Mechanical Properties of Egg-Shell/Al Green Composites

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Abstract

The mechanical properties of egg-shell (ES)/ Aluminium (Al) composites have been studied. In the present work, the egg-shell reinforced composites were prepared via stir casting at a temperature of 700 ºC. The higher relative density varied in the range between ~87% to ~95% through stir casting technique and the densification of Alumnium composites reduced with the egg-shell powder addition. The hardness of composites (BHN: 99.8) increased by adding the ES powder upto 3 wt.%. The tensile strength of the composites increased upto 3 wt.% and further decreased with the addition of reinforcement. The impact strength of the ES/Al composites enhanced to 30 KJ/m^2.

Keywords
Egg-Shell/Al composites, Mechanical Properties, Stir casting, Densification.

1. Introduction
A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibers, particles, or flakes. The matrix phase materials are generally continuous. Examples of composite systems include concrete reinforced with steel and epoxy reinforced with graphite fibers etc.

They are composed of a metallic matrix (aluminium, magnesium, iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase. Examples of matrices in such composites include aluminium, magnesium, and titanium. Typical fibers include carbon and silicon carbide. Metals are mainly reinforced to increase or decrease their properties to suit the needs of the design. For example, the elastic stiffness and strength of metals can be increased and large coefficients of thermal expansion and thermal and electric conductivities of metals can be reduced, by the addition of fibers such as silicon carbide. Increasingly found in the automotive industry, these materials use a metal such as aluminum as the matrix, and reinforce it with fibers such as silicon carbide.

1.1 Objectives
The knowledge gap in the existing literature summarized above has helped to set the objectives of this research work which are outlined as follows:
Preparation of egg-shell reinforced Al composites by stir casting method
To obtain the high densification of ES/Al composites
To analyze the mechanical behaviour of composites

2. Literature Review
Historically, MMCs were among the first continuous-fiber reinforced composites studied as a model system. Initial work in the late 1960s was stimulated by the high-performance needs of the aerospace industry. In these development efforts, performance, not cost, was the primary driver. Metal-matrix composites (MMCs) have emerged as a class of materials capable of advanced structural, aerospace, automotive, electronic, thermal management and wear applications.

Pramod Kumar et al. (2019) aim to present the mechanical characteristics of the biomass fly ash reinforced aluminium metal matrix by the stir casting method. Biomass fly ash with different proportions (1%, 3%, 5%, 7%) has been reinforced in the aluminium alloy. The hardness aluminium, tensile and fracture toughness tests were performed. An alloy as reinforced material, improves the mechanical & wear properties but a high cost of creation is linked with them. The Biomass fly ash is considered a growastes, are a great alternative for utilizing as the reinforcement. The results showed that an increase in the biomass fly ash content in the melted leads results in an increase in the microhardness but decrease in the tensile strength and impactstrength. (Siddhartha Sarkar et al., 2017) describes the fabrication characteristics and mechanical behavior of aluminium alloy; Al- 6061 alloy reinforced with Silicon carbide (SiC) and Rice husk ash (RHA); an agro waste derivative. The ratios of RHA and SiC in Composites were 1:4, 2:3, 0:1 with weight percentage of 8%. The composites were prepared using stir casting method. The physical such as density and porosity test and SEM and EDX were utilized to get a proper. Microstructure images. Tensile test, Impact test, Hardness test, Machinability test were performed. It is also observed that there is a slight reduction in tensile strength and % elongation with increase in the RHA content in the reinforcement.

Yu Zou et al. (2021) describe the relationship between mechanical properties and microstructure of corn cob; where microstructures are obtained using Scanning Electron Microscope (SEM). Mechanical properties such as Axial, radial compression and three-point bending tests are performed on corn cob using universal testing machine. An Impact testing machine is used for Impact test. The results show that the pitch is a (porous sponge like tissue) has great bearing capacity while maintaining low density. It also a progressively hardening material with good buffering properties under impact loads. (S Venkatesan et al., 2017) focused on the compilation of work related to aluminium alloy matrix composite accomplished by the squeeze casting process and its process variably. The effectiveness and influence of parameters on the mechanical characteristics are observed. The influencing parameters such as temperature, processing method are considered during the investigation of mechanical characteristics of the composites. (Włodarczyk Fligier et al., 2008). In this he used two methods to produce composites one by powder metallurgy technique and another by pressure infiltration method. Both aluminium matrix composites are reinforced by ceramic particles. He concluded that pressure infiltration method gives good surface quality and powder metallurgy method helps in manufacturing small elements and pressure infiltration method consumes more energy than the power metallurgy technique. The results show they conduct different methods one is pressure infiltration and another one is powder metallurgy method.

