Mechanical Behaviour of Reinforced Epoxy Composite Materials

[1]Venkatesh Rentala, [2]Chetan Reddy Kancherla, [3]Paga Pavan Kumar, [4]Avunuri Ramesh, [5]C.Srikar Rao
[6]Chenna Kesav Reddy

[1,2,3,4,5]Department of Mechatronics, JNTU Hyderabad, Telangana, INDIA
[6]Department of Mechanical engg, JNTU Hyderabad, Telangana, INDIA

Abstract : Day by day the usage of polymers is increasing and epoxy and poly epoxide being one of the examples. Recently synthetic filler material reinforced epoxy is preferring because of its better Toughness. But natural filler materials are suitable alternatives to synthetic fillers for reinforcing polymers due to their environmental friendliness, renewability, cost effectiveness and better strength.

From the previous decades nearly 80 million tons of fly ash (FA) produced every year from coal fired plants. Fly ash has good mechanical properties. The usage of fly ash is very low compared to wastage. The major constituents of fly ash are Silica (SiO_2), alumina (Al_2O_3), ferric oxide (Fe_2O_3) and calcium oxide (CaO). Orange peel (OP), one of the natural fibres has good mechanical properties and also lubricant properties. The usage of orange peel is very less compared to utilization. So the composite of fly ash and orange peel leads to a material having good mechanical and lubricant properties which will be applied under heavy machinery applications. This study assess the mechanical properties of fly ash and orange peel powder reinforced epoxy resin composite also. The epoxy resin has wide applications among all other resins. So we use Epoxy resin as binder and as a Matrix material in this study. Coconut shell powder (CSP) has good binding property and mechanical properties. Some researchers studied FA and CSP mechanical properties individually. This experimental study is to determine mechanical behavior of FA and CSP reinforced epoxy composite.

Keywords: Orange peel fiber, fly-ash, epoxy.

I. INTRODUCTION

Nowadays composite materials are emerging chiefly because of unprecedental demand from technology due to rapidly advancing activities in aircraft, aerospace and automotive industry. These materials due to their low density, excellent stiffness and good thermal and mechanical properties are particularly superior to many traditional materials such as metals. Recent developments on various applications of polymer composite are well documented in many literatures. Different types of polymer show different friction and wear behavior. However neat polymers is very rarely used as bearing materials and wear resistance material because unmodified polymer could not satisfy the demands arising from the situations wherein a good mechanical properties is required [1]. There are many application areas where these composites are used. One such importance area is mechanical applications such as bearings, gears, etc where liquid lubricants cannot be used [2] because of various constraints. These composites are also being used in applications such as pipeline carrying sand slurries in petroleum refining, helicopter rotor blade, gas and steam turbine blades, pump impellers in mineral slurry processing.

Visualizing the importance of polymer composite reinforced with cellulosic fibers like sisal, coconut(coir), bamboo, banana in their natural form as well as several waste cellulosic products such as shell flour, wood flour and pulp have been used as reinforcing agents of different thermosetting and thermoplastic composites[3-10]. The tribological behavior of these filler materials have been reported by several authors [11-15] in details. However as per the information of the authors there is no information available on the tribological behavior of fruit waste. Their results showed that there was improvement in thermal stability of the carbon black filled composite compared to the neat epoxy.

Christian J.Espionze Santos [16] performed details characteristics studies on coconut fibers. He observed that increase in weight percent of fiber reinforcement increase the flexural strength of the composite.

M L Miranda-Medina[18] carried out research work on Detection and classification of OP on polished steel surfaces by interferometric microscopy and found that OP can be used has lubricating property and OP polished surfaces can improve surface parameters.

Manoj Singla and Vikas Chawla[19] did research work on Mechanical Properties of Epoxy Resin – Fly Ash Composite and found that strength of composite could increased by reinforcing the FA into epoxy resin.

Hence in the present work an attempt has been made to study the mechanical behavior of fly-ash and orange peel reinforced epoxy composite.

II. EXPERIMENT

2.1 Materials

Orange is a citrus fruit mainly originated in Southeast Asia. It is the most commonly grown tree fruit in the world. Like all citrus fruits, the orange is acidic having pH range 2.9-4.0. OP, the outer cover part of an orange, mainly consists of cellulose, essential oils, proteins and some simple carbohydrates. The orange peels were collected locally and were sun dried for 7 days with care. Sun drying was necessary to remove the moisture from the peels as shown in figure 2.1. The fibers were then grinded into fine powder as shown in figure2.2. The collected powders were sieved as shown in figure 2.3 and a particle size distribution in a sample of +90 to +150 microns was around taken as per volume% calculation, for the present investigation we have taken this particle size for further experimentation.

