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RESEARCH ARTICLE

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ALUMINIUM FLY ASH COMPOSITE – AN EXPERIMENTAL STUDY WITH MECHANICAL PROPERTIES PERSPECTIVE

MURUGANANDHAN.P[1]., Dr.ESWARAMOORTHI.M[2], KANNAKUMAR .K[3]

[1]PG Scholar,Nandha Engineering College (Autonomous) , Erode

[2]Professor, Nandha Engineering College (Autonomous), Erode

[3]Assistant Professor, Shree Venkateshwara Hi-Tech Engineering College, Erode

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ABSTRACT

There has been an increasing interest in the composites containing high strength and thermal conductivity, lower density and good damping properties. Metal matrix composite has improved properties compared to unreinforced alloys like Al6061, Al7075. In this paper, an attempt is made to investigate the mechanical behavior of Aluminium- Fly ash composite. Aluminium 7075 is used as a matrix material with fly ash and titanium carbide as reinforcement materials. A comparison has been made between the reinforced and unreinforced alloys. The investigation results reveal that the tensile strength and hardness of the proposed composite increase by increasing the weight percentage of fly ash and titanium carbide.

Keywords—: Reinforced alloy, tensile strength, hardness, metal matrix composite.

1. INTRODUCTION

Metal matrix composites (MMCs) provide significantly enhanced properties such as higher strength, stiffness and weight savings compared to conventional monolithic materials. MMCs combine metallic properties (ductility and toughness) with ceramic properties (high strength and high modulus) which lead to greater strength in shear and compression and higher service temperature capabilities. The scope of availability of relatively cheaper reinforcements and growth of various processing routes, interest in MMCs for automotive, aerospace and other structural applications is increasing year after year. To characterize the mechanical behavior of reinforced metal matrix composites, a hugequantity of work were carried out by numerous researchers.

2. LITERATURE REVIEW

Anil et al.[2011] investigated the mechanical properties like compressive strength, ductility and hardness using aluminium fly ash composites. By increasing the weight fraction of the fly ash particles the above mentioned properties were found to be improved. Different composition needed to be added in the fly ash composites to enhance their properties further.[1]

Vivekanandan et al.[2013] have fabricated the aluminium fly ash composite by stir casting process. The addition of fly ash acts as a barrier to the movement of dislocations and thereby increases the hardness of the composite. And also by adding

fly ash to the aluminium in molten state increases the abrasive wear resistance due to solid solution strengthening, dispersion strengthening and particle reinforcement.[2]

Garg et al.[2012] have prepared a composite by using aluminium 6061 as the matrix and SiC, fly ash as the reinforcement. The composite is produced by stir casting technique in which the weight fraction of the silicon carbide is varied (from 2.5%, 5%, 7.5%. 10%) by fixing the fly ash weight fraction (5%). From the analysis, it is clear that increase in weight fraction of SiC improvesthe tensile strength and hardness of the composite.[3]

Prasad et al. [2013] have investigated the mechanical properties of hardness and wear rate of Al-fly ash using different casting techniques.In this, Al –fly ash with 7.5% weight fraction has high hardness and wear rate when compared to the aluminium alloy produced by squeeze casting and gravity casting. The sample produced in this gravity casting has low hardness and high wear rate. [4]

Prasad et al.[2013] have used eutectic -Al - Si -alloy as a matrix material with increasing fly ash (in wt. %) as a reinforcement and prepared a composite using squeeze casting by applying pressure.By increasing the weight percentage of fly ash the sliding wear resistance of the composite gets improved. The results further revealed that the porosity in composite has been minimized due to the squeeze casting method.[5]

Anandhamoorthy et al.[2012] have produced Al/fly ash/graphite metal matrix composite using stir casting by fixing wt % of graphite (3%) and varying the composition of fly ash (3 to 9%). It has been observed that the sliding wear rate depends on the load and hardness of the hybrid metal matrix composite is more when compared to Al 6061.[6]

Mahendra et al.[2007] fabricated the metal matrix composite using Al-4.5% Cu as the matrix material and fly ash with varying weight fraction (5 to 15%) as the reinforcement material. The composite is produced by stir casting method in which the impact strength, compressive strength, tensile strength and hardness increases with increase in fly ash content. But the density and corrosion resistance decreases.[7]

Bienias et al. [2003] investigated the pitting corrosion behaviour and corrosion kinetics of Al alloy. In this method, AK12 is used as the matrix material and fly ash as the reinforcement to produce the composite by gravity casting and squeeze casting. Addition of Fly ash particles resulted in enhanced pitting corrosion.[8]

Motgi et al.[2013] have used LM25 aluminium alloy as the matrix material and constant weight fraction of fly ash (3%) with varying weight fraction of aluminium oxide (5%,10%,15%) as the reinforcement to produce the composite by stir casting. By analyzing this sample, the tensile strength and hardness seemed to be increased with increase in % wt of aluminium oxide. But the major issue is the reduction of ductility and impact strength.[9]