Madhuri Deshpande et.al. (2017) successfully fabricated Pitch-based carbon fiber reinforced Al matrix composites Powder Metallurgy (PM) route. Volume % of carbon fibre are (5-50)% uncoated (UnCf) and coated milled pitch-based carbon fibers (NiCf) and AA7075 as matrix with different volume contents of carbon fibers. Uncoated and Ni coated carbon fibers were mixed with AA7075 aluminium alloy powder and subsequently hot pressed and they studied on densification and hardness. A greatest of 11% decreases in thickness is watched for 50vol% Cf composite compared to as cast Al7075. It is observed that the composites developed with uncoated carbon fibre exhibit lower values of hardness as compared with Pure Al7075 hot pressed specimen. (Niranjan K.N et al., 2017) their work was on the investigation of hybrid composites i.e, aluminium alloy 6061 as a base material and reinforced material as sic (6%) and graphite (3%,6%&9%). They calculated mechanical properties of tensile, compressive and hardness tests. They have increased the percentage of reinforcement (graphite), then the hardness will be decreased and tensile, compressive strength will be increases with the influence of sic particles. The results show that the mechanical properties of MMCs having aluminium as lattice profoundly depends on the particles utilized for fortifications, increased the percentage of reinforcement (graphite). (Niranjan nanjayyanamath et al., 2008) This paper discuss about the composite material they have taken base material as aluminium alloy 6061 and reinforcement material as fly ash (5%, 10%&15%). The particle size ranges of fly ash were 5-20, 25-30 & 50- 60μm. They calculated mechanical properties of tensile, compressive and hardness. They have expanded the rate of support (fly cinder), and after, that the hardness and compressive quality will be increments. The results show that increasing the ratio of reinforcement, and then the hardness and compressive quality will be increases.

Ajit kumar senapati et al. (2021) their work was on the study of the aluminium alloy 6061 and reinforcement as fly ash (10 and 15%wt). They have considered almost the mechanical behaviour of unreinforced combination and metal network composites. They compared the metal lattice composite arranged with 15% of fly ash debris show wat better mechanical property to unreinforced amalgam as well as MMC. The results show that they compared the metal network composite arranged with 15% of fly ash show superior mechanical properties to unreinforced amalgam as well as MMC. (Bansal and Saini, 2015) fabricated two composites. One, Al6061 with silicon carbide and the other one Al6061with silicon carbide/graphite. In both types of composites, ductility reduced because of the fact of localized crack initiation. This was due to the local stress concentration factor which has resulted in the increase in embrittlement effect. The increase in the weight% of fly ash resulted in the reduction of the ductility due to the clustering and brittleness of the particles. (Rahman and Rashed, 2013) showed that the 20% weight fraction of silicon carbide in the aluminium matrix has the maximum tensile strength. The reason for the increase in the tensile strength is due to the tensile load transfer to the strongly bonded silicon carbide reinforcement which increases the dislocation density and thus resulting in the grain refining effect. The results of the tensile test on Al6061 reinforcement with silicon carbide and particulates of graphite showed that Al6061-graphite was having higher tensile strength thanAl6061-silicon carbide.

Veeresh Kumar et al. (2021) investigated and concluded that fluid metallurgy strategies were effectively embraced within the arrangement of Al6061-SiC and Al 7075-Al2O3 composites containing the filler substance up to 6%. The densities of the composites are found made strides than their base framework. Hardness of the composites found expanded with expanded filler substance. The pliable quality properties of the composites are found higher than that of base network. Al6061-SiC composites have predominant pliable quality properties than that of Al7075-Al2O3 composites. (Saravanan and Kumar, 2014) performed the experiment on aluminium (Alsi10Mg) with rice husk ash as the reinforcing material. Rice husk was added at 9 and 12 wt.% considering different weights of microns. After analyzing its properties, it was observed that the compressive strength increased in this aspect. However, all the properties tend to decrease with increase in the size of particles. (Vinitha and Motgi, 2014) examined the parameters of aluminium 7075 with reinforcements such as silicon carbide, fly ash and red mud. The results of Charpy impact test showed that the impact strength increased with increase in the percentage of silicon carbide but decreased with increase in the percentage of fly ash and red mud. When red mud and fly ash were compared, the former showed more impact strength. The composite of aluminium alloy with silicon carbide as the reinforced material showed that as the content of silicon carbide increased, the impact energy decreased and the reason behind this was the brittle nature of the material. L. (Subash et al., 2020) performed two specimen of Magnesium with reinforcement, 4% of Alumina and 6% carbonized and uncarbonized Egg shell using casting assisted by stir casting method. The specimens were subjected to Mechanical tests such as Micro Vickers Hardness test, compression test, tensile test and impact test. In addition, the corrosion study of these uncarbonized and carbonized reinforcement was carried out and analyzed. This composite technique employed to replace the existing aluminum alloys used in the automobile and aerospace industry without compromising on its properties.

Himagireesh et al. (2019) describe the mechanical properties of aluminium metal matrix composite reinforced with the Aloe vera powder (aluminium metal matrix composites for meeting their production rates with least cost consideration without sacrificing the specific properties). Aloe vera powder as a reinforcement material for aluminium material matrix, is readily available less denser eco-friendly material at low cost and it could be alternative to the fly ash in respective of better physical and mechanical properties such as hardness, tensile, strength and impact strength. When Aloe vera used as reinforcement material to that of fly ash. (Sabitha et al.. 2020) describes the mechanical and micro structure properties of Aluminum Alloy (AA) 2024 reinforced with egg shell powder 7%,10%,13% weight percentage of egg shell powder was used to fabricate three different composites. The mechanical properties such as Tensile strength, hardness, compression strength are been evaluated. The FESEM analysis was also carried out to examine the distribution of reinforcement in matrix. The use of naturally available resources as reinforcement is being explored to reduce the cost of composites.