Fig: 2.1 orange peels

Fig: 2.2 orange peel powder

Flyash:

Silica (59.5%), Alumina (20.3%), FeO /Fe2O3 (6.5%), remaining being FeO, MgO and unburnt coal etc.The FA collected locally and sieved and a particle size distribution in a sample is +90 to +150 microns was around taken as per volume% calculation, for the present investigation we have taken this particle size for further experimentation.

Coconut Shell Powder:

Take some coconut shells and dry under sun for two days to remove moisture content. Rub coconut shells with emery paper until we get smooth surface. Drop some smooth surfaced shells in ball mill for grinding. After some time remove the material from basin. The CSP powder collected and sieved and a particle size distribution in a sample is +90 to +150 microns was around taken as per volume% calculation, for the present investigation we have taken this particle size for further experimentation.

Fig: 2.3Fly-ash

2.2 Methods

A sheet mould (dimension 170X60X8mm) figure-2.4 was used for casting the composite sheet. A mould release spray was applied at the inner surface of the mould for quick and easy release off the composite sheet. A calculated amount of epoxy resin and hardener (ratio of 10:1 by weight) was taken and mixed with OP, FA and CSP powder particulate with gentle stirring to minimize air entrapment.

After keeping the mould on a sheet (Applied with Mould releasing spray) the mixture is then poured into it as shown in figure 2.5. Care was taken to avoid formation of air bubbles. Pressure was then applied from the top and the mould was allowed to cure at room temperature for 72 hrs.

Fig: 2.4 Mould composite material

Fig: 2.5Mould after pouring

During application of pressure some amount of epoxy and hardener squeezes out. Care has been taken to consider this loss during manufacturing so that a constant thickness of sample could be manufactured. This procedure was adopted for preparation of mentioned weight fractions of OP & FA and CSP & FA. After 72 hrs, the samples were taken out of the mould as shown in figure 2.6, cut into different sizes and kept in air tight container for further experimentation.

Fig: 2.6 Samples after removing from mould

2.2.1 Density Measurement

The theoretical density of composite materials in terms of weight fraction is found out from the following equations as given by Agarwal and Broutman [17]

$\rho ct = \sum \rho iVi$

Where 'v' , 'i' and 'ρ' represents the volume fraction, invidual component and density respectively. The suffix f, m and ct stand for the fiber, matrix and the composite materials. The void content of composite sample has been determined as per ASTM D-2734-70 standard procedure respectively. The volume fraction of voids (Vv) in the composites was calculated by using equation:

$$V_v = \frac{\rho_t - \rho_a}{\rho_t}$$

Where ρ t and ρ a are the theoretical and actual density of composite respectively.

2.2.2 Hardness Test

Leitz Micro –hardness tester was used for Hardness measurement. The operating lever is kept in horizontal position. Then the specimen is placed on the test table the hand wheel is turned in clockwise direction such that the specimen touches of the ball indenter. Initially 3kg load applied on the specimen. Then the load is applied gradually over the indenter by moving the lever u from horizontal position and apply some white Powder for clear visibility under microscope. For Brinnel hardness test, the diameter of the indentation as shown in figure 2.7 can be calculated by using Microscope as shown in figure 2.8 with a graduated scale in it. Calculate the BHN by using the given formula. Brinnel hardness number (BHN) is calculated by using following relation

$$BHN = \frac{2P}{\Pi D (D - \sqrt{D^2 - d^2})}$$

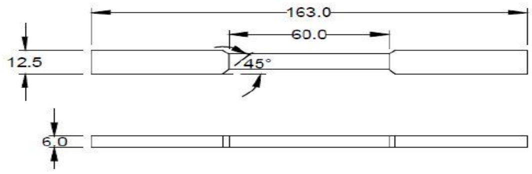
D is Diameter of indenter, d is Diameter of indentation and P is load applied.

Fig:2.7 Specimens indented Leitz Micro –hardness tester.

Fig: 2.8. Indentation Measuring under Leitz Microscope.