Arunkumar et al.[2011] have chosen Al6061 alloy as the matrix material and 2 to 8wt% of fly ash with 2 and 6wt% of e-glass fibre as the reinforcement to produce the composite by stir casting. The hardness, tensile strength and compressive strength increases as the wt % of fly ash increases. The samples were tested in ultrasonic flow detector to identify the defects.[10]

Umashankar et al.[2010] have opted Al6061 alloy as the matrix and bottom ash as the reinforcement to produce the composite by stir casting. Micro hardness and tensile strength of the composite increases with increase in wt% of bottom ash particles. The tensile strength and micro hardness decrease when the wt% of fly ash increases beyond 9%.[11]

Uthayakumar et al.[2012] have used aluminium alloy 6351 as the matrix material and fly ash with weight percentage (5 to 15%) as the reinforcement to produce the composite by stir casting. The result shows that the applied load has the greatest effect on dry sliding wear and the composite did not wear at low loads.[12]

Bharat et al.[2014] have utilized eutectic Al-Si-alloy LM6 containing 12.2491% Si as the matrix and the cenosphere of two different types (fly ash type- A and type -B) as the reinforcement to produce the composite by stir casting. The micro hardness, tensile strength, impact strength and hardness were highfor type-B fly ash because of its microstructural differences and presence of a small amount of carbon.[13]

Sreenivasareddy et al.[2012]have used Al 7075 alloy as the matrix material and e-glass fibre

with fly ash by varying the weight percentage to produce the composite.The hardness and tensile strength of the heat treated specimen is higher when compared to the cast specimen. The percentage of e-glass fibre and fly ash can be varied to enhance the mechanical properties further.[14]

Anilkumar et al. [2013] have chosen Al 6061 alloy as the matrix material and fly ash with varying weight percentage (10%, 15%, 20%) with particle size of 4-25, 45-50, 75-100 µm as the reinforcement to produce the composite by stir casting. By analyzing the sample, the hardness, tensile strength, compressive strength increases with increase in weight fraction of fly ash.[15]

The review reveals that by increasing the weight fraction of fly ash particles, the mechanical properties like tensile strength, compressive strength and hardness were improved. The density of the material decreases with increase in the amount of fly ash content. Most of the compositions are done on fly ash with aluminium oxide, silicon carbide and boron carbide. Use of Titanium carbide (TiC) as a reinforcement material (which is having good wear resistance) in MMC finds less attention in the scholarly literature. Further, Al7075 is not used in the composites with TiC as reinforcements, even though it has superior properties over other alloys of aluminium. Hence, an attempt is made in this paper to develop a MMC with Al7075 as a metal matrix element and titanium carbide with fly ash as reinforcement materials.

3. MATERIALS

3.1METAL MATRIX

Aluminium 7075 is chosen as the matrix materialsince, it is low cost and has better properties like good thermal conductivity, high shear strength, abrasion resistance, high-temperature operation, noflammability, minimal attack by fuels and solvents, and the ability to be formed and treated onconventional equipment.The chemical composition of aluminium 7075 is listed in Table-1.

Table 1 - Chemical composition ofAluminium7075

Component	Wt%	Component	Wt%
Al	87.1-91.4	Cu	1.2-2
Mg	2.1-2.9	Fe	Max 0.5
Cr	0.18-0.28	Mn	Min-Max0.5

Al 7075 suits the applications like worm gears, bearings, bike frames, gears and shafts.

3.2 REINFORCEMENT MATERIAL

Titanium carbide and fly ash are used as reinforcement materials.The chemical composition of titanium carbide is listed in table-2.

Table 2-Chemical Composition of TiC

Component	Wt%	Component	Wt%
Al	0.005	Na+K	0.002
Ca	0.005	Mg	0.005
Mo	0.1	Ti	Remaining
C	19	S	0.002

Titanium Carbide is an extremely hard ceramic material. It has good lubricating properties, high wear resistance, exhibits low friction response.

Fly Ash is the residue left out during the combustion of coal. Mixing Fly Ash in aluminium reduces cost, decreases density, increase hardness, stiffness, wear and abrasion resistance. The chemical composition of fly ash is listed in Table-3.

Table 3- Chemical Composition of Fly Ash

Component	Wt%	Component	Wt%
Al_2O_3	28.44	Fe_2O_3	8.85
SiO_2	59.46	TiO_2	2.75

The size of fly ash particles range from 2 µm to 10 µm and spherical in shape. The fly ash contains major constituents like silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3) with trace concentrations of the heavy metals such as nickel,vanadium, cadmium, barium, chromium, copper, molybdenum, zinc and lead. The fly ash are of ASTM C618 Class F.

4. EXPERIMENT

The composition of aluminium-fly ash-Titanium carbide (5%, 10%)composites which has been chosen based on trial and error method.weight proportions of 5%, 10% were chosen. The samples were prepared by stir casting process. 400 gm of aluminum 7075 and (5, 10) wt% of fly ash and (5) wt% of Tic were added to the Al melt for production of two different composites. The fly ash particles were preheated to 373^{o}K for two hour to remove the moisture. Al7075 was melted by raising its temperature to 993^{o}K and degassed by purging hexachloro ethane tablets. Then the melt was stirred using a mild steel stirrer. Fly-ash particles were added to the melt at the time of formation of vortex in the melt. During the addition of the particles, the melt temperature was maintained at

953°K-993°K. Then the melt was casted in a clay graphite crucible. Two set of samples were prepared with a specimen size of length 25cm and diameter of 2.5cm.

