PREPARATION OF A NOVEL ALUMINIUM ALLOY BASED COMPOSITE BY REINFORCING COMPOSITE BY REINFORCING WITH A WASTE COCONUT SHELL ASH MATERIAL

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ABSTRACT

Many researchers have been carried out previously in the area of conventional metal matrix composite material to improve the mechanical properties and implemented in wide area of application for both automobile and aerospace industry. The present work aims to effect of mechanical properties on waste material such as Coconut Shell Ash (CSA) reinforced aluminium alloy (A356) matrix composites. The most significant objectives of this research are to select a waste material for preparation of reinforcement material incorporate with aluminium alloy for developing a new material. The present study is based on a CSA particle of 5% and 10% by weight were used to develop metal matrix composites using a liquid metallurgical process. In this work, the mechanical properties such as tensile strength, compressive strength, impact strength and hardness are studied for reinforced CSA composites. The outcomes reveal that the percentage reinforcement of CSA will increase ultimate tensile strength, compressive strength and hardness of composite material.

1. INTRODUCTION

For many years there has been a continuous quest for high performance materials to operate in ever more extreme conditions of temperature and environment, without incurring a high weight penalty. These Conditions arise in critical areas such as aerospace/defence and the nuclear sectors, as well as in civilian sectors such as automotive and other applications. Researches all over the world today are focusing on ways of utilizing, either industrial or agricultural wastes as a source of raw materials for the industry. These wastes utilization would not only be economical, but may also result to foreign exchange earnings and environmental pollution control [1]. In recent years there has been an incredible interest in composites containing low density and low cost reinforcements.

Aluminium alloys are among the traditional engineering materials considered to fulfil the above requirements, and have been used extensively to successfully meet many of the needs of industry. It should also be noted that, Aluminium based matrices also have the advantage that they are the cheapest among other competing matrix materials (Copper, Titanium, Magnesium) for metal matrix composites (MMCs) development.

Alloy A356 has greater elongation, higher strength and considerably higher ductility than Alloy 356. A356 has improved mechanical properties because of lower iron content, compared to 356. Here, A-356 alloy was used so as to evaluate the effect of reinforcements on the structure and mechanical properties of the composite without modification effects. This has made AMCs as a strong competitor to steel and other relevant alloy for use in a wide range of engineering applications.

Among various reinforcements used like SiC, Al_2O_3etc., Coconut shell ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by product. Coconut shell is an agricultural residue from the coconut.

2. LITERATURE REVIEW

Aluminium is widely used as a structural material for the aerospace industry, automobile sectors because of its light weight property. The various reinforcement element such as SiO_2, SiC particles and whiskers are added to aluminium to reduce the problem involved with the help of various methods like powder metallurgy, stir-casting method, infiltration casting, direct melt oxidation, hot dipping.

The various waste products when disposed to the land they will produce CO_2 gas due to burning. So, the reuse of this waste is required to reduce the environmental pollution. The aim of this project is to utilise largely available coconut shell ash as reinforcement in the production of aluminium matrix composite and developing new materials with superior mechanical properties.

2.1 Composite

Composites are usually man-made materials but can also be sometimes natural such as wood. They are mostly formed by the combination of two different materials separated by a distinct Interface. The properties of a composite as a whole are enhanced as compared to the properties of its components. Composites are typically used in place of metals because they are equally strong but much lighter. The two phases that make up a composite are known as reinforcing phase and matrix phase. The reinforcing phase is embedded in the matrix phase and mainly provides strength to the matrix. The reinforcing phases usually found in composites are particles, fibers or sheets and the matrix materials can be of the form of polymers, ceramics or metals.

2.1.1 Why to Use Composite?

The most important advantage associated with composites is their high strength [2] and stiffness along with low weight. This high strength to weight ratio enables the greater usage of composites in space applications where being light and strong is given prime importance. The fibers present in composite share the load applied and prevents the rapid propagation of cracks as in metals. It is because they can be moulded to form various shapes be it easy or complex. Composites with proper composition and manufacturing can withstand corrosive and high temperature environments. With all these advantages it is obvious to think why the composites have not replaced the metals. One major drawback linked with the composites is its high cost which is often due to the use of expensive raw materials and not due to the manufacturing processes.

