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Experimental Investigations on Mechanical Properties of Aluminium and Egg Shell Matrix Composites

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Abstract—

Metal matrix composites reinforced by inorganic particles are very hopeful materials, proper for a large number of applications. These composites consist of a metal matrix packed with inorganic particles featuring physical and mechanical properties very different from the conventional matrix. The particles be capable of improve the base material in terms of wear resistance, damping properties and mechanical strength and give a response to active forever increasing service necessities of such industries as transportation, aerospace, automobile, marine, etc. In this work we aim to investigate the effect of mechanical properties of the metal matrix composite using the Al 6061 with the combinations of egg shell powder (ES).The matrices were prepared with different combinations of the presence and absence of the ESP as well as different weight percentage like 3%, 6% and 9% using stir casting process. The presence of both Al 6061/ ES particles also assisted in improving overall mechanical properties including hardness, tensile strengths, ductility. The results suggest that these alloys and composites have significant potential in diverse engineering applications when compared to Al 6061 alloy.

Keywords— Egg shells,Aluminium alloy, Mechanical properties,Stir casting

I. INTRODUCTION

A composite is a structural material composed of a duly arranged mixture or the combination of two or more micro, macro or nano constituents with an interface. The constituents are combined at a microscopic level and which are effectively insoluble in each other. The discrete constituent is called the reinforcement and the continuous phase is called the matrix. According to the chemical nature of the matrix phase, composite are classified as metal matrix (MMC), polymer matrix (PMC) and ceramic matrix composites (CMC). Low cost reinforcement has always been preferable in all kinds of applications. The production and utilization of using by-products from the industry as reinforcement has given better mechanical properties and wear properties in the earlier studies.(Smith and Hashemi, 2008). Due to the tailored mechanical, physical and thermal properties including their superior abrasion and wear resistance, low densities, improved thermal and electrical conductivities, better strength to density ratio, etc., Metal Matrix Composites (MMC) have been broadly used as a class of materials for the aerospace, electronic, automotive, and wear applications. (Aigbodion and Hassan, 2007; Naresh, 2006). Organic reinforcement like coconut ash,fly ash improve the ultimate tensile strength and yield strength(Himanshu et al). The compressive yield strength is improved when cenosphere is filled with Mg matrix alloy(Huang zhi-qui et al).Percentage of reinforcement of RHA increases the mechanical properties of the Al alloy(Senthil kumar et al).(Bienia et al.,2003) have used fly ash in the reinforcement of aluminium matrix. (Aigbodian, 2007) used Kankara clay(alumino silicate) in reinforcing Al-Si alloy. (Naresh, 2006), have used red mud insdustrial waste on the development and characterization of metal matrix composite for wear resistant applications, they all reported that good dispersion and recovery of the particles in the composite castings. Egg Shell has been used as a new bio-filler for polypropylene composites. The study reveals that While maintaining a similar stiffness and modulus of elasticity (E) compared to the talc composites, ES composites showed lower modulus of elasticity values than talc composites,where talc filler may be replaced by upto 75% with ES. (Patricio et al., 2007)

(Hussein et al., 2011) considered the mechanical properties and water absorption characteristics of high – density polyethylene/ ES composite. It showed that the addition of egg shell powder to the polymer leads to decrease in the tensile strength, modulus of elasticity. At the same time the % elongation at break and impact strength were increased. Water absorption of the composites has also been investigated, the absorbed amount of water increases, by increasing the wt.% of ES

constant exposure time. The potential of using eggshell particles as a reinforce in metal matrix has not been explored. The earlier studies have proved that Chicken Egg Shell (ES) is an agricultural waste mainly considered as futile and discarded mostly because it contributes to pollution of environment, especially in those countries where the egg product industry is well developed. About 150,000 tons of shell waste has been disposed in landfills in the U.S. alone (Shuhadah et al., 2008). This waste has potential for producing hydroxyapatite(a type of mineral) and a major component found in bone and teeth. The egg shell contains 95% Calcium Carbonate and 5% by weight of materials like Al_2O_3,SiO_2,S,P,CrO_2,MnO. The generalized egg shell structure is a protein lined with mineral crystals, mostly of a calcium compound such as calcium carbonate. These characteristics qualify ES as a good material for bulk quantity, inexpensive, lightweight and low load-bearing composite applications, such as the automotive industries, trucks, homes, offices and factories.