Figure 1 Stir Casting Machine

The stir casting machine used for the fabrication of metal matrix composite is shown in figure 1. The heating element which can generate temperature of 1300-1400ºc

5. RESULT AND DISCUSSION

5.1 Tensile Test

Universal testing machine is used to find out the tensile strength. The results illustrate that the tensile strength of the composites increased with the increase in the weight percentage of fly ash and titanium carbide.

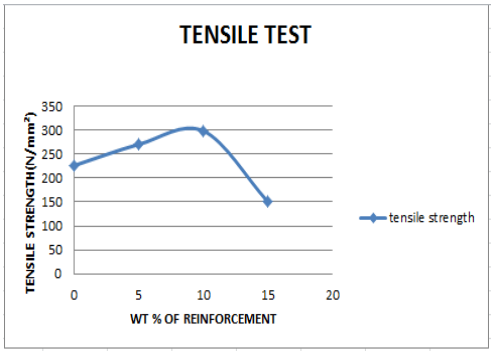

Figure 2 Tensile strength variation with wt% of fly ash

Figure 2 shows the effect of the volume fraction on the tensile strength.The tensile strength of sample1 is226 N/mm^2 and this value increasesto a maximum of 298N/mm^2.The tensile strength increase upto nearly 25%.This is due to the hardening of the aluminium alloy by fly ash particles.

Table 3-Values of Tensile Strength and Elongation

Composition	Tensile strength (N/mm^2)	Elongation (%)
Al 7075	226	10
Al7075+5%TiC+5%Fly Ash	270	2.9
Al7075+5%TiC+10%Fly Ash	298	1.5

The table 3 describes about the tensile strength and elongation of aluminium alloy with fly ash and Titanium carbide. But when the fly ash percentage is increased to 15%, the tensile strength of the composite decreases.This is because of the transition from ductility to brittleness.The elongation also tends to decrease by adding the weight percentage of reinforcements.

5.2 Hardness Test

Brinell hardness tester is used to test the hardness of the composite. The results of hardness test are listed in Table-3.

Table 3-Values of hardness

Composition	Hardness (BHN)
AL 7075	**110**
Al7075+5%TiC+5%Fly Ash	**135**
Al7075+5%TiC+10%Fly Ash	**159**

It can be found that the hardness of the composite increased with the increase in weight percentage of fly ash and titanium carbide. The hard fly ash helps in increasing the hardness of the aluminium alloy. From figure 3 it is evident that the hardness of the material is higher than its base metal. This is due to the presence of metal oxide in fly ash.

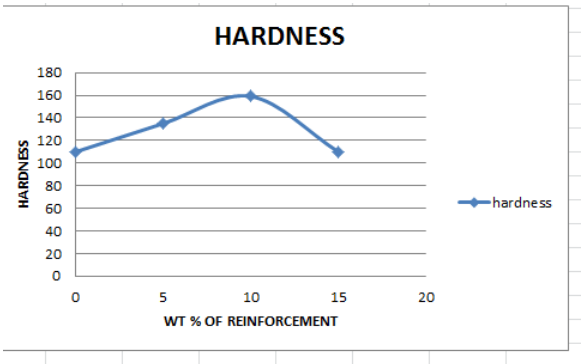

Figure 3 Hardness variation with wt% of fly ash

Figure 3 describes about the hardness and the wt% of reinforcement.The hardness of the unreinforced

alloy is lower than the hardness of the reinforced alloy with fly ash 5% ,Tic 5% which is lower than the reinforced alloy with fly ash 10%,Tic5%. But the hardness decreases when the fly ash weight percentage was increased from 10 to 15. This is because of the brittleness developed in the composite.

6. CONCLUSION

Based on the experiment done on the fly ash with TiC containing Al7075 as the metal matrix composite, the following conclusions are drawn:

I. Al7075 with fly ash composites were synthesized successfully by using stir casting technique.

II. By adding fly ash and TiC, the strength of Al7075 gets improved. This is due to the presence of hardened fly ash particles and the oxide particles in the fly ash and titanium carbide.

III. Compared to the base alloys, the reinforced Al7075 exhibits more tensile strength.the tensile strength increases by 32% more than the base alloy. This is because of the hardening of aluminium alloy by fly ash particles.

IV. By increasing the wt% of fly ash content upto 10% in the composite ,the hardness also increases up to 40%,but after 10% the hardness decreases. This is due to the brittleness of the particle.

V. It is found that the elongation tends to decrease with increasing the weight percentage of fly ash particlesupto 10%.Beyond 10% addition of fly ash particles, the mechanical properties tends to decrease.This is due to the brittleness of the particle.

7.Future Scope

The work can be continued by the researchers in future by having fixed fly ash content and varying TiC content and vice versa. Different reinforcements can be experimented with aluminium alloy in future.

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