2.1.2 Types of Composites

On the basis of the reinforcing phase and matrix phase the composites can be classified into the following:

ON THE BASIS OF REINFORCEMENT

1. PARTICLE REINFORCED COMPOSITE

Particle reinforced composites are again divided into large particle composites and dispersion strengthened composites [3]. In large particle composites the size of particles is larger than that of dispersion strengthened composites. Concrete and Reinforced Concrete are examples of large particle composites. In dispersion strengthened the particle size varies from 10-100 nm. Sintered Aluminium Powder (SAP) is an example of dispersion strengthened composite.

2. FIBER REINFORCED COMPOSITE

Fiber reinforced composites can be further subdivided into continuous and discontinuous fibers. Continuous fibers are those which have lengths normally greater than 15 times the critical length (l >15 lc) and discontinuous fibers have lengths shorter than this. The discontinuous fibers can be aligned or randomly oriented. Examples of some fibers are carbon fibers, boron fibers, E-glass fibers, SiC fibers, etc.

3. STRUCTURAL COMPOSITE

The most commonly used structural composites are laminar composites and sandwich panels. Laminar composites are made up of sheets or panels which are two-dimensional.

ON THE BASIS OF MATRIX

1. POLYMER MATRIX COMPOSITE (PMC)

They contain polymer as the matrix phase and fibers such as E-glass, carbon or aramid as the reinforcing phase. The different varieties of Polymer-Matrix Composites (PMC) which are mostly used are Glass Fiber-Reinforced Polymer (GFRP) composites, Carbon Fiber-Reinforced Polymer (CFRP) composites and Aramid Fiber-Reinforced Polymer Composites. The most commonly used polymers as matrix are vinyl esters and polyesters.

2. CERAMIC MATRIX COMPOSITE (CMC)

The ceramic matrix composite contains ceramic materials as matrix phase. CMCs are developed primarily to improve the fracture toughness of ceramic materials. This dispersed phase can be fibers, particles or whiskers.

3. METAL MATRIX COMPOSITE (MMC)

The matrix phase for a MMC is a metal. MMCs are having high strength to weight ratio, high resistance to abrasion and corrosion, resistance to creep, good dimensional stability, and high temperature operability. Usually Aluminium and Copper are used as the metal matrix.

4. HYBRID COMPOSITE

In a hybrid composite usually there are two or more fibers which are different from one another in a single matrix phase. The generally used hybrid composite is the one which contains polymeric resin as the matrix and both glass and carbon fibers as reinforcing phase.

2.2 Metal Matrix Composite

A metal matrix composite (MMC) is a type of composite material with at least two constituent parts; one being a metal, the other material may be a different metal or another material, such as a ceramic or organic compound.

2.2.1 Why Aluminium (Al356) Used As Matrix

Aluminium is considered as the most popular matrix for the metal matrix composites (MMCs). When aluminium or aluminium alloy is taken as matrix and reinforced with say SiC, Al_2O_3etc then the composite is termed as Aluminium metal matrix composite. They are very attractive due to their isotropic mechanical properties and their low costs. The Al alloys are quite attractive due to their low density, their capability to be strengthened by precipitation, their good corrosion resistance, high thermal and electrical conductivity, and their high damping capacity.

The various advantages of Aluminium matrix are improved stiffness, low density Enhanced electrical performance, improved damping capacity, and improved abrasion and wear resistance, Improvement of corrosion resistance, Reduction of thermal elongation, Increase in fatigue strength etc.

Table 2.1 Chemical Composition of Aluminium A356 Alloy

Si	Fe	Cu	Mn	Mg	Zn	Ni	Ti
6.5-7.5	0.15	0.03	0.10	0.4	.07	0.5	0.1

Table 2.2 Chemical Composition of CSA

Constituents	SiO_2	MgO	Al_2O_3	Fe_2O_3	CaO
%	45.05	16.2	15.6	12.4	0.57

2.3 Liquid Metal Technique

This technique involves the incorporation of dispersed phase into matrix phase followed by solidification. To provide high mechanical properties of the composite good bonding between the dispersed phase and the liquid matrix should obtain. The simplest and the most cost effective method of liquid state fabrication is sit casting.

The various liquid state fabrications of metal matrix composites are:

- Stir casting
- Infiltration
- Pressure Die infiltration
- Gas Pressure infiltration
- Deposition process

2.3.1 Stir Casting Process

Stir casting process is relatively simple and less expansive as compared to other processing methods. Stir casting is a liquid state method of composite material fabrication, in which the dispersed phase is mixed with a molten metal matrix by means of mechanical stirring .The liquid composite material, is then cast by conventional casting methods and may also be prepared by conventional metal forming technologies. This liquid metallurgy technique is the most economical of all the available routes for metal matrix composite production. Its advantages lie in its simplicity, flexibility and applicability to large quantity production.