Balan et al. (2020) describes the tensile strength and corrosive resistance properties of the c type glass fiber and egg shell powder reinforced with aluminium alloy (Al-7075) in a fixed proportions and composites are produced through Stir casting method. As the addition of egg shell powder, corrosion in habitors and C type glass fiber addition increases the tensile strength of aluminium & composites. In results it is found that due to inclusion of glass fiber the tensile strength of material increases and addition of egg shell powder increases the corrosion resistance. (Verma et al., 2018) In this 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. There are two composites have different egg shell weight percentage A1. (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. (Kumar and Kanagaraj, 2014) produced the aluminium hybrid composite of Al6061/silicon carbide/graphite/alumina and concluded that addition of 17% weight fraction of alumina increased the tensile strength but graphite showed no significant change. The reason might be the thermal mismatch which tends to be the major driving force for increasing the dislocation density of the base alloy.

3. Materials and Methods

3.1 Preparation of egg-shell Powder

The egg-shell were collected, they had been then washed with water to eliminate any foreign objects and the skinny outer membrane. The egg-shell had been then sun dried for duration of 48 hours in dry condition. The dried egg-shell were then pulverized to attain fine powder with the help of a grain miller. This powdered egg-shell is properly weighed according to the requirements and separated as shown in Figure 1. Mix the alloy with the egg-shell powder with different percentages. First take the first sample accordingly.

Table 1. Composition of egg-shell powder in aluminium.

S. No	Composition (wt %)	Weight (g)
1	0	250.0 + 0
2	3	242.5 + 7.5
3	5	237.5 + 12.5
4	7	232.5 + 17.5
5	9	227.5 + 22.5
6	11	222.5 + 27.5
7	13	217.5 + 32.5

3.2 Melting of aluminium scrap

The aluminiusm is melted in the induction furnace at the temperature 700°C. Induction furnace capacities range from less than one kilogram to one hundred tonnes, and are used to melt iron and steel, copper, aluminum, and precious metals. The advantage of induction furnace is a clean, energy-efficient and well controllable melting process compared to most other means of metal melting**.** Most modern foundries use this type of furnace, and now also more iron foundries are replacing cupolas with induction furnaces to melt cast iron, as the former emit much dust and other pollutants. Since no arc or combustion is used, the temperature of the material is no higher than required to melt it; this can prevent loss of valuable alloying elements. The one major drawback to induction furnace usage in a foundry is the lack of refining capacity; charge materials must be clean of oxidation products and of known composition and some alloying elements may be lost due to oxidation. The Figure 1. shows the induction furnace is used for melting of aluminium.

Figure 1. Induction furnace used to melt the aluminium scrap chips.

3.3 Mixing of reinforcement and matrix

The main operation was done on stir casting machine. Stir casting process is mainly used for manufacturing of particulate reinforced metal matrix composite (PMMC). It is a primary process of composite production whereby the reinforcement ingredient material is incorporated into the molten metal by stirring with a speed of 25 rpm. The stir casting of metal matrix composites involves producing a melt of the selected matrix material followed by the introduction of a reinforcement material into the melt before adding the reinforcement material the melt should be subjected to a suitable medium, because the molten metal reacts with atmospheric oxides and undergoes oxidation by degrading the properties of the base materials. The machine consists of a crucible and furnace. The crucible is placed on the top end of the machine. The reinforcement (aluminium and egg-shell) are put in the crucible. The Figure 2 shows the stir casting machine.

Figure 2. Stir casting machine to mix the egg-shell powder in Al matrix.

3.4 Sample preparation

Sand casting process is used for sample preparation, utilizes expendable sand molds to form complex metal parts that can be made of nearly any alloy. Because the sand mold must be destroyed in order to remove the part, called the casting, sand casting typically has a low production rate. The sand-casting process involves the use of a furnace, metal, pattern, and sand mold. The metal is melted in the furnace and then ladled and poured into the cavity of the sand mold, which is formed by the pattern. The process cycle for sand casting consists of six main stages, which are explained below. They Are (1) Pattern Making (2) Making of mould (3) Heating of mould (4) Pouring (5) Solidification (6) Fetling (7) Cleaning.

3.4.1 Pattern Making

Patterns come in many materials, including wood, metal, plastics, and wax. The pattern material is chosen based on the casting volume and process used. Wood and metal patterns are usually used with sand casting, while wax is rarely used but investment casting. Patterns vary in complexity, depending on the size, shape, and number of resulting castingsrequired. The patterns used for casting the metal matrix composite are shown in the above Figure 3.

Figure 3. wooden patterns for castings.

