Fabrication and Characterisation of Aluminum Alloy 6351-Egg Shell Composite

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Abstract - In present days, wastage disposal is becoming a major problem in our country. Egg shells are one of the wastes produced in a large amount each day. In this paper, we have recycled these egg shells by reinforcing with the aluminum alloy 6351. The naturally occurring bio-waste material eggshell is added to aluminum alloy 6351 by stir casting and its effects on the mechanical properties and microstructure of the composite were studied, Rockwell Hardness, Tensile Strength, Impact Energy and density were estimated. The results showed an increase in hardness. The density of the composite also reduced significantly with an increase in the composition of the egg shell in the aluminum alloy 6351. It was also noted that the tensile strength of the composite has decreased with the addition of the egg shell in the aluminum alloy. The SEM images showed a good bonding between the eggshell and the aluminum alloy 6351. The egg shell can be used as reinforcement in aluminum alloy to increase its hardness and its very less expensive reinforcement material.

Keywords – Aluminum egg shell, Aluminum composites, Al 6351 Composites

I. INTRODUCTION

Metal Matrix Composites are composed of a metallic matrix (Al, Mg, Fe, and Cu etc) and a dispersed ceramic (oxide, carbides) or metallic phase (Pb, Mo, W etc). Ceramic reinforcement may be silicon carbide, boron, alumina, silicon nitride, boron carbide, boron nitride etc. Whereas metallic reinforcement can be tungsten and beryllium etc. Reinforcement may be tungsten, beryllium etc. MMCs are used for Space Shuttle, commercial airliners, electronic substrates, bicycles, automobiles, golf clubs and a variety of other applications. From a material point of view, when compared to polymer matrix composites, the advantages of MMCs lie in their retention of strength and stiffness at elevated temperature, good abrasion and creep resistance properties. Most MMCs are still in the development stage or the early stages of production and are not so widely established as polymer matrix composites. The biggest disadvantages of MMCs are their high costs of fabrication, which has placed limitations on their actual applications. There are also advantages in some of the physical attributes of MMCs such as no significant moisture absorption properties, non-inflammability, low electrical and thermal conductivities and resistance to most radiations. MMCs have existed for the past 30 years and a wide range of MMCs have been studied.

II. EXPERIMENTAL PROCEDURE

2.1 Material And Equipment

The broiler hen egg shells are used as reinforcement material, Al Alloy 6351 is the metal matrix. The equipments used are Stir casting furnace for casting the composite at 900ºc and 250 rpm for 15 minutes, ball mill for powdering egg shell, UTM for tensile testing, Rockwell Hardness Testing Machine, Digital Impact Testing Machine, Weighing Scale for measuring the weigth of materials, Density meter to estimate the density of the composite.

2.2. Method

The broiler egg shells were collected and cleaned to remove the dust particles present in it. Then the egg shells are washed thoroughly with water and allowed to dry in the sun for 48 hours and the dried egg shells were powdered using ball mill at 200 rpm. The egg shell powder was placed on a set of sieves and vibrated for 15 minutes and was repeated for 3 times and fine particulate egg shells were collected and the size of the egg shell used the test was 100µm.

The composite under study is Al Alloy 6351 and the egg shell with varying composition of 15% and 20% by weight of the egg shell in the metal matrix. The samples were manufactured using the stir casting method, a very fine trace of magnesium was added to increase wettability of the aluminum alloy and the bonding of the egg shell with the aluminum alloy.

The mixture of Al alloy 6351,egg shell and trace amounts of magnesium was stirred thoroughly for about 20 minutes at 250 rpm and 900ºc . Then the composite was poured in to the dies of size 25mm dia and 30omm length by bottom pouring method. The obtained samples were machined to get the specimens of standard dimensions to conduct the various tests.

The density of the samples were calculated using a density meter , then the tensile test was conducted in the Universal Testing Machine and the microstructures were taken using the Scanning Electron Microscope, then samples were used to determine their hardness,using the Rockwell hardness tester with 1/16 diamond indentor and the load applied was 100 Kgf.

III. RESULTS AND DISCUSSIONS

3.1 Density.

The density of the composite reduced significantly with addition of the egg shell particles in the Al Alloy 6351. The density of the Al Alloy 6351 was found to be 2.8 gmm/cc. The density of the composite reduced with the increasing percentage of the egg shell composition in the composite. The density decreased from 2.8 gm/cc to 2.15 gm/cc at 20% by weight of the egg shell in the composite.