DENSITY

A material's density is defined as its mass per unit volume. It is, essentially, a measurement of how tightly matter is crammed together. The principle of density was discovered by the Greek scientist Archimedes. The symbol for density is ***ρ (rho).***

Mathematically

$$\rho = m / v$$

Where ρ is the density, m is the mass, and V is the volume. The SI unit of density is kilogram per cubic meter (kg/m^3).

The Archmedics Principle, states that when an object is totally or partially immersed in a fluid, the weight of the object is equal to the weight of the fluid displaced.

HARDNESS

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration and scratching. Hardness is dependent on ductility, elastic stiffness, plasticity, strain, strength, toughness, viscoelasticity, and viscosity. The various method used for the determination of hardness are Brinnel, Rockwell, Vikers hardness test.

BHN can be found as,

$$BHN = \frac{P}{(\pi D/2)\left(D - \sqrt{D^2 - d^2}\right)} = \frac{P}{\pi D t}$$

Where,

P is applied load in N = 187.5 kgf,
D is diameter of ball in mm,
d is diameter of indentation in mm,
t is depth of the impression in mm

CHARPY TEST

The Charpy impact test, also known as the Charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's notch toughness. It is widely applied in industry, since it is easy to prepare and results can be obtained quickly.

COMPRESSION

Compression is a process in force is applied from both sides by keeping the cylindrical material in between two plates. For brittle materials, the compressive strength is relatively easy to obtain, showing marked failure. However, for ductile materials, the compressive strength is generally based on an arbitrary deformation value.

TENSILE STRENGTH

The tensile strength of a material is the maximum amount of force that it can take before failure, for example breaking. It is customarily measured in units of force per cross-sectional area. The various points involved in tensile strength are Yield point, Ultimate point and Breaking point.

The engineering stress is:

$$\sigma = \frac{P}{A_0}$$

Where,

P is the load in Non the specimen and

A_0 is the original cross-sectional area near the center of the specimen

During the tensile test, the elongation of the gauge section is recorded against the applied force. The elongation measurement is used to calculate the engineering strain, ε, using the following equation:

$$\varepsilon = \frac{l - l_0}{l_0}$$

3. EXPERIMENT AND PROCEDURE

3.1 Powder Preparation

The coconuts were collected from a nearby local temple. The 500 coconut half shells were sun-dried for three to four days. Sun-drying was necessary to ease removal of the meat from the inner shells of the coconut pieces. After scraping the meat from the inner shells, the inner portions of the shells were cleaned using knives. The fibres on the outer shells were also scraped and cleaned. Emery paper was used to clean the outer shells.

Figure 3.1 Coconut Shell

The cleaned coconut shells obtained were cut into pieces of dimensions of 1 sq.cm. using hammer and were put in stainless steels containers. The containers were then kept into muffle furnace for carbonization (carbonization is the production of charred carbon from a source material.

Figure 3.2 Crushed coconut shell

The process is generally accomplished by heating the source material usually in the absence or limited amount of air to a temperature sufficiently high to dry and volatilize substances in the carbonaceous material). The carbonization temperature selected as 600 and 800 degrees. After a soak time of 4 hours, the sample gets carbonized. As the furnace cools down, containers were taken out.

Figure 3.3 Coconut shell power

The collected char was ground to form powder using a grinding machine. The powder was then sieved to a size of 150 μm with the help of standard sieves**.** Further Ball milling is carried out to get the particle size as 50 μm.

Figure 3.4 Coconut shell ash

3.2 Composite Preparation

After the preparation of the reinforcing material i.e coconut shell ash then the composite preparation was carried out. For this Al A356 alloy heated to 700-750*C till the entire alloy melted, which is carried out in a Crucible made of graphite. CSA prepared for reinforcement is preheated to 400-450*C for 1 hour before mixing in melt. Then the molten metal (Al alloy, A356) is stirred to create a VORTEX and the particulate are added and Stirring is done at 600-650rpm.

Then the preheated CSA particle is added slowly in small packets of aluminum foil constantly for better mixing and uniform composition and Stirring is continued for another 5 minutes. Mixture is then poured to the mold (cylindrical with diameter of 30mm and length of 300mm) which is also preheated to 350-500*C for 20 minute for uniform solidification.