3.4.2 Making of mould

The first step in the sand casting process is to create the mold for the casting. In an expendable mold process, this step must be performed for each casting. A sand mold is formed by packing sand into each half of the mold. The sand is packed around the pattern, which is a replica of the external shape of the casting. When the pattern is removed, the cavity that will form the casting remains. Any internal features of the casting that cannot be formed by the pattern are formed by separate cores which are made of sand prior to the formation of the mold. Further details on mold-making will be described in the next section. The mold-making time includes positioning the pattern, packing the sand, and removing the pattern. The mold- making time is affected by the size of the part, the number of cores, and the type of sand mold. If the mold type requires heating or baking time, the mold-making time is substantially increased. Also, lubrication is often applied to the surfaces of the mold cavity in order to facilitate removal of the casting. The use of a lubricant also improves the flow the metal and can improve the surface finish of the casting. The lubricant that is used is chosen based upon the sand and molten metal temperature. Figure 4 shows the process of preparing the mould for casting of the metal matrix composite.

Figure 4. Mould preparation.

3.4.3 Heating of mould

Mould temperature has a greater influence on the quality and productivity of plastic products. Mould temperature and its fluctuations have influence on shrinkage, dimension stability, mechanical properties, deformation, stress cracking and surface quality. The surface of mould cavity is heated by a flame as shown in Figure 5, and then the metal can be poured.

Figure 5. Heating of mould.

3.4.4 Pouring

After the preparation of the molten metal according to their chemical composition for casting, and conversion of aluminium from a solid to a liquid state in a furnace. The molten metal is maintained at a set temperature in a furnace, after the mold has been clamped then molten metal transferred in a ladle to the molding area of the foundry where it is poured into the molds. The pouring can be performed manually as shown in Figure 6 or by an automated machine enough. Molten metal must be poured to fill the entire cavity and all channels in the mold. The filling time is very short in order to prevent early solidification of any one part of the metal.

Figure 6. Pouring molten metal into mould.

3.4.5 Solidification

The molten metal that is poured into the mold will begin to cool and solidify once it enters the cavity. When the entire cavity is filled and the molten metal solidifies, the final shape of the casting is formed. The mold cannot be opened until the cooling time has elapsed. The desired cooling time can be estimated based on the wall thickness of the casting and the temperature of the metal. Most of the possible defects that can occur are a result of the solidification process. If some of the molten metal cools too quickly, the part may exhibit shrinkage, cracks, or incomplete sections. Preventative measures can be taken in designing both the part and the mold and will be explored in later sections. Figure 7 shows the solidification of the molten metal in the mould.

Figure 7. Solidification of egg-shell/Aluminium composites.

3.4.6 Fettling

After the predetermined solidification time has passed, the sand mold can simply be broken, and the casting removed. This step, sometimes called shakeout, is typically performed by a vibrating machine that shakes the sand and casts out of the flask. Once removed, the casting will likely have some sand and oxide layers adhered to the surface. Shot blasting is sometimes used to remove any remaining sand, especially from internal surfaces, and reduce the surface roughness. The Figure 8 shows the removal of the solidified part from themould.

Figure 8. Removal of the solidified part.

3.4.7 Cleaning

During cooling, the material from the channels in the mold solidifies attached to the part. This excess material must be trimmed from the casting either manually via cutting or sawing, or filing as shown in Fig. 3.10 and Fig. 3.11. The time required to trim the excess material can be estimated from the size of the casting envelope. A larger casting will require a longer trimming time. The scrap material that results from this trimming is either discarded or reused in the sand-casting process. However, the scrap material may need to be reconditioned to the proper chemical composition before it can be combined with non- recycled metal and reused.

4. Characterization

a. Density measurement

A material's density is defined as its mass per unit volume. Put another way, density is the ratio between mass and volume or mass per unit volume. It is a measure of how much "stuff" an object has in a unit volume (cubic meter or cubic centimeter). Density is essentially a measurement of how tightly matter is crammed together. To calculate the density (usually represented by the greek letter "ρ") of an object, take the mass (m) and divide by the volume (v):

$\rho = m / v$

The SI unit of density is kilogram per cubic meter (kg/m3). It is also frequently represented in the cgs unit of grams per cubic centimeter (g/cc).

b. Hardness measurement.

The Rockwell scale is a hardness scale based on the indentation hardness of a material. The Rockwell test measures the depth of penetration of an indenter under a large load (major load) compared to the penetration made by a preload (minor load). There are different scales, denoted by a single letter, that use different loads or indenters. The result is a dimensionless number noted as HRA, HRB, HRC, etc., where the last letter is the respective rockwell scale. When testing metals, indentation hardness correlates linearly with tensile strength. The determination of the Rockwell hardness of a material involves the application of a minor load followed by a major load. The minor load establishes the zero position. The major load is applied, then removed while still maintaining the minor load. The depth of penetration from the zero datum is measured from a dial. The material gives a lower measure. That is, the penetration depth and hardness are inversely proportional. The chief advantage of Rockwell hardness is its ability to display hardness values directly, thus obviating tedious calculations involved in other hardness measurement techniques.

c. Impact strength measurement.