2.2.3 Tensile Test

The tension test is generally performed on flat specimens. The most commonly used specimen geometries are the dog-bone specimen, followed figure, and straight-sided specimen with end tabs. The standard test method as per ASTM D3039-76 has been used. The length of the test specimen used is 163 mm. The tensile test is performed in universal testing machine (UTM). The tests were performed with a cross head speed of 0.5mm/min. For each test composite of single sample was tested and value was taken for analysis. Figure shows the machine used for the test and the sample in loading condition.



Dog bone shape of the tensile testing sample

$$S_u = \frac{P_{max}}{A_o}$$

Su is Tensile Strength, Pmax is maximum load and Ao is Original cross sectional area.

2.2.4 Absorption Test

Long term water immersion method was used to determine the absorption behavior of composites. The conditioned composite sample was placed in a beaker with water at 23±1o. At the end of 24 hours one of the sample is removed from the water at a time, all surface water wiped off with a dry cloth and weighed immediately and then replaced in the water and this procedure was repeated at every 24 hours till 3 days and the data was recorded. The percentage increase in weight was calculated to the nearest 0.01% by using equation as follows,

$$\text{Increase in weight\%} = \frac{\text{Wet Weight - Conditioned weight}}{\text{Conditioned weight}} \times 100$$

III. RESULTS AND DISCUSSION

3.1 Density

From the figure 3.1 it is observed that as the reinforcement percentage of FA increases in the epoxy the Volume fraction of voids % decreases gradually up to 30 %. Whereas comparing theoretical densities density is less at OP-10%, FA-20%.

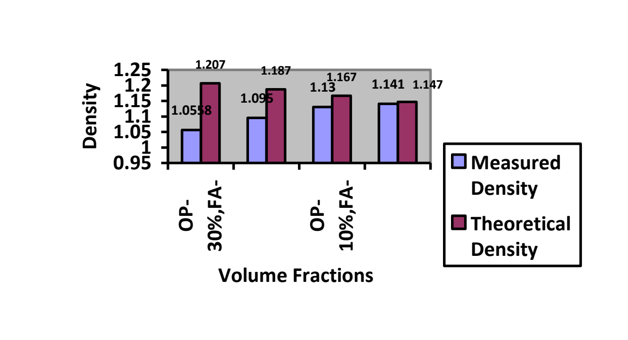


Fig: 3.1. Densities of different samples

As the reinforcement percentage of fly ash increases in the epoxy the Volume fraction of voids % decreases gradually up to 30 %.

Volume Fractions of Particulates (%)	Measured Density (gm/cm3)	Theoretical Density (gm/cm3)	Volume fraction of voids (%)
CSP-30%,FA-0%	1.0857	1.00227416	9.58868
CSP-20%,FA-10%	1.107865	1.056145	4.66842
CSP-10%,FA-20%	1.15778	1.103916	4.6523
CSP-0%,FA-30%	1.149532	1.146	0.307255474
CSP-0%,FA-0%	1.0824	1.0812	0.1108

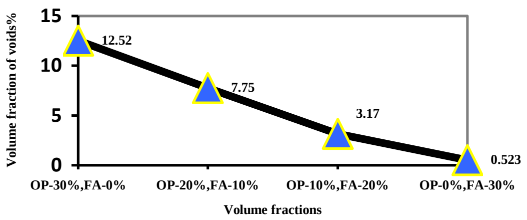
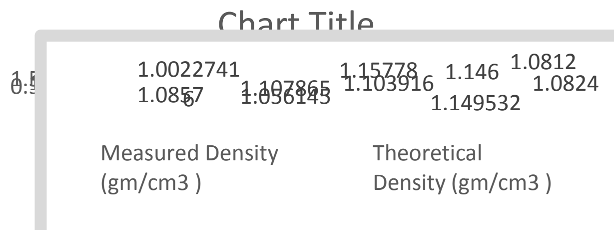
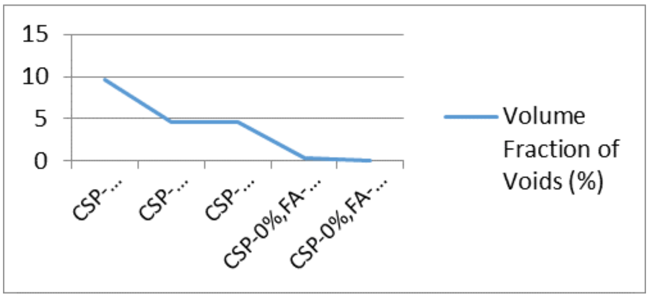


Fig:3.2