MOLD:

Shape : Cylindrical

Dimension: Diameter:-30mm and Length:-300mm

3.3 Density Test Procedure

The density is the mass per unit volume of a substance.

Mathematically, $\rho = M / V$

The density can be measured by various methods. But we have measured the density by **Archimedes' Principle.** According to this principle, when an object totally or partially immersed in a fluid, then the weight of the object is equals to the weight of the water displaced by the object.

At first measure the diameter and length of the sample using vernier calliper. Take a graduated beaker and put water in it to a known level of height. Then put the sample in the beaker. So that the level of water will rise in beaker due to the weight of sample. Measure the raised water level height in the beaker. Then find out difference between the initial and final height of water in the beaker. Using the following formula we can find out the density of the sample,

$$\rho_1 V_1 = \rho_2 V_2$$

Where ρ_1 =density of sample

V_1 =volume of the sample, $\frac{\pi}{4}d^2h1$

d =diameter of the sample

h_1 =height of sample

ρ_2 =density of water

V_2 =volume of water displaced

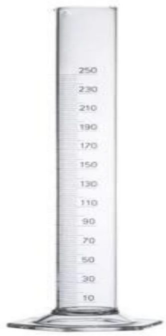

Figure 3.5 Graduated Beaker

3.4 Hardness Test Procedure (Brinnel Hardness Number,BHN)

In this project we have measured the Brinnel hardness number the samples. At first the samples are prepared to the dimension of 10mm*17mm .Then the sample is placed on the base of the plate and the indenter is having a diameter of 10mm. The indenter is pressed on the surface of the sample. The pressing of the indenter is done with the help of a constant load. The applied load is 187.5 kgf. Then the indentation is magnified with the help of a microscope and find out the diameter of the indentation. Using the formula we can find out the Brinnel hardness number.

$$BHN = \frac{P}{(\pi D/2)\left(D-\sqrt{D^2-d^2}\right)} = \frac{P}{\pi D t}$$

Where, P= Applied load (187.5kgf)

D =Diameter of the indenter (10 mm)

d =Diameter of the mark on the sample

Figure 3.6 Brinnel Hardness Testing Machine

3.5 Compression Test Procedure

At first the samples are prepared to the dimensions of length to diameter ratio (L/D) as 1.5. Then the specimen is placed centrally between the two compressions plates, such that the centre of moving head is vertically above the centre of specimen.

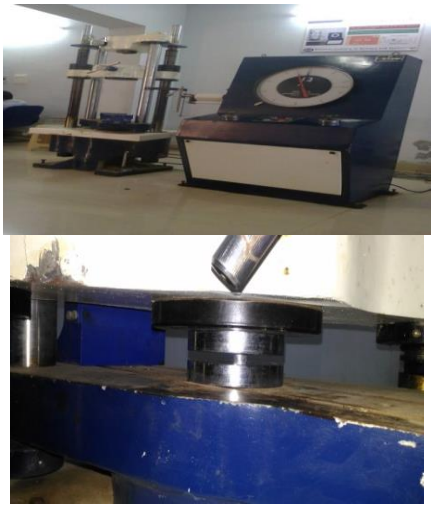

Figure 3.7 Universal Tester Machine; Specimen during test

Load is applied on the specimen by moving the movable head towards down. And the samples are compressed to the different percentage such as (10%, 20%, 30%, and 40%) as per our requirement.

Figure 3.8 Composite specimens showing bulge profiles at various deformation stages under compression testing

Apply the load until the specimen fails. Then find out the load at which the sample is compressed, from the display of UTM.

3.6 Charpy Test Procedure

The specimen is prepared as per the requirement i.e. 10mm * 10mm. The notch of 2mm is done on the specimen with the help of triangular files.

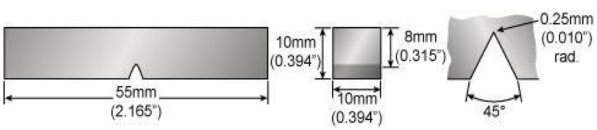

Figure 3.9 Notched Specimens

Then the specimen is placed in the base of impact test machine and is struck and broken by a single blow with the help of a cylindrical rod. The energy absorbed by the specimen before failure can be find out from the displacement of pointer.