The Izod impact strength test is an ASTM standard method of determining the impact resistance of materials. A pivoting arm is raised to a specific height (constant potential energy) and then released. The arm swings down hitting a notched sample, breaking the specimen. The energy absorbed by the sample is calculated from the height the arm swings to after hitting the sample. A notched sample is generally used to determine impact energy and notch sensitivity. The test is similar to the charpy impact test but uses a different arrangement of the specimen under test. The izod impact test differs from the charpy impact test in that the sample is held in a cantilevered beam configuration as opposed to a three-point bending configuration. The impact is a very important phenomenon in governing the life of a structure.

d. Tensile strength measurement.

Tensile strength of the metal matrix composite are performed on universal testing machine (UTM), also known as a universal tester materials testing machine or materials test frame, is used to test the tensile strength and compressive

strength of materials. An earlier name for a tensile testing machine is a tensometer. The "universal" part of the name reflects that it can perform many standard tensile and compression tests on materials, components, and structures (in other words, that it is versatile). The set-up and usage are detailed in a test method, often published by a standards organization. This specifies the sample preparation, fixturing, gauge length (the length which is under study or observation), analysis, etc.
The specimen is placed in the machine between the grips and an extensometer if required can automatically record the change in gauge length during the test. However, this method not only records the change in length of the specimen but also all other extending / elastic components of the testing machine and its drive systems.

5. Results and discussion

a. Densification

The density values of ES/Al composites are listed in Table 1. From Table 1, we can conclude that after calculating density on different samples of compositions 0%, 3%, 5%, 7%, 9%, 11%, 13%. It is observed that density is constantly decreasing by increasing the percentage of egg-shell powder. The increase in density of ES/Al is observed because the density of egg-shell powder is less than aluminium.

Table 1. The density of ES/Al composites**.**

S. No	Sample	Density (g/cc)
1	AL+0% ES	2.56
2	AL+3% ES	2.53
3	AL+5% ES	2.51
4	AL+7% ES	2.48
5	AL+9% ES	2.45
6	AL+11% ES	2.40
7	AL+13% ES	2.34

b. Hardness

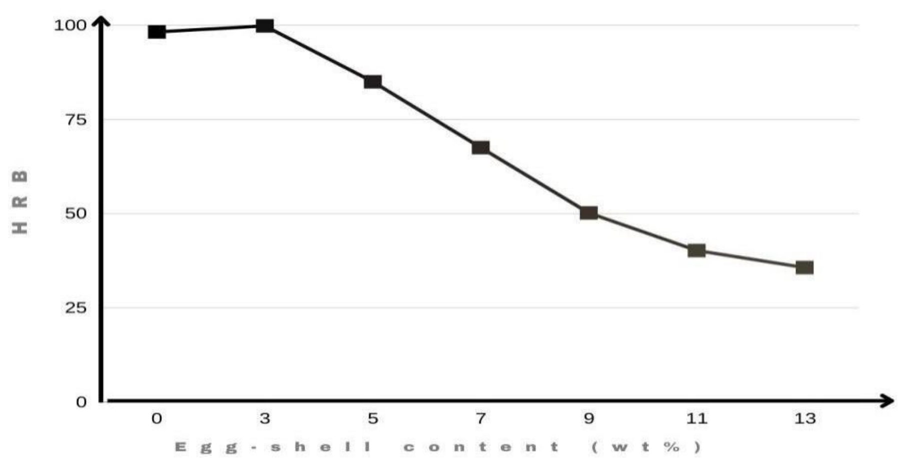

Figure 9. Hardness of egg-shell/Al compostes.

From the Figure 9 we can conclude that after conducting hardness test on different samples of compositions (0%, 3%, 5%, 7%, 9%, 11%, 13). The hardness is been gradually decreasing with increase in the percentage of egg-shell powder. The maximum hardness of the ES/Al composite varied in the range between 99 to 35 HRB. It is maximum at 3% due to less porosity and high denstification of the composite.

Table 2. Rockwell hardness test results.

SAMPLE	HRB					Average
AL+0% ES	94	100	98.0	97.3	102	98.2
AL+3% ES	95	102	102	98	102	99.8
AL+5% ES	86.5	85.2	90.2	83.7	79.6	85.0
AL+7% ES	65.2	63.1	72.0	65.2	72.1	67.5
AL+9% ES	54	42.6	53.6	42.6	58.2	50.2
AL+11% ES	39	42.5	40.9	36	43	40.2
AL+13% ES	37	36.8	34.0	38	33	35.7