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II. MATERIALS

The matrix material used in the present investigation was high purity aluminium 6061-T6 alloy (with chemical composition presented in Table1). Aluminium was purchased from Metal Mart, Coimbatore, Tamilnadu, India. White Chicken Egg Shells were locally available. The Photograph of the Egg Shell and its powder are shown in Fig.1 and Fig.2

III. METHODS

The egg shells were collected and washed thoroughly in water and dried for about 48 hours in sun, then the dried egg shells were ball milled at 250 rpm. The powdered egg shells were placed on a set of sieves and were vibrated for about 15 minutes and it is repeated for about 3 times and a fine particulate egg shells were collected from the sieves. The composite taken in this study was Al 6061 and the Egg Shells with a varying composition of 3,6, and 9 % by wt of the egg shell in the matrix. The samples were manufactured by using Stir Casting technique.

Al 6061 was melted by heating up to 750˚C with use of crucible in the furnace, and then the metal in the molten state was kept for one and hour in the furnace itself. The ES particles were preheated up to the temperature of 400˚C to 450˚C for 30 minutes to oxidize the surface of the ES particles. After that we have to stir the alloy and ES mixture. So the furnace which was used to stir the mixture was heated up to the temperature equalant to the molten temperature of alloy. The molten state of alloy was taken into the stirring furnace. Then the ES was added manually in the furnace and a very fine trace amount of copper was added for the bonding of Al with the egg shells. At this instant the furnace was to tack at 200 to 400 RPM. After thorough mixing of the alloy and ES particles, the mixture was poured into the mould of die casting equipment.

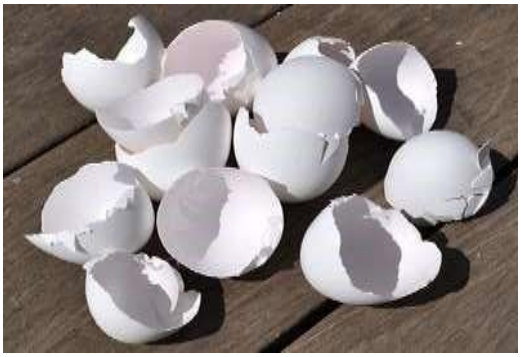

Fig.1 Egg Shell

Fig 2.Egg Shell Powder

Table-I

Chemical Composition of Al 6061

Chemical Elements	% of Elements

Cu	**0.15-0.4**
Mg	**0.8-1.2**
Si	**0.4-0.8**
Fe	**Max 0.7**
Mn	**Max 0.15**
Cr	**0.04-0.35**
Zn	**Max 0.25**
Ti	**Max 0.15**
Al	**Remainder**

Table-II

Chemical Composition of waste egg shell sample

Chemical Elements	% of Elements
CaO	**50.7**
SiO_2	**0.09**
Al_2O_3	**0.03**
MgO	**0.01**
Fe_2O_3	**0.02**
Na_2O	**0.19**
P_2O_5	**0.24**
SrO	**0.13**
NiO	**0.001**
SO_3	**0.57**
Cl	**0.08**
Loss of Ignition	**47.8**

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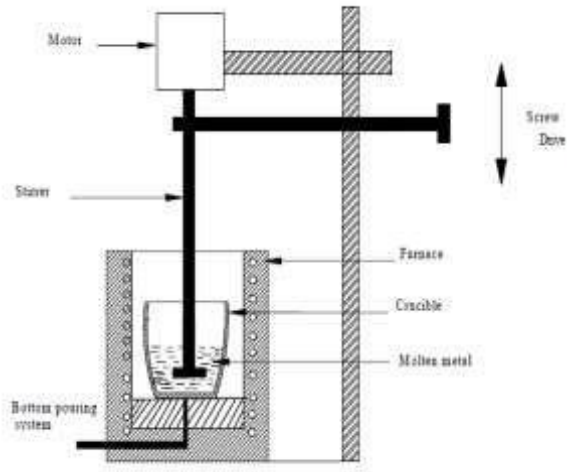