Table 1: Density of the Materials.

S.No	Specimen	Density (gm/cc)
1	Al-6351	2.8
2	Al-6351 15% eggshell	2.3
3	Al-6351 20% egg shell	2.15

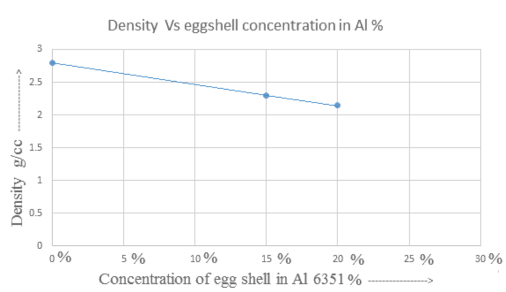

Fig 1: Density Vs Egg shell concentration

3.2 Hardness

The Rockwell Hardness test was performed on the Al alloy 6351 and the composite samples with 1/16 inch diamond indentor and a load of 100 Kgf . The hardness was measured using the Rockwell 'B' Scale. The results showed an increase in hardness with the increase in the percentage of the egg shell in the metal matrix material.

The improvement in hardness is due to brittle nature of the egg shell particles which was incorporated into the Al Alloy 6351.The egg shell particles carry the load along with the matrix materials and by the formation of incoherent interface between the particles and the matrix, thus the composite gets strengthened.

Table 2: Hardness of the Materials

S.No	Specimen	Rockwell Hardness (HRB)
1	Al-6351	60
2	Al-6351 15% Eggshell	78
3	Al-6351 20% Eggshell	86

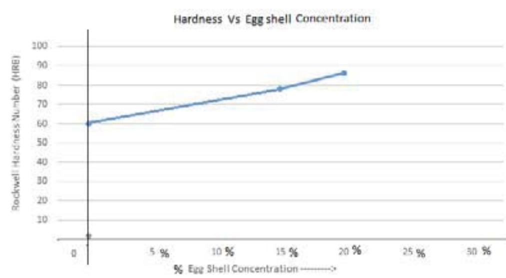

Fig 2: Hardness Vs egg shell concentration

3.3. Tensile Strength

The tensile strength of the composite has reduced with increasing amount of the egg shells added by weight in the Al alloy 6351. This may be due the increase in the britlleness of the composite due to the addition of the egg shell particles and the composite has lost its ductility.In this composite the reinforcing phase carries the bulk of the load and the matrix transfers the load to the reinforcing phase restrict the free elongation of the matrix ,so the composite has become brittle.

Table 3 Tensile Strength of the materials

S.No	Specimen	Tensile Strength (N/mm^2)
1	Al 6351	387.473
2	Al 6351-15% egg shell	108.786
3	Al 6351-20% egg shell	101.044

The Load Vs cross head travel for Al Alloy 6351 is shown in the figure 2 below

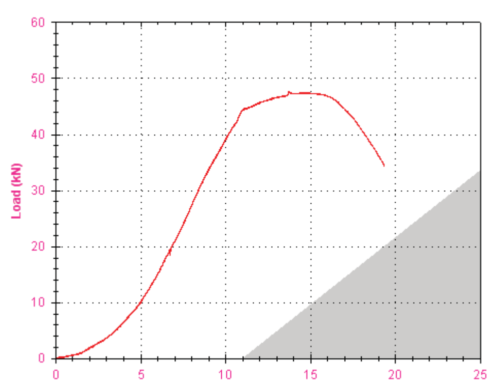

Fig 3 :Load Vs cross head travel for Al Alloy6351

The Load Vs cross head travel for Al Alloy 6351-15% egg shell composite is shown in the figure 3 below:

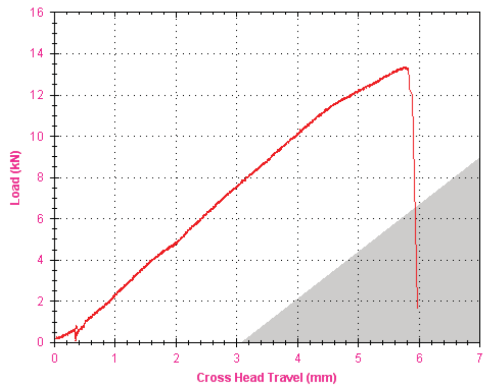

Fig4: Load Vs cross head travel for Al Alloy 6351-15% egg shell composite

The Load Vs cross head travel for Al Alloy 6351-20% egg shell composite is shown in the figure 3 below:

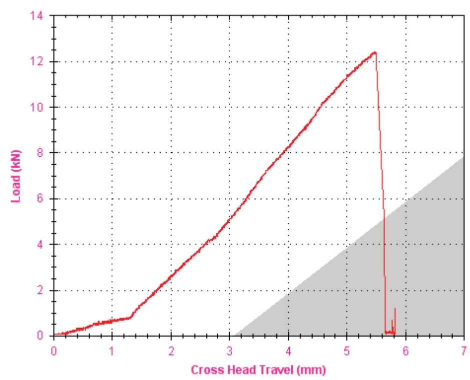

Fig 5: Load Vs Cross head travel for Al Alloy6351- 20% egg shell composite.

From the above Fig 3,4 and 5 showing the plot of load Vs Crosshead travel in UTM it can be observed that the composite material breaks suddenly without necking and Al Alloy 6351 has more yield strength and necking occurs before fracture.

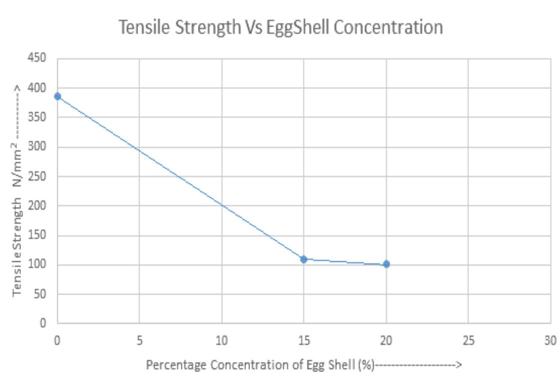

Fig 6: Tensile Strength Vs egg shell

concentration

Fig 6 above shows the plot of tensile strength Vs Egg shell concentration on the composite which shows that the tensile strength has decreased significantly with the addition of the egg shell particles in the al alloy 6351.

3.4 Impact Energy

The impact energy of the composite was lesser than that of the Al alloy 6351 . The impact energy of the Al alloy 6351 Composite decreased with the increase in the amount of the egg shell by weight added in the matrix.

Table 4 Impact Energy of the materials

S.No	Specimen	Impact Energy
1	Al 6351	6.368 Joules
2	Al 6351+15% egg shell	2.412 Joules
3	Al 6351+20% egg shell	2.214 Joules

3.5 Micro Structural Analysis:

The microstructural analysis of the samples(fig 7 to 9) shows that they have particles of different size ,shapes porosity , the dispersion of the egg shell particles and the trace amounts of various elements in the composite. The micro structure reveal that the egg shell was uniformly distributed in the Al alloy 6351. The egg shells were retained in the phase can be clearly observed in the micro structures.

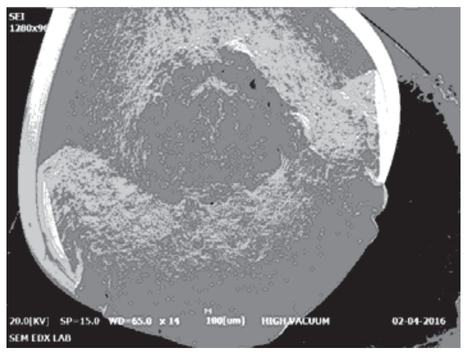

Fig 7: SEM image of Al Alloy 6351

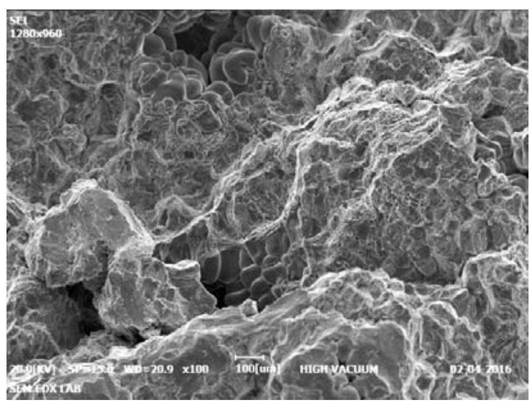

Fig 8: SEM image of Al Alloy 6351-15% eggshell composite.

