Effects of waste eggshells and silicon carbide addition in the synthesis of aluminium alloy 6061 hybrid green metal matrix composite

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Abstract - *The Composites are framed by consolidating materials together to shape a general structure with properties that contrast from the whole of the individual segments, it implies their are a few changes in physical and mechanical and thermal properties as compares to single matrix material. Some improved properties are like tensile strength, hardness, density, stiffness and fatigue properties, which enable the structural design to be more appropriate for uses. Due to their some improvement into physical and mechanical and thermal properties they are used in aerospace industry, mechanical engineering applications (internal combustion engines, thermal control and machine components), electronic packaging, automobile, and aircraft structures and some other mechanical components. The challenging part of MMCs are to reduce the reinforcement cost as well as the material cost , egg shells are added to the reinforcement to reduce their cost as well as improve the useful properties. The earlier studies proved that the Egg shells are biodegradable that is one of the world's worst environmental problems, especially in the countries where the egg product industry is well developed. The production of chicken eggs on a widespread industrial level has led to the generation of a large amount of egg shells. These egg shells are considered to be bio-hazardous waste materials. In the present investigation, effort has been made to incorporate waste poultry egg shell particles (ESP) in carbonized (C) form into the matrix of an Aluminium alloy(6061) and silicon carbide(black powder) in 5 microns to improve its mechanical properties. When at least three materials are present, it is called a hybrid composite. Their are two composites have different egg shell weight percentageA1.(AA6061+ silicon carbide 5%wt of AA6061+ carbonized eggshells 5%wt of AA6061). A2.(AA6061+ silicon carbide 5%wt of AA6061+ carbonized eggshells 8%wt of AA6061) were compared with other commercial materials. There has been an increasing interest in composites containing low density and low cost reinforcement The stir casting technique followed to fabricate metal matrix composite so that the tensile strength, hardness and yield strength increased by the addition of eggshell particles in AA6061 matrix alloy for carbonized reinforced composites. The effect of carbonized egg shell particles on mechanical properties like hardness tensile strength and percentage elongation of composites are studied. Also, the surface morphology of fractured surface after tensile testing is examined using microscopic images.*

Key Words: Aluminium Alloy, Silicon Carbide, Egg Shells, Stir Casting, Tensile and hardness tests etc.

1. INTRODUCTION

During the second half of the 20th century the true revival of using lightweight composite structures were stated. After using of their special properties they were used to improve the structural performance of spacecraft and military aircraft and became popular in the last two decades of the previous century. First at any costs, with development of improved materials with increasing costs but now a day's main aim of the manufacturer is to reduce the material cost and operation time. The future composites will be fabricated significantly more coordinated plan process bringing about the ideal development as indicated by parameters, for example, shape, mass, quality, solidness, toughness, costs. Now a day laminates are the composite material where different layers of materials give them the specific character as composite materials having a specific function to perform. For engineering and industrial applications aluminium, both in pure and alloy form is suitable.

Thus, the physical, chemical and mechanical properties of aluminium have fascinated researchers to explore its potential. In aluminium matrix composites, the extensively used reinforcement is in particulate form and is widely employed in automotive and aerospace industries (Surappa, 2003). In India poultry is an influential sector it has an average growth rate of 6% in egg production per annum.

The poultry population of India is 489 million that produces 47 billion eggs per year and ranks third highest among egg producing countries in the world (Anon., 2009). Egg shells are biodegradable so it may be utilized as a low cost reinforcement in the matrix for composites. About 95% of the dry eggshell is calcium carbonate weighing 5.5 grams. The eggshell contains around .3% phosphorus and .3% magnesium and signs of sodium, potassium, zinc, manganese, iron and copper. On the off chance that the calcium from the shell is expelled, the natural grid material is abandoned. Carbonized egg shells are the third material which is added to the MMCs. It will provide the good mechanical properties. Like hardness, low density, high melting point, good abrasive properties.

Agunsoye et al. (2015) investigated the mechanical and wear resistance properties of recycled aluminium can/egg shell composite at different weight percentage. An increase in wear resistance, hardness and yield stress was observed with increasing weight percentage of egg shells. Hassan and Aigbodion (2015) studied the effects of eggshell particles on the microstructures and properties of Al–Cu–Mg/ES particulate composites with different weight percentage in both carbonized and uncarbonized form. It was concluded that values of hardness and tensile strength improved notably but a decreasing trend in impact energy was observed when carbonized egg shell particles were used as reinforcement.

1.1 Objectives of hybrid Metal Matrix Composites

The fabrication of HMMCs is done to achieve the following objectives:

1. Resistance to fatigue at higher temperature.

2. To improve yield and tensile strength at room temperature as well as the variation in the temperature.

3. To reduce the weight of the composite with compromise with its properties

4. To improve hardness values.

1.2 Aluminium-SiC-Carbonized Eggshells Metal Matrix Composite

Aluminum is delicate, light weight, strong, flexible and moldable metal with appearance ranges from slivery to dull dark, subject to the surface unpleasantness. It is the third most abundant element after oxygen and silicon. It makes up about 8% by weight of Earth's solid surface. The chief source of aluminium is bauxite ore. Its Atomic number is 13.

It is easily machined, cast, drawn and extruded. Corrosion resistance can be excellent due to a thin surface layer of aluminium oxide that forms when the metal exposed to air, effectively preventing further oxidation. Aluminium is non-magnetic and non-sparking. Aluminum has around 33% the thickness and firmness of steel.

1st component of hybrid metal matrix composite is AA6061 which is precipitation solidified aluminum combination, containing magnesium and silicon as its major alloying elemnts.it has various applications in Aircraft fittings, camera focal point mounts, couplings, marines fittings and equipment, electrical fittings and connectors, enlivening or misc. equipment, pivot pins, magneto parts, brake cylinders, water powered cylinders, machine fittings, valves and valve parts; bicycle outline, entryways, window outlines, shop fitting, architected applications, expulsions and so on.

Fig.1. Aluminium alloy 6061

2nd component of hybrid metal matrix composite is Silicon carbide (SiC)

otherwise called carborundum is a compound of silicon and carbon with synthetic recipe SiC. It happens in nature as the to a great degree uncommon mineral moissanite.it is a semiconductor containing silicon and carbon Synthetic silicon carbide powder has been mass-created since 1893 for use as a grating. Grains of silicon carbide can be fortified together by sintering to frame hard earthenware production that are broadly utilized as a part of uses requiring high perseverance, for example, auto brakes, auto grasps and fired plates in impenetrable vests.

Fig.2. Silicon carbide (SiC)

3rd component of hybrid metal matrix composite is carbonized eggshells.

Around 95% of the dry eggshell is calcium carbonate weighing 5.5 grams. The average eggshell contains about .3% phosphorus and .3% magnesium and traces of sodium, potassium, zinc, manganese, iron and copper.

How they converted into carbonized form? First the egg shells were collected from households, and then they were washed out by demineralized water to remove any foreign objects and the thin outer membrane.

They egg shells were then sun dried for 72 hours then egg shells were kept in a furnace preheated to a temperature of 1000 degree Celsius for a period of 45 minutes and then converted to powder using the grain miller after cooling to room temperature.

The obtained powder was passed through sieves of required size so as to obtain particles with uniform size distribution.

Fig.3. carbonized egg shells

2. Preparation of Castings:

Different Method used to Manufacture Particulate Reinforced MMCs. MMCs manufacturing can be broken into three types: solid, liquid and vapor. Present works utilizes the stir casting techniques for fabrication of MMCs. The details of stir casting are as follows:

2.1 stir casting

The stir casting procedure was used for the fabrication of CESP-AL-Si composite as well as the control castings. Stir casting process has been mostly used be the for fabricating Metal Matrix Composites (MMCs).

Its simplicity and applicability for large scale industrial production has superseded other fabrication options such as powder metallurgy, infiltration techniques and squeeze casting etc. Stir casting set-up mainly consists a furnace and a stirring assembly shown in figure

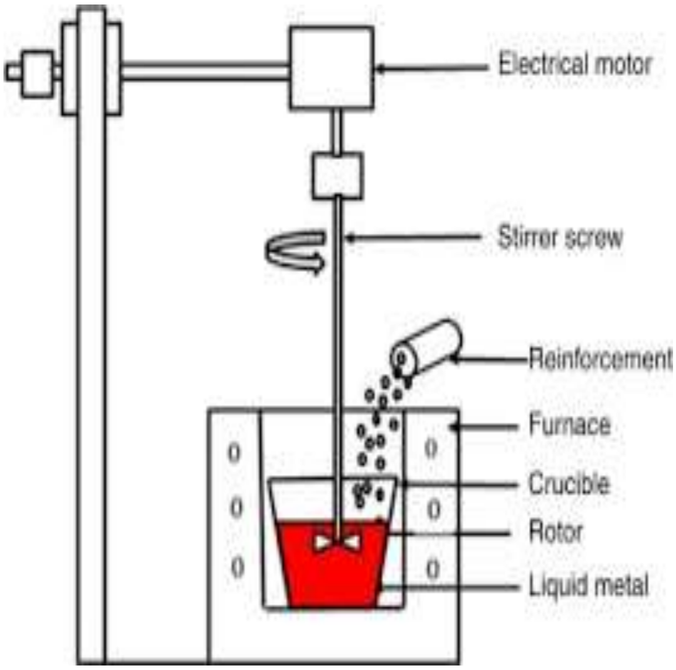

Fig-4: Stir casting

In getting ready metal matrix composites by the mix throwing technique, there are a few factors that need impressive consideration include:

1. Porosity in the cast metal matrix composites.

2. Chemical reaction between the reinforcement material and the matrix alloy.

3. The difficulty in achieving a uniform distribution of the reinforcement material.

4. Wettability between the two main substances.

Steps involved for fabrication of hybrid metal matrix composites (Al-6061/SiC/CESPs) are as follows:

Required amount of egg shells are sun dried for 72 hours then egg shells were kept in a furnace preheated to a temperature of 1000 degree Celsius for a period of 45 minutes and then converted to powder using the grain miller after cooling to room temperature.

The obtained powder was passed through sieves of required size so as to obtain particles with uniform size distribution.

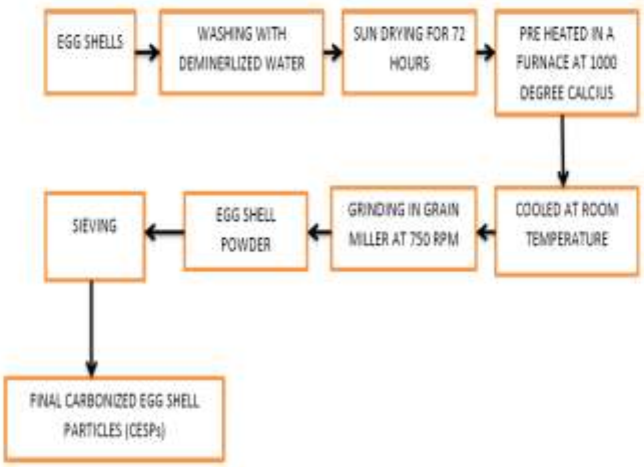

Fig.5. Process flow diagram

Egg shells

Carbonized Egg Shells

Carbonized Egg Shells Powder

Fig.6. Egg shells to carbonized egg shells powder

2. Silicon carbide particles are preheated in the induction resistance furnace at 1100 c for 1 hour to make their surfaces oxidized.

3. Aluminum alloy6061 (circular rod) is heated to the temperature of 950 (above the liquidus temperature of alloy) for 30 minutes.

4. The furnace temperature was first raised above the melting temperature so that the alloy scraps completely melt and was then cooled down to keep the slurry in a semi-solid state. At this stage the preheated SiC (5 micron) and carbonized eggshells particles were added and mixed manually.

5. After sufficient manual mixing is done, the composite slurry is reheated to a fully liquid state and then automatic mechanical mixing is carried out for about 10 minutes at a normal stirring rate of 250 rpm.

6. In the final mixing process, the furnace temperature was controlled within 760±10 degree Celsius.

7. Pouring of the composite slurry has been carried out in the sand mould prepared according to the specifications for hardness, impact and normalized displacement test. A sand pattern for solid rod was made whose dimensions were 25mm thick and 300mm in length.

Composites	Compositions
A1	Aluminium (90wt %) +silicon carbide (5wt %) +carbonized eggshells (5wt %)
A2	Aluminium (87wt %) +silicon carbide (5wt %) +carbonized eggshells (8wt %)

Designation of composites:

Furnace

pattern

pouring

sample

Fig.7 Process Flow

RESULT AND DISCUSSION:

3.1 Tensile Test: Tensile test is one of the major mechanical properties of component. Tensile test shows various properties such as tensile strength, elongation and yield strength. In my work to find the tensile result I am using a servo- hydraulic UTM.

TABLE:

Sample	Composition	Tensile strength results (TEMP 30 DEGREE C)	Unit of measure ments
A1	Aluminum (90wt %) +silicon carbide (5wt %) +carbonized eggshells (5wt %)	79.49	N/sqmm
A2	Aluminum (87wt %) +silicon carbide (5wt %) +carbonized eggshells (8wt %)	87.10	N/sqmm

Sample Tested:

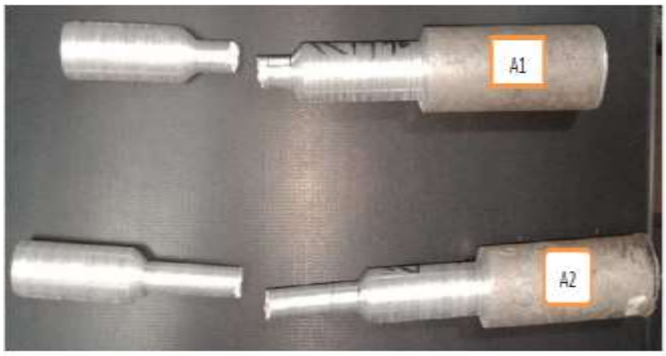

Fig.8. Tensile Test

CHART:

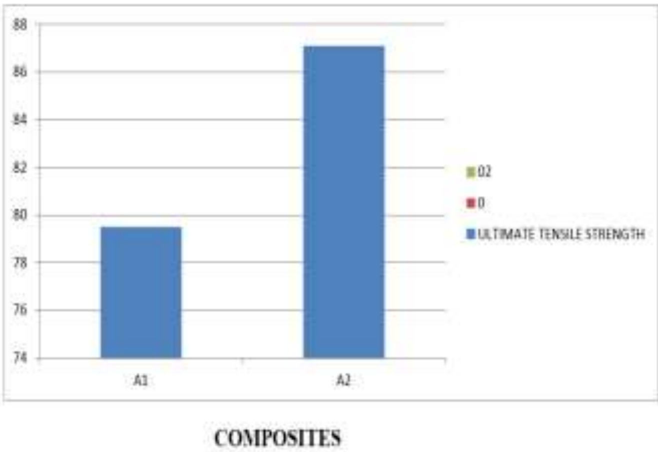

Fig.9. Comparison of ultimate tensile strength of two composites

Yield Test:

TABLE:

Sample	Composition	Yield strength (TEMP 30 DEGREE C)	Unit of measure ments
A1	Aluminum (90wt %) +silicon carbide (5wt %) +carbonized eggshells (5wt %)	73.37	N/sqmm
A2	Aluminum (87wt %) +silicon carbide (5wt %) +carbonized eggshells (8wt %)	76.74	N/sqmm

CHART:

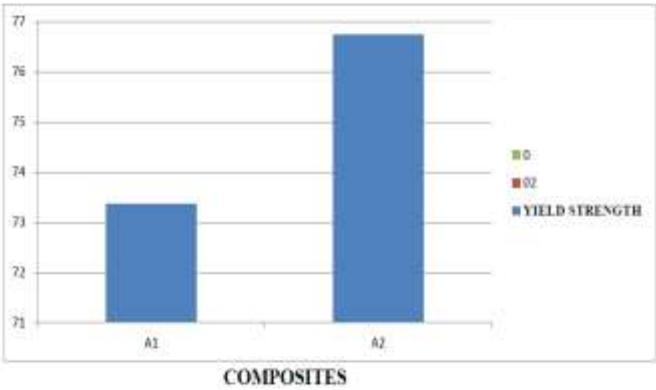

Fig.10.Comparison of yield strength of two composites

TABLE:

Elongation Test:

Sample	Composition	Elongation (TEMP 30 DEGREE C)	Unit of measure ments
A1	Aluminum (90wt %) +silicon carbide (5wt %) +carbonized eggshells (5wt %)	1.74	%
A2	Aluminum (87wt %) +silicon carbide (5wt %) +carbonized eggshells (8wt %)	2.54	%

CHART:

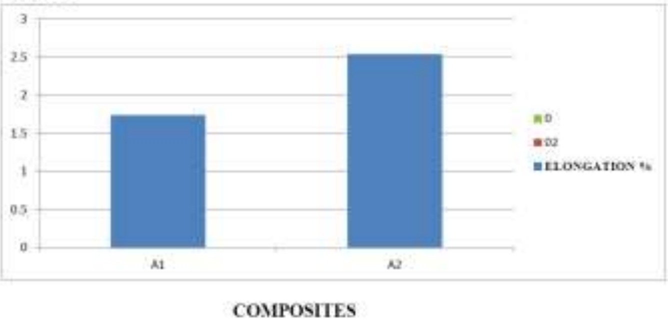

Fig.11.Comparison of elongation chart of two composites

The result shows that after adding 3% more carbonized eggshells particles in composite A2 it was giving 7.61 N/sqmm more tensile strength then A1. So after adding some specific amount of CESPs the tensile strength of the composite was improved. Same as for yield strength and elongation tests both are improved by added some 3% more carbonized eggshells particles in composite A2. As shown in previous charts.

3.2 Effect of reinforcement on hardness of composites:

Hardness is the property of the material which empowers it to oppose plastic misshapening, as a rule by infiltration or. The term of hardness is likewise alluded to firmness or temper, or to protection from bowing, scratching, scraped area, or cutting. Here the surface hardness of the composites is considered as a standout amongst the most vital factor that administers the wear opposition of the composites. After the reinforcement of carbonized eggshells in AL-SI matrix the results shows that hardness values of the composite A2 is increased as compare with A1. This can be attributed to the fact that after carbonization, the ESPs become more rigid due to the removal of moisture thus enhancing the hardness of composite to a level higher than the uncarbonized one. Similar trend in hardness has been observed by other researchers also. The calcium carbonate present in the ESPs on the surface of composites act as rigid particles resisting the surface plastic deformation and resulting in an increase in the hardness values.

Fig.12. Hardness & Microstructural Test

TABLE:

Sample	Composition	Hardness (Vickers)	unit
A1	Aluminum (90wt %) +silicon carbide (5wt %) +carbonized eggshells (5wt %)	44.2 to 51.3	HV 5
A2	Aluminum (87wt %) +silicon carbide (5wt %) +carbonized eggshells (8wt %)	50.9 TO 56	HV 5

CHART:

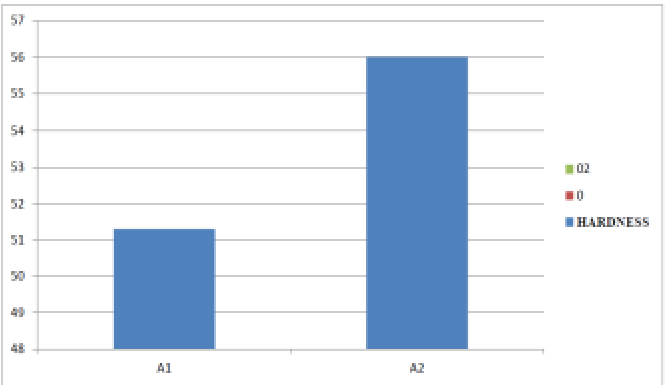

Fig.13. COMPOSTIES

4. CONCLUSIONS:

The following conclusions are drawn as per the results:

(A) Successful fabrication of Carbonized eggshells and SiC reinforced Aluminium matrix composite by Stir-casting method.

(B) Addition of 5wt% to 8wt% of Carbonized eggshells particles as reinforcement in aluminium matrix improves the hardness, tensile ,compressive,elongation and yield strength of the matrix material.

(C) Tensile strength of A1.composite (AA6061+ silicon carbide 5%wt of AA6061+ carbonized eggshells 5%wt of AA6061) is 79.49N/sqmm and for A2.(AA6061+ silicon carbide 5%wt of AA6061+ carbonized eggshells 8%wt of AA6061) is 87.10 N/sqmm Elongation of A1 composite is 1.74% and elongation of A2 composite is 2.54% and Hardness of A1 composite is 51.3 HV5 and hardness of A2 composite is 56 HV5

(D) As per results 3wt% more adding of carbonized eggshells was in A2 composite was imporving the hardness by .8% and tensile strength by 7.61 N/sqmm.

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