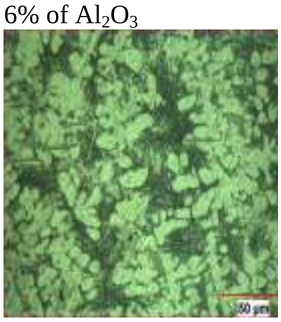
3% of Al_2O_3



6% of Al_2O_3



9% of Al_2O_3



12% of Al_2O_3

Fig.3: Microstructure of prepared composite with different weight percentage of reinforcement

B. Hardness Test

The Vicker's hardness test results for prepared composite are tabulated in Table 3. Hardness tests were performed on Al alloy LM13-Al_2O_3 of different micron size composites to know the effect of reinforcement in the matrix material. The specimens prepared were tested using Vicker's microhardness testing machine. The test was carried out at three different locations, and the average value was taken as the hardness of the composite specimens. Hardness value of the prepared composites are higher than the base Al alloy. The figure 4 shows hardness value of the composite for varying amount of reinforcement material. It is also shown that the hardness of the composite material increases with wt.% of alumina content. This may be because of addition of alumina makes the ductile Al LM13 alloy more brittle.

Table 3: Tabulated Hardness value of the prepared composites

Wt. % of Al_2O_3	VHN
3	129
6	141
9	146
12	143

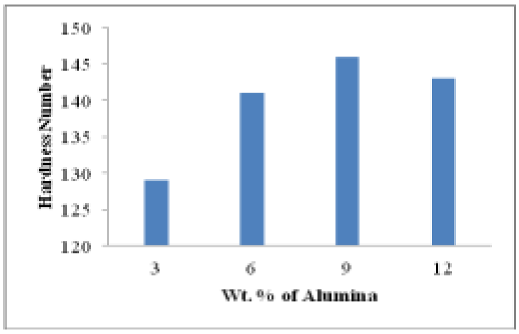


Fig. 4: Hardness value v/s Wt. % of Alumina

C. Tensile Test

The Table 4 shows the tensile strength results obtained from tensile test for the prepared composite. The tensile strength increased with increased wt.% of reinforcement alumina. Because the increase in the percent of alumina particulate reinforcement content would create more sites for crack initiation and hence lower down the load bearing capacity of the composite and the bonding between alumina particulate increases with the base aluminum alloy matrix. The value of tensile strength for varying % of alumina is shown in figure 5.

Table 4: Tabulated Tensile Strength value of the prepared composites

Wt. % of Al_2O_3	Tensile Strength (MPa)
3	237
6	241
9	262
12	253

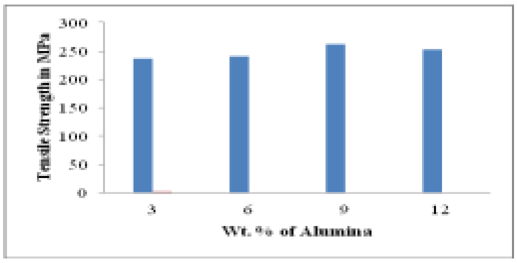


Fig.5: Tensile Strength value v/s Wt. % of Alumina

D. Compression Test

The Table 5 shows the compression strength results obtained from compression test for the prepared composite. The compression strength increased with increased wt.% of reinforcement alumina. The value of compression strength for varying % of alumina is shown in figure 6. The increase in compression strength of composite is attributed to direct strengthening due to transfer of load from matrix material LM13 alloy to reinforcement material alumina. After 9 weight percentage of alumina the compression strength decreases because the bonding between the particles with base alloy decreases.

Table 5: Tabulated Comprssion Strength value of the prepared composites

Wt. % of Al_2O_3	Compression Strength (MPa)
3	475
6	494
9	549
12	498

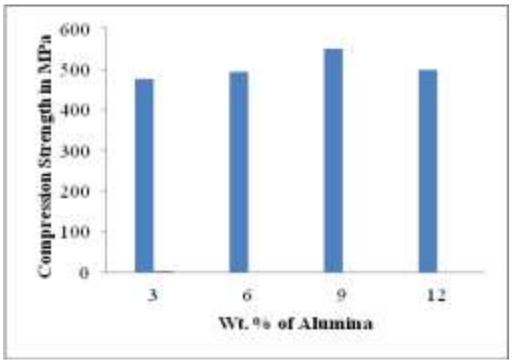


Fig.6: Compression Strength value v/s Wt. % of Alumina

V. CONCLUSION

The significant conclusions of the studies on Al alloy LM13-Alumina metal matrix composites are as follows.

1. Stir casting method is successfully adopted in the preparation of Al alloy LM13-Alumina composites.
2. The micro structural studies revealed that the uniform distribution of alumina particles in the matrix alloy.
3. Hardness of the composites found increased with increased up to 9 weight percentage of alumina, after that decreased.
4. Tensile strength and compression strengths are increased up to 9 weight percentage of alumina.
5. Finally it can be concluded that Al alloy LM13-Alumina exhibits superior mechanical properties when compared with base alloy.

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