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Effect of Marble Dust on Microstructure and Mechanical properties of Al-Cu-Ni / Marble Dust Particles Composites.

[1]Rajendra Kumar.N, [2]Saravanan. R
[3]Sellamuthu. R
[1]PG scholar, [2]Assistant Professor,
[3]Professor,
[1]Department of Mechanical Engineering
[2]Amrita School of Engineering, Coimbatore
[3]Amrita Vishwa Vidyapeetham, India
nrajendra34@gmail.com, r_saravanan@cb.amrita.edu

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Abstract

Metal matrix composites (MMC) are replacing many conventional materials that are used in automotive, aerospace, and marine applications due to their superior properties. The objective of this work is to study the effect Marble Dust(MD) particles on Microstructure and Mechanical properties of Al-Cu-Ni/Marble Dust particles composites. The total weight percent of reinforcement is varied by 3, 6, 9 and 12 %. The Al-Cu-Ni/Marble dust composites were fabricated by Stir casting technique. SEM and EDS were done and the presence of reinforcing particles was confirmed. The Hardness and Tensile Strength is increased by 49.45 % and 22.9 % respectively at 9 wt.% Marble Dust particles composite when compared to the unreinforced alloy. The percentage of elongation and Impact energy is decreased by 34 % and 40 % respectively till 9 wt.% Marble Dust Particles Composite. Beyond 9 wt.% there is a decrease in the hardness and tensile strength which is due to the agglomeration

of Marble Dust particle. ***Key Words*:** Metal matrix composites; Marble Dust(MD); Stir casting; Microstructure

1 Introduction

Metal Matrix Composites (MMCs) are fabricated by the addition of reinforcement to enhance the properties of composites when compared to the unreinforced alloy. MMCs are being used as a material for aerospace, automobile, industrial and other variety of applications [14]. Because of their alluring properties including low density, higher hardness, higher strength and wear resistance, there are successfully using in many applications [57]. By the choice of different parameters like weight Percent (wt.%), reinforcement shape and size, dispersion of reinforcement in matrix materials enhances the mechanical properties of MMCs. Aluminium alloys have wide applications in aerospace and automobile industries due to their low density, good mechanical and corrosion properties. Due to their ductile nature, there is a limitation in use for many applications. Aluminium Metal Matrix Composites (AMMCs) have shown a substantial increase in mechanical and tribological properties when equated to monolithic alloys [8,9]. Ceramics particles are used commonly as the reinforcement, but these particles while increasing hardness and strength of the composite reduces the ductility significantly. SiC, MgO, Zircon, TiC, Al2O3, and B4C are some of the ceramic reinforcements used with aluminium alloy [4,7,1012]. The ever-increasing demand for minimum cost reinforcement urged the enthusiasm for the generation and use of Argo/Industries waste as a reinforcing material since they promptly exist or normally available at a modest cost [1,3]. Apasi [2] used coconut shell-ash as reinforcing the material in Al-Si-Fe alloy and due to the mixing of coconut shell ash, there is a rise in strength and hardness of the composite. Hassan [3] developed Al-Cu-Mg/eggshell particulates composite by using double stir casting method and there is an increase in tensile strength and hardness of composite when equated to base alloy. Some other researchers have been done by using Coconut Husk ash, Fly ash, Rice husk ash and Sugarcane ash alone and combining with another ceramic particle as reinforcements for developing AMMCs [5,6,13-16]. Ajith [6] made a comparative investigation of

Al-Si alloys reinforced with Fly ash and rice husk ash particulates and reported that composite with fly ash has higher hardness and strength when compared with the composite reinforced with Rice Husk Ash. Siva Prasad [14] successfully added SiC and Rice husk ash with Al-Si alloy and investigated the damping behaviour of the composite. Subbaiah [16] fabricated MMC by using less particle size sugar cane ash as reinforcement and AA6061 as the matrix material reported that there is agglomeration effect seen when there is an increase in reinforcement content. Many researches are going on by using Industrial/Agro and other wastes as reinforcement for fabricating of MMCs. Marble Dust is the by-product which is dumped as a waste obtained from the operations like cutting and machining of Marble tiles were performed in Marble producing industries. The waste MD can cause an environmental problem and economic loss if the waste is not used properly. Previous studies have proven that MD particles have successfully used as reinforcement in SiBr alloy composites [17]. No work was done by using MD as a reinforcement for fabrication of AMMCs. The main aim of the present study is to investigate the possible advantages and mechanical behaviour of the Al-Cu-Ni alloy incorporated with MD by using stir casting method and fabricate AMMCs to reduce the impact of solid waste and utilization of MD produced from Marble Cutting Industries.

2 MATERIAL AND METHOD

2.1 Material

The chemical composition of Al-Cu-Ni alloy is listed in below table 1. The particle size of the MD was taken by using different size of a sieve which is arranged in decreasing order of sieve size [3]. The particle size of the MD was obtained in between range 25 to 53 m. The chemical composition of MD is present in the below table 2.