c. Tensile strength

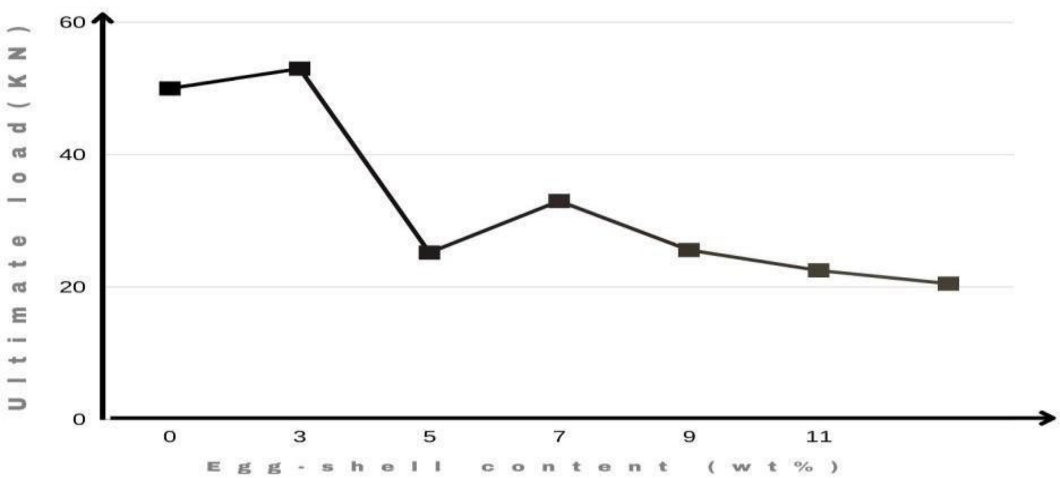

Figure 10. Ultimate load graph.

The above Figure 10 shows as ultimate load is increased with increase in the percentage of egg-shell powder at 3% and gradually decreased for other compositions. The ultimate load of the ES/Al composite varied in the range of 50 KN to 20 KN.

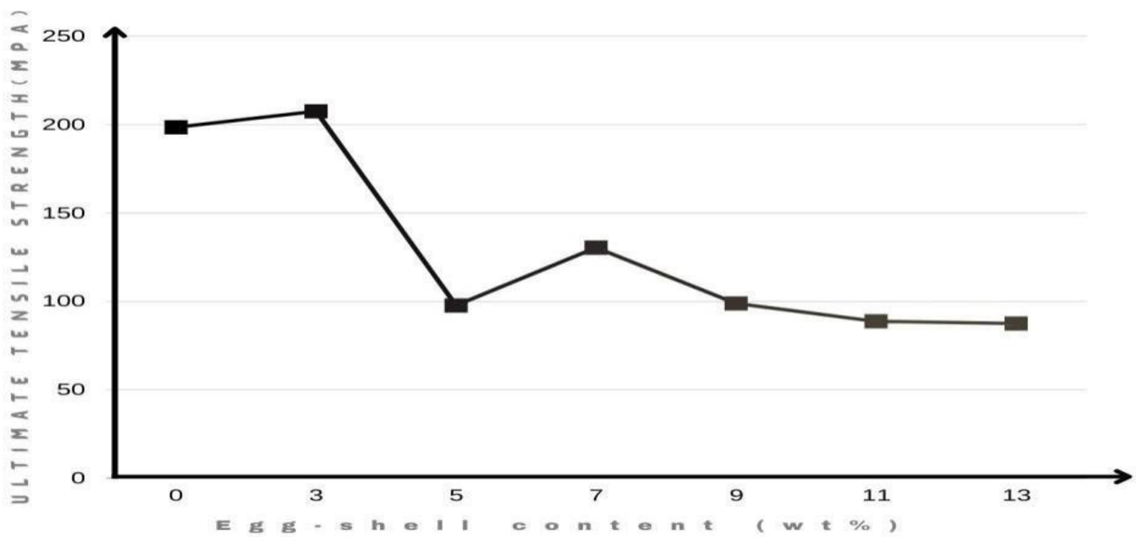

Figure 11. Ultimate tensile strength graph.

Figure 11 shows ultimate tensile strength is increased with increase in the percentage of egg-shell powder at 3% and gradually decreased for other percentages due to less porosity and high densification of the composite. The maximum ultimate tensile strength of the ES/Al composites varied in the range between 207 MPa to 87 MPa.

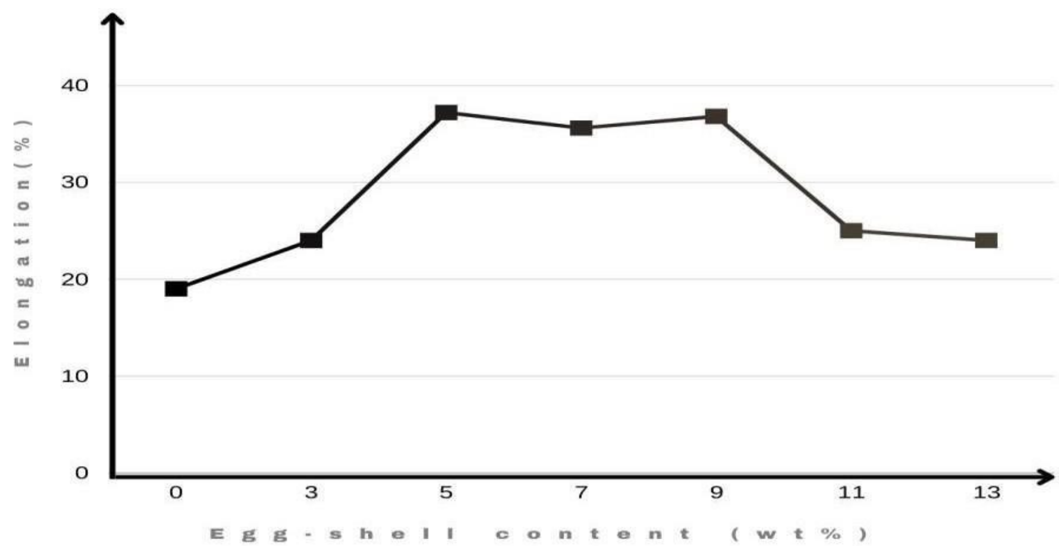

Figure 12. Elongation graph.