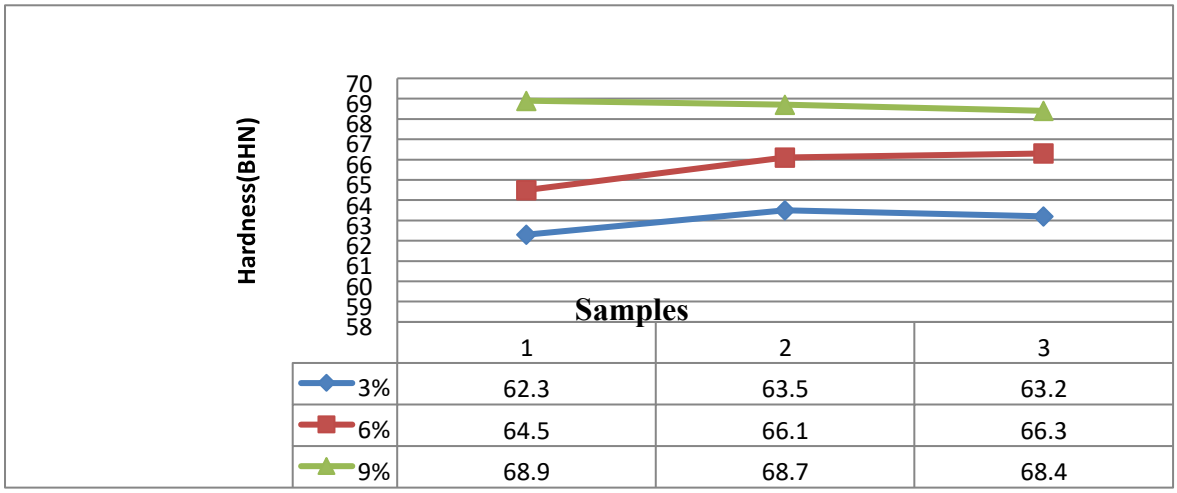
Fig.3 stir casting furnace

IV. EXPERIMENTAL TEST

A.Hardness:

Hardness tests were performed on the composite material specimens and the pure aluminium alloy on a Brinell hardness testing machine with a load of 250Kgf and the diameter of the steel ball indenter is 5mm.The hardness value of the samples were calculated by using the diameters of the impressions made by the steel ball. The test was carried out at three different locations and the average value was taken as the hardness of the composite specimens.

The relation between weight percentage of ES reinforcement and hardness of fabricated MMCs was shown in figure. The result showed that the hardness values were improved gradually in the matrix material with an increase in the percentage of the egg shell particles. But the improvement in the hardness is less than that of the base metal. This is because of the stirring speed, stirring time, casting temperature or particle size or the incorporation of hard ES phase with the ductile aluminium material which have a direct Impact on the hardness of the material.



	1	2	3
3%	62.3	63.5	63.2
6%	64.5	66.1	66.3
9%	68.9	68.7	68.4

Fig.4 Effect of variation of ES on hardness of the composite material

B.Density:

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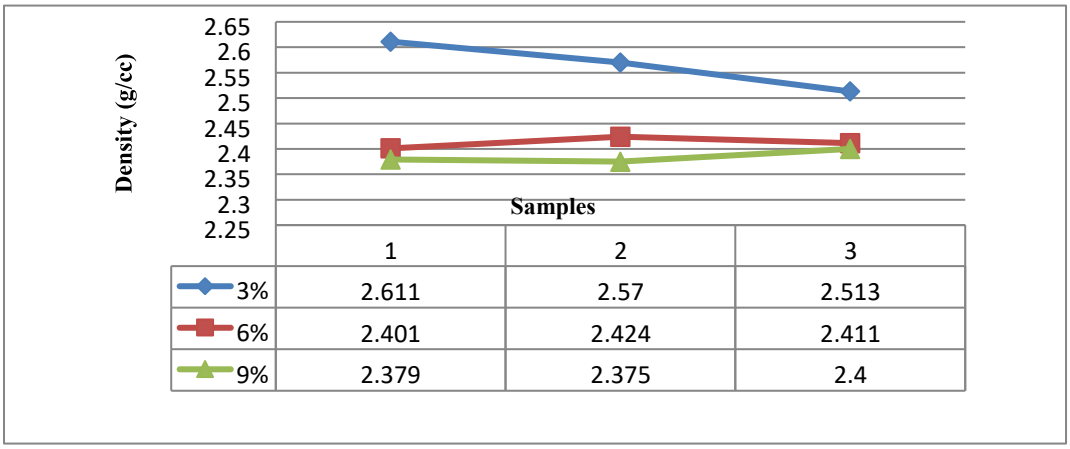
The density of a solid was measured using Archimedes principle. The density of fresh water is less than that of salt water. In this experimental work, the density of a solid is found from its volume and mass.

The mass of a solid is measured in air and in water. The difference between the real mass measured in air and the apparent mass measured in water is found to be equal to the mass of the water that the solid displaces.