2.2 Experimental Procedure

Matrix material charged into a graphite crucible kept in a stir casting furnace and heated to a temperature about is 750 oC till the matrix material is completely melted.

Table 1: CHEMICAL COMPOSITION OF Al-Cu-Ni ALLOY

Element	**Wt.%**
Cu	4.25
Ni	1.76
Mg	1.33
Si	0.56
Fe	0.45
Al	Bal

Table 2: CHEMICAL COMPOSITION OF MD

Compound	**Wt.%**
CaO	60.93
SiO2	18.53
MgO	5.95
Al2O3	14.29

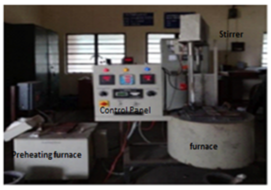

Figure 1 Stir Casting Setup

Preheating of 3 wt.% MD at 150 oC was carried in a separate furnace before adding into molten material to remove moisture and improve wettability with the matrix material [14,15]. The molten liquid was cooled to 550 oC semi-solid state. The pre-heated 3 wt.% MD was charged in the semi-solid-state melted and stirred manually for 5 to 10 minutes. The semi-solid melted mixture was heated to 750 oC and stirred with the use of an automated stirrer. The speed of the stirrer was maintained constant at 550 RPM for 10 minutes for uniform mixing of MD in the matrix material. The molten mixture was poured into preheated cast iron die at 300 oC for uniform solidification. The die dimensions of 10010010 mm was used for producing composites. The same method was followed for fabrication of the composites containing 6,9 and 12 wt.% MD particulates. Archimedes principle was used to measure the Density of MD and Composite samples [1]. A comprehensive study of the microstructure of composite was done using Scanning Electron Microscopy (SEM). A technique like EDS was done to know whether MD particles are present in the matrix. The Vickers microhardness of the various composites was measured by using Mitutoyo MVK H11 micro-hardness tester. The tensile properties were measured by using Ultimate Tensile Machine as Per ASTM standards. Charpy Impact tests of the samples were also done.

3 RESULTS AND DISCUSSIONS

3.1 Density

The density of the MD was found to be of the 2.51g/cc. The variation of density values is shown below in fig 2. From the results, it can be observed that there is no significant change in density of the developed composites when compared to the matrix material.

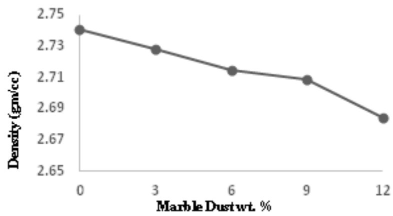

Figure 2 Variation of Density with wt. % of MD

3.2 Microstructure

The SEM image (see fig 3) reveals the shape of the particle present in the MD, the shape of the particle present in the MD particles are in irregular shapes. The EDS results of the Marble dust show that the elements Ca, O, Si, Al, Mg is present in the MD particles. The EDS of the Composites also confirms the presence of the CaO, SiO2, Al2O3 and MgO in the matrix, shows in the form of elements O, Ca, Si, Al and Mg. Presence of MD particles and interfacial bonding between the matrix material reinforcement particles is observed from the SEM images (see fig 4,5). This effect can be attributed due to the factors include stirring of the slurry, good wettability and preheating of reinforcement and die. The agglomeration of MD particles seen in Composite reinforced with 12 wt.% MD particles (see fig 5). Color mapping (see fig 6) of the Composite with 9 wt. % MD particles also confirmed the presence and distribution of all constituents of MD particle.