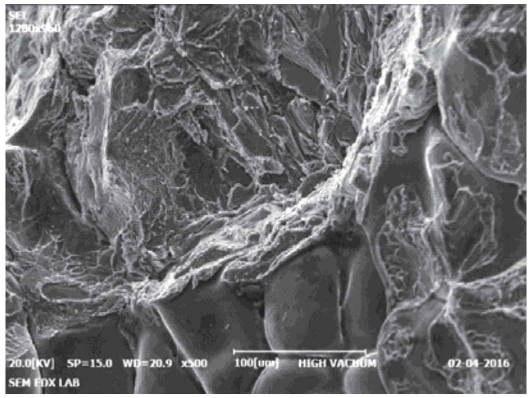

Fig 9: SEM image of Al Alloy 6351-20% egg shell composite

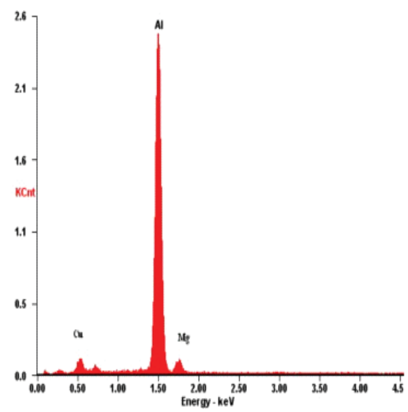

Fig 10: EDX of Al Alloy 6351

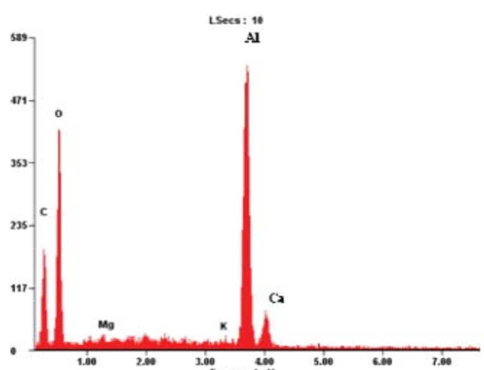

Fig 11: EDX of Al Alloy 6351-15% Egg shell composite

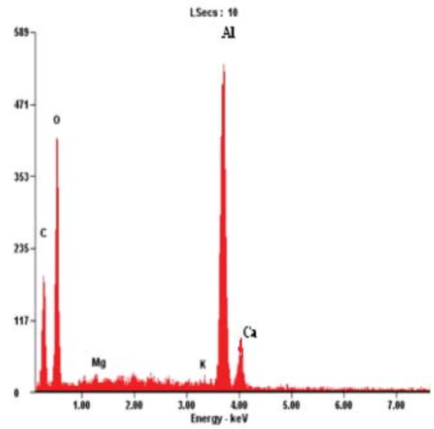

Fig 12: EDX of Al Alloy 6351-20% Egg shell composite

The SEM and EDX analysis of the Al Alloy 6351 and the egg shell composites (Fig7-12) show that the composites possess the elements like Aluminium,Carbon, Oxygen in major amounts and Sodium,Silicon,Zinc, Magnesium, Copper in small amounts. From the SEM images it is clear that the egg shell particles have been incorporated into the phase of the Al Alloy 6351. There were no gaps present between the egg shell particles and the Al Alloy 6351, thus indicating a good bonding between the reinforcement and the metal matrix.

IV. CONCLUSIONS

Results conclude that the egg shell particles were successfully incorporated into the Al alloy 6351 by the Stir casting method. The microstructure analysis reveal that the egg shell is properly and uniformly distributed in the matrix phase and has a good bonding between the Al alloy 6351 and the egg shell particles.

The addition of the egg shell particles in the Al alloy 6351 increased the hardness of the composite . This increase in hardness of the composite is due to the bonding of the hard egg shell phase with the ductile Al alloy 6351 phase which leads to increase in dislocation density at the matrix phase. The density of the composite has also reduced with the addition of the egg shell particles in the matrix phase. Strengthening of the composite is due to dispersion strengthening and particle reinforcement.

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