The above Figure 12 shows percentage elongation is been gradually increasing with increase in the percentage of egg-shell shell powder unto 5% due to less porosity and high densification of the composite. The percentage elongation of the ES/Al composite varied in the range between 19% to 37%.

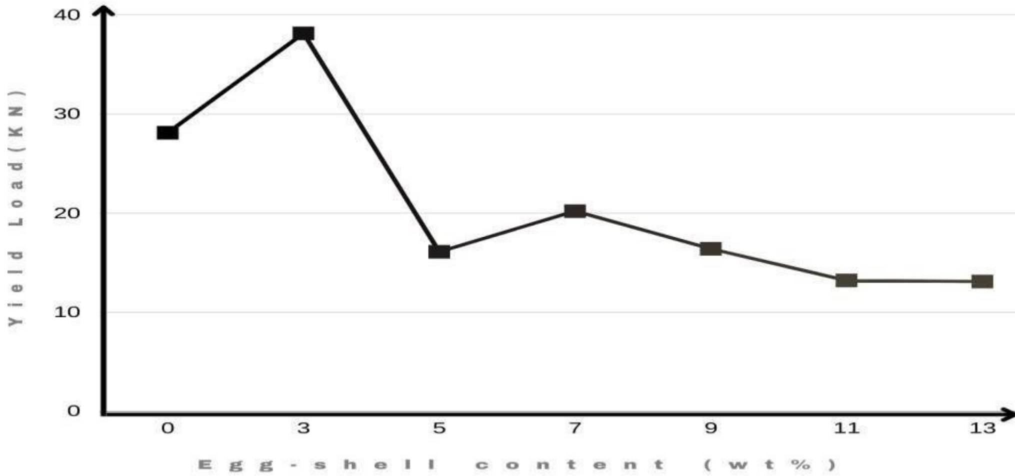

Figure 13. Yield load graph.

As shown in above graph the yield load is been gradually increasing with increase in the percentage of egg-shell powder upto 3% due to less porosity. The maximum yield load of the ES/Al compositevaried in the range between 28 KN to 13 KN.

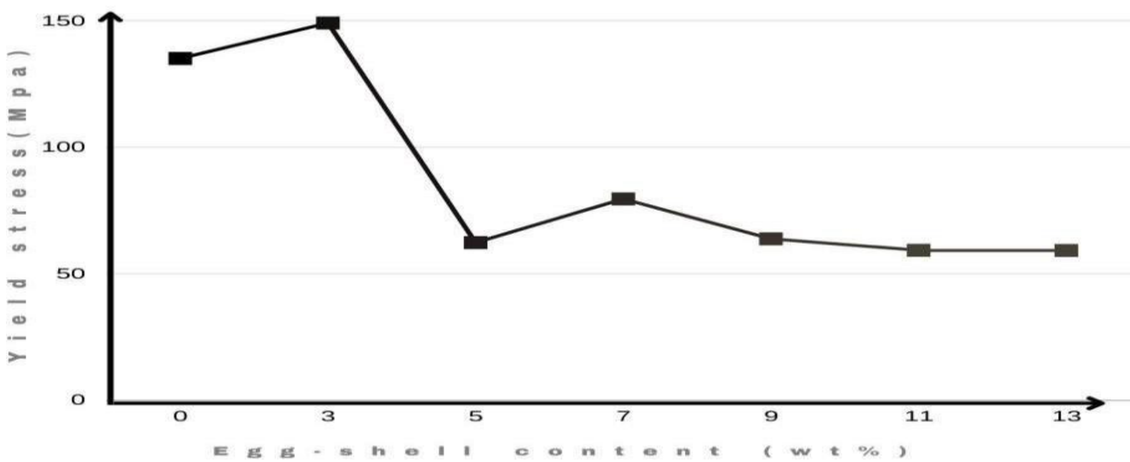

Figure 14. Yield stress graph.

The yield stress is been gradually increasing with increase in the percentage of Egg shell powder upto 3% due to less porosity and high denstification of the composite. Hence we conclude that the maximum yield stress is attained at 3% of egg-shell powder.
From the above graphs we can conclude that after conducting tensile strength test on different samples of compositions (0%, 3%, 5%, 7%, 9%, 11%, 13%). The tensile strength is been gradually increasing with increase in the percentage of Egg shell powder between 3%- 5%.

Table 3. Tensile test results.

Analysis	**ES content (wt.%)**						
	0%	**3%**	**5%**	**7%**	**9%**	**11%**	**13%**
Ultimate Load (KN)	50.0	53.0	25.2	33.0	25.6	22.5	20.5

Ultimate Tensile Strength (MPa)	198.5	207.5	97.7	130.4	99.8	88.7	87.5
Elongation %	19%	24 %	37.2 %	35.6 %	36.8 %	25%	24%
Yield Load (KN)	28.1	38.120	16.10	20.2	16.4	13.2	13.1
Yield Stress (MPa)	135.1	149.1	62.3	79.6	63.8	59.3	59.2

d. Impact strength

In the above Tables (Table 2 and 3) impact load on different samples of compositions (0%, 3%, 5%, 7%, 9%, 11% and 13%) are noted. The average has been calculated based on the impact 1 and impact 2 and graph has been drawn between impact load and wt % of egg-shell powder. The impact strength of the ES/Al composite varied in the range between 11.0 to 30.0 kgf (Figure 13, 14 and 15).

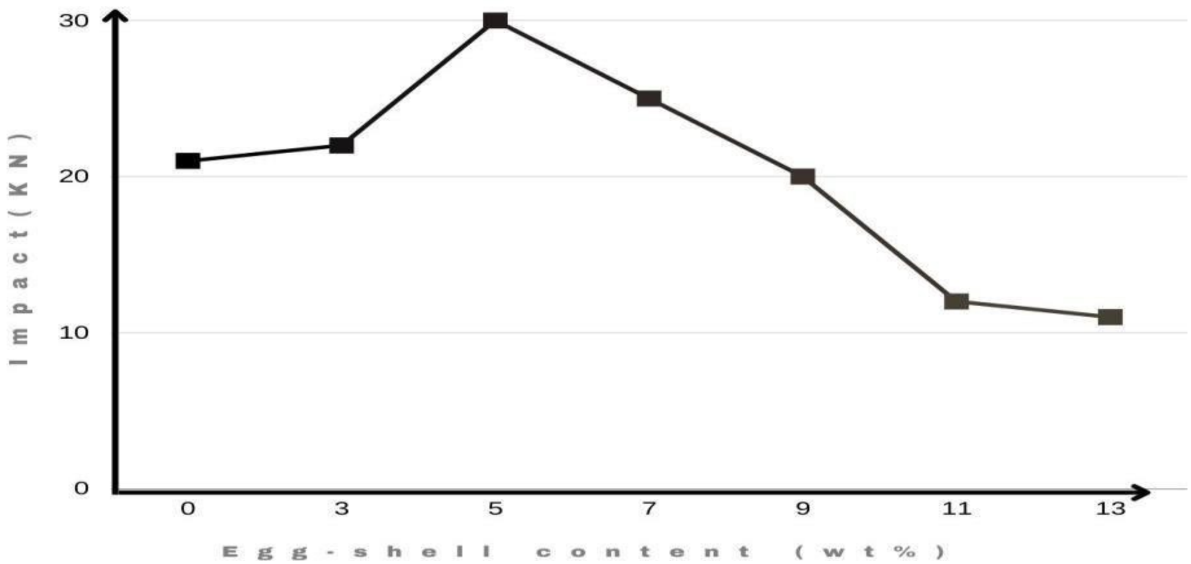

Figure 15. Impact strength graph.

The impact strength is been gradually increasing with increase in the percentage of egg-shell powder upto 5% due to minimal porosity. The maximum impact strength of the ES/Al composites varied in the range between 30 kgf to 11 kgf (Table 4).

Table 4. IZOD Impact test results.

	Impact strength (kgf)		
SAMPLE	**Sample 1**	**Sample 2**	**Average**
AL+0% ES	20	22	21.0
AL+3% ES	23	21	22.0
AL+5% ES	31	29	30.0
AL+7% ES	25	25	25.0
AL+9% ES	22	18	20.0
AL+11% ES	11	13	12.0
AL+13% ES	11	11	11.0

6. Conclusion

The mechanical properties such as impact strength, tensile strength, hardness as well as density of the composites are greatly influenced by the weight percentage of egg-shell powder in the matrix. The aluminium alloy and egg-shell powder composites were successfully fabricated by stir casting with different compositions like (0%, 3%, 5% , 7%, 9%, 11%, 13%) of egg- shell powder. The rise in impact strength value upon increasing the percentage quality of egg-shell shell powder upto 5% and decreases if further egg-shell powder is added. Increment in the tensile strength has been observed but only up to a certain extent i.e, beyond 5% egg-shell Shell powder, there is a substantial reduction in the tensile strength.

The hardness of composite depends upon the hardness of the reinforcement and matrix. The mixing of egg-shell powder less than 5% attains more tensile strength and hardness values. On comparing the impact strength from it shows that 3% - 5% of reinforcement of egg-shell powder has good effectiveness of impact strength. In the density there is constant decrease in the density as the wt% of egg-shell powder increases. Even though the trends in the various tests suggest that Al6061 alloy reinforced with egg-shell is not the way forward, its still serves as a better replacement that non reinforced Al6061 alloy. Egg-shell powder can thus be said to have a bright future to function as a supplementing reinforcement for the production of low-cost high performance aluminium hybrid composites.

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