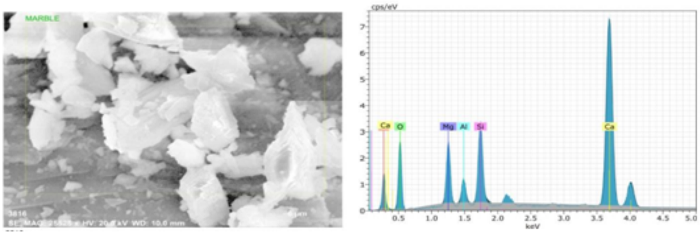

Figure 3 SEM/EDS image of MD

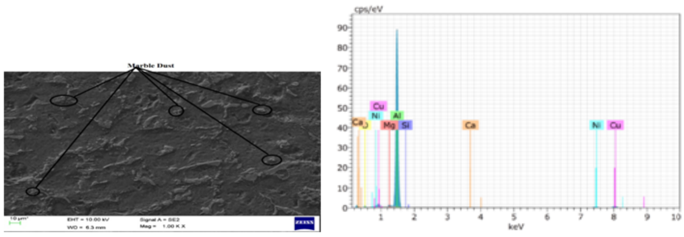

Figure 4 SEM/EDS images of Al-Cu-Ni/9 wt% MD Particles

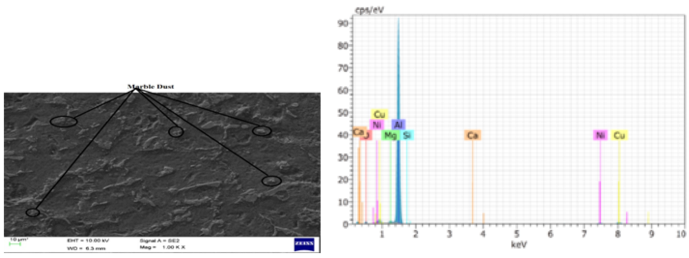

Figure 5 SEM/EDS images of Al-Cu-Ni/12 wt.% MD Particles

3.3 Hardness

The hardness value increases from 91 HV for a base to 136 HV for 9 wt.% MD particulates which are about 49.45% improvement over unreinforced alloy. The reason for the increase in hardness is the presence of CaO, SiO2, MgO and Al2O3 in the chemical made up of particles. [13,10,16]. Reinforcement arrests the dislocation movement when the load is applied, resulting in growth in hardness. This result is in agreement with work done by Atuanya [1] and Hassan [3]. The hardness values were increased with an increase in the reinforcement till 9 wt.% and hardness decreased for 12 wt.% MD particles. This decline in hardness can be due to the agglomeration of MD particle which reduces the interfacial bonding between reinforcement and matrix material (see fig 5). This result is in agreement with the work done by Swati Gangwar [17] and Shanmughasundaram [18]. The variation of hardness values is shown below in fig 7.

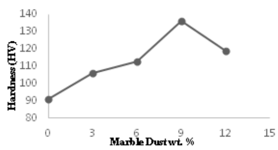

Figure 7 Variation of Hardness with wt.% of MD

3.4 Tensile Strength

Tensile strength(TS) is increased from 161 MPa for a base to 198 MPa for 9 wt. % MD particles which is about 22.9% improvement over unreinforced alloy. This result is in agreement with Atunya [1], Apasi [2] and Hassan [3]. Enhancement in the tensile strength can be due to the effect of good wettability and good bonding between the matrix and MD particle. The applied loads were transmitted to the MD particles present in the composite which increases the load-bearing capacity. By the increase in the reinforcement from 3 to 9 wt. % tensile strength was increased, this is due to increase in reinforcement causes more loads to be transferred to MD particles present in the composite. It is also noted that there is a decrease in the percentage of elongation from 8.8 for a base to 5.8 for 9 wt. % MD particles which is about 34% decrement with unreinforced alloy. But the composite reinforced with 12 wt. % MD particles there is a reduction in the Tensile strength and a slight increase in the ductility than composite reinforced with 9 wt. % MD particles. It can be due to the effects of agglomeration and segregation of MD particles in the composite (see fig 5). This decrease in results is in agreement with the work done by Apasi [2], and Shanmughasundaram [18]. Below figures 8, 9 show the variation of the tensile strength and Percentage of elongation of composites with base, 3, 6, 9 and 12 wt. % MD particles.

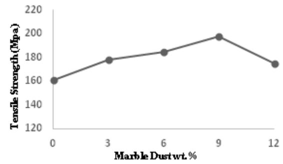

Figure 8 Variation of TS with wt.% of MD

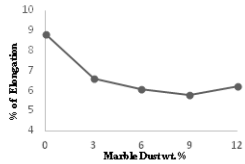

Figure 9 Variation of % of Elongation with wt.% of MD

3.5 Impact Energy

Due to the addition of MD brittle nature of composites increases. As the charging of MD particles increases, the ability of the composites to absorb impact energy decreases. Impact energy is decreased by 40 % at 9 wt.% MD particle Composite over unreinforced alloy. These outcomes are in agreement with work done by Hassan [3]. For the Composite with 12 wt.% MD particles Impact energy is more when compared to 9 wt.% MD particles. This result is in agreement with the work done by Aigbodion [19]. The variation of Impact energy with wt.% of MD shown below fig 10.

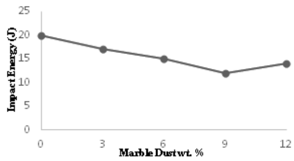

Figure 9 Variation of Impact Energy with wt.% of MD

By using stir casting method, Al-Cu-Ni alloy reinforced with different wt.% of MD particles were fabricated. The results are as follows:

1. The distribution and presence of MD particles in the matrix material were discovered from SEM and EDS analysis.

2. The hardness of the composites is increased by increasing wt.% of MD particles till 9 wt.%, resistance to dislocation motion increases thus, more load is needed for same penetration resulting in high hardness and there is a decrease at 12 wt.% in the hardness can be due to agglomeration effect.

3. The maximum Tensile Strength value is obtained at 9 wt.% MD particles is due to good bonding between the MD particles and matrix material, beyond 9 wt. % there is a decrement in the strength value due to the agglomeration of MD particles. There is a reduction in Impact Energy and percentage of elongation with an increase in the reinforcement till 9 wt.%.

4. Accumulation of the MD particles in the Al-Cu-Ni matrix can lead to the making of the low-cost composites with improvement in hardness and strength that can be used in many applications in automobile and aerospace fields.

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