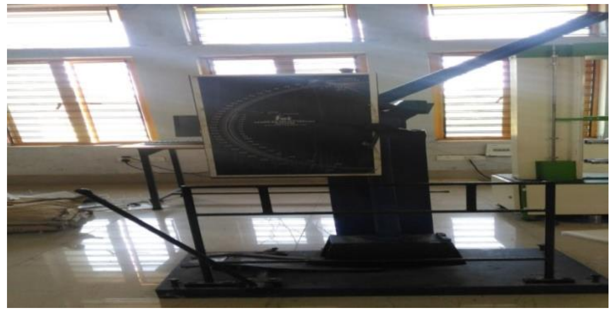

Figure 3.10 Impact Test Instrument

3.7 Tensile Test

The tensile test is a common test performed on metals, wood, plastics, and most other materials. The specimen required for tensile test is prepared in the workshop.

Figure 3.11 Tensile specimen

Gauge length=23.5mm Diameter=6.4mm

Care is to be taken to ensure that the specimens did not have any notching or cracks from manufacturing or any surface defects that would adversely affect the tensile tests.

Before loading the specimens in the tensile machine, the computer system connected to the machine was set up by inputting the necessary information of gauge length and width of the specimen. The computer system was then prepared to record data and output necessary load-deflection graphs.

The test sample is securely held by top and bottom grips attached to the tensile or universal testing machine. During the tension test, the grips are moved apart at a constant rate to stretch the specimen. The force on the specimen and its displacement is continuously monitored and plotted on a stress-strain curve until failure.

Figure 3.12 Tensile machine

4. RESULT AND DISCUSSION

4.1 Density Test

The result of density test for the wt. % variation of reinforcement material that is coconut shell ash and matrix Al alloy A356 are shown in table number 1.

Table 4.1 Density Test Results

MATERIAL	DENSITY(g/cc)
H 1(A356 alloy+5% CSA)	0.98
H 3 (A356 alloy)	1.034

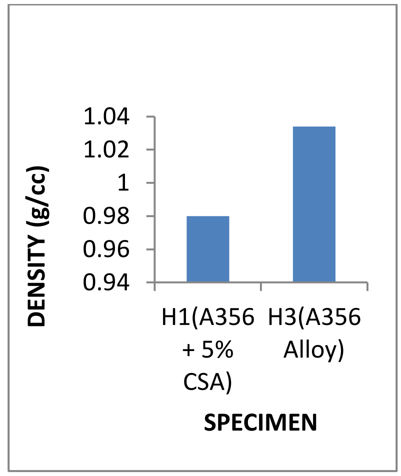

Figure 4.1 Comparison of density with % variation of CSA

In the above figure, the result shows that the density of composite material is less than the pure alloy. Due this low density, composites are light in weight than the alloys.

4.2 Hardness Test

The result of Brinnel hardness test for the wt. % variation of different reinforcement like coconut shell ash and Al alloy A356 are shown in table number 2.

Table 4.2 Hardness Test Results

MATERIAL	HARDNESS (BHN)
H 1(A356 alloy+5% CSA)	76.18
H 3 (A356 alloy)	70.58

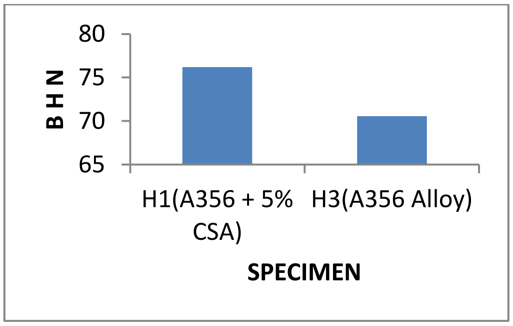

Figure 4.2 Comparison of hardness with % variation of CSA

In the above figure, the result predicts a uniform increase in hardness. This is due to increase in resistance to deformation by adding CSA as reinforcement in A356 alloy.

4.3 Charpy Test

The result of density test for the wt. % variation of reinforcement material with matrix Al alloy A356 are shown in table.