The density of the pure Al-6061 alloy was found to be 2.7 g/cc. Added egg shell particles in the Aluminium alloy has reduced the density of the composite considerably. The density of the composite was reduced progressively with increasing the weight percentage of the egg shell particles

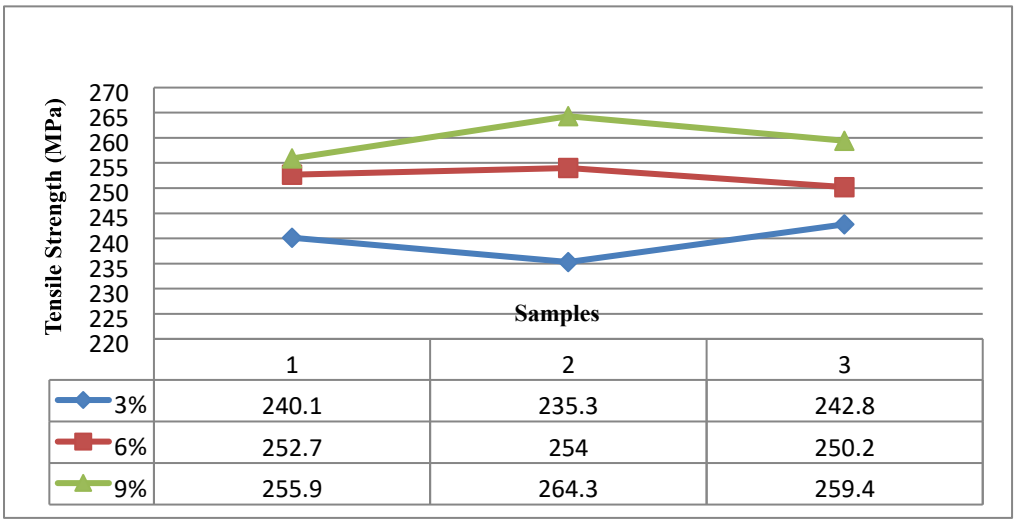


	1	2	3
3%	2.611	2.57	2.513
6%	2.401	2.424	2.411
9%	2.379	2.375	2.4

Fig.5 Effect of variation of ES on density of the composite material

C:Tensile Strength

According to ASTM E8 standards, the test specimens were prepared where specimen having 8mm in diameter and 60mm gauge length. The specimen was loaded in Hounsfield Universal Testing Machine until the failure of the specimen. Different combinations of reinforcing materials were taken and ultimate tensile strength and ductility were measured.



	1	2	3
3%	240.1	235.3	242.8
6%	252.7	254	250.2
9%	255.9	264.3	259.4

Fig.6 Effect of variation of ES on tensile strength of the composite material

For conducting a standard tensile test, the specimen's cross-sectional area and gauge length is measured and placed in the testing machine and the extensonometer is attached. Simultaneous readings of load and elongation are taken at uniform intervals of load. Figure-6 shows that the effect of egg shell on ultimate tensile strength of composite material.

From the graph it is also evident that the tensile strength of the composite samples also increased gradually with increase in reinforcements.

However the obtained tensile strength is less than that of base metal, the inclusion of egg shells leads to improve the tensile property of the material.

The observed decreament in tensile strength of the composite compared to the base metal was attributed to the fact that the filler egg shell particle possesses the poor wettability of the reinforcement with the matrix.

V.CONCLUSION

The conclusions drawn from the present investigation are as follows:

- Egg Shell, the agricultural waste can be successfully used as a reinforcing material to produce Aluminium Metal-Matrix Composite by stir casting method. It can be effectively used in place of conventional aluminium intensive material.
- With the increase in the percentage variation in the egg shell composition into the aluminum phase increased the hardness of the composite. This is because of the bonding of hard egg shell phase with the ductile aluminium phase.
- The density of the composite was reduced with increased weight percentage of the egg shell composition .This shows that composite with light weight can be made with egg shells.
- The tensile strength of the composite gets decrease with increase in the weight fraction of reinforced egg shell particles.
- It is concluded that even though the tensile strength of the composite decreases, there was a gradual increase in its strength upto 9%. So that predicting the tensile strength values inclusion of ES beyond 9% is noticeable.
- Now a days, the replacement of conventional materials by lighter metals with low costs are a desirable thing. Aluminium matrix with ES particles could lead to the production of low cost and light weight aluminium composites with enhanced hardness. These composites can be found applications in automotive components like pistons, connecting rods, cylinder liners, and as well as applications where light weight materials are required.

This work is a preliminary study and the detailed study is necessary to evaluate the contribution of ES and the aluminium matrix on the mechanical properties of the composites.

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