Table 4.3 Charpy Test Results

SPECIMEN (unit)	**MAX. ENERGY ABSORBED** (joule)
H 1(A356 + 5% CSA)	19.82
H 3(A356 Alloy)	17.5

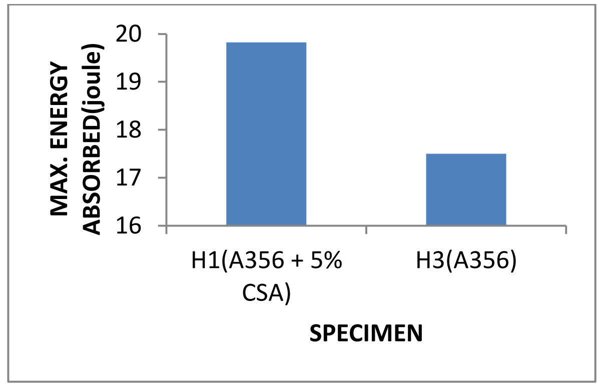

Figure 4.3 Comparison of IMPACT STRENGTH with % variation of CSA

The figure shows that with increase in the %volume of reinforcement material the Impact strength increases w.r.to base material. This is due to the proper dispersion of coconut shell ash into the matrix or stronger bonding in between the Al alloy A356 and CSA interfaces.

4.4 Tensile Test

The values for stress and strain for the various samples of aluminium alloy reinforced with coconut shell ash are given in the following table.

Table 4.4 Stress Strain Values for Sample H1 (A356 + 5% CSA)

Table 4.5 Stress Strain Values for Sample H2 (A356 + 10% CSA)

STRESS	STRAIN
1.088	0.0044
2.33	0.00881
7.46	0.13
13.99	0.017
21.15	0.022
29.54	0.026
37.63	0.030
45.41	0.035
53.18	0.039
61.89	0.044
70.29	0.048
78.38	0.052
86.15	0.057
94.24	0.061
100.77	0.066
106.37	0.070
113.53	0.074
119.75	0.079
125.66	0.083
132.19	0.088
137.48	0.092
143.07	0.096
147.43	0.101
152.09	0.105
156.76	0.110
158.63	0.114
163.29	0.118
166.40	0.123
169.51	0.127
171.07	0.132
174.18	0.136
177.29	0.140
180.71	0.145
182.27	0.149
184.13	0.154
185.69	0.158
187.24	0.162

STRESS	STRAIN
0.93	0.0044
2.48	0.0081
6.84	0.013
12.13	0.017
17.41	0.022
22.08	0.026
30.79	0.030
38.88	0.035
47.27	0.039
56.92	0.044
66.87	0.048
78.07	0.052
88.02	0.057
98.28	0.061
107.62	0.066
116.64	0.070
126.59	0.074
135.92	0.079
144.01	0.083
152.09	0.088
158.94	0.092
165.16	0.096
171.08	0.101

Table 4.6 Stress Strain Values for Sample H3 (A356 Alloy)

STRESS	STRAIN
2.33	**0.0044**
7.46	**0.0081**
13.99	**0.013**
21.77	**0.017**
28.3	**0.022**

35.76	**0.026**
45.1	**0.03**
52.87	**0.035**
56.29	**0.039**
61.58	**0.044**
69.67	**0.048**
78.07	**0.052**
84.91	**0.057**
93.62	**0.061**
100.15	**0.066**
107.3	**0.07**
113.53	**0.074**
120.99	**0.079**
126.59	**0.083**
131.19	**0.088**
134.8	**0.092**
139.76	**0.096**
143.43	**0.101**
146.09	**0.105**
148.14	**0.11**
152.18	**0.114**
154.48	**0.118**
156.66	**0.123**
158.96	**0.127**
160.78	**0.132**
162.75	**0.136**
164.55	**0.14**
166.65	**0.145**
168.25	**0.149**
170.36	**0.154**
171.05	**0.158**
172.09	**0.162**
174.25	**0.167**

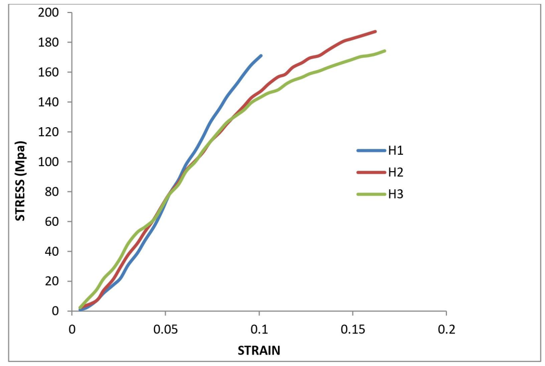

Figure 4.4 Stress vs. Strain

It exhibits a linear stress- strain relationship up to yield point. The linear portion of the curve is the elastic region and slope is the modulus of elasticity. It shows that the yield point increases as the wt. % of reinforcement increases. This happens due to dispersion of CSA which creates hindrance to dislocation motion. To remove this, a large stress is required. The ultimate tensile strength also increases as the wt. % of reinforcement increases.

4.5 Compression Test

The values for true stress and true strain for the various samples of aluminium alloy reinforced with coconut shell ash are given in the following tables.

Table 4.7 True Stress ~ True Strain Values for Sample H1 (A356 + 5% CSA)

DEFORMATION	TRUE STRESS	TRUE STRAIN
0%	0	0
10%	263.45	0.117
20%	290.41	0.23
30%	295.57	0.35
40%	315.65	0.47

Table 4.8 True Stress ~ True Strain Values for Sample H2 (A356 + 10% CSA)

DEFORMATION	TRUE STRESS	TRUE STRAIN
0%	0	0
10%	287.59	0.117
20%	320.37	0.23
30%	326.43	0.35

Table 4.9 True Stress ~ True Strain Values for Sample H3 (A356 Alloy)

DEFORMATION	TRUE STRESS	TRUE STRAIN
0%	0	0
10%	261.85	0.117
20%	285.97	0.23
30%	290.45	0.35
40%		0.47

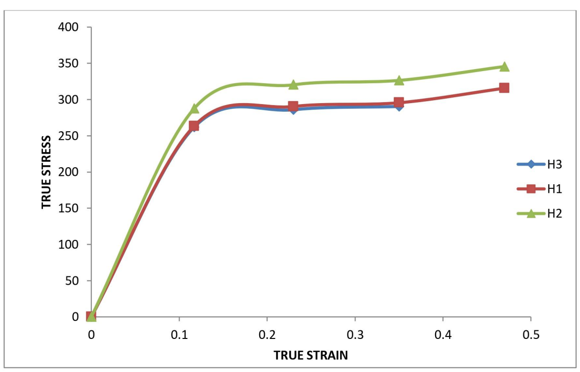

Figure 4.5 True Stress vs. True Strain

Form the curve it was observed that, both alloy and composites shows an increase in load with increasing displacement and exhibit strain hardening behaviour. The composites show higher loads than the alloy and the increase in load increases with the increasing reinforcement contents. The high work hardening is due to the presence of reinforcements and its corresponding weight fractions.

4.6 Hardness after compression

Table 4.10 Hardness after Compression

DEFORMATION(mm)	H1	H2	H3
2	69.10	69.10	69.10
4	74.07	74.07	72.57
6	79.57	92.55	85.65
8	100.24	108.90	

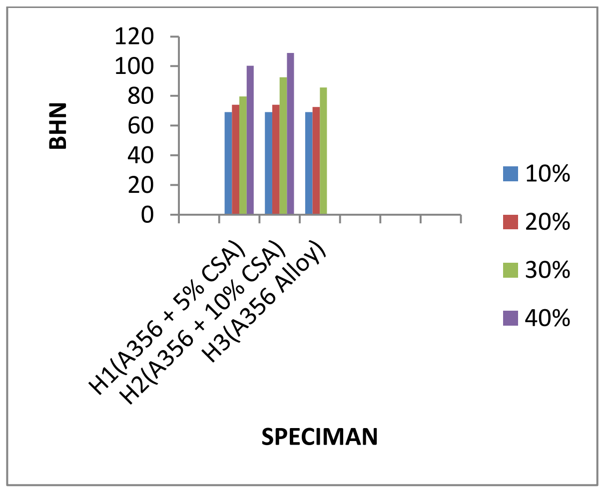

Figure 4.6 Comparison of Hardness after compression with % variation of CSA

It has found that the hardness value after compression increases with increases in the % variation of CSA. This increase in hardness is due to the increase in strength after compression test.

5. CONCLUSION

From the analysis of the results and discussion given above, the following conclusions can be made,

1. The stir formed A356 alloy with CSA reinforced composite is superior to the base

alloy A356 and the uniform distribution of CSA particles occurs.

2. The hardness test, shows an increase in Brinnel Hardness number by 7.35% due to increase in wt. % of reinforcement and proper dispersion of CSA particles.
3. It has found that the density of composites reinforced with CSA is 5% less than the base alloy.
4. Impact strength increases by 13.2% due to addition of CSA were conformed from the result.
5. It was also found that the tensile strength starts increasing with increase in wt. % of CSA.
6. Similarly, it was observed that the load required to compress the composite is more than the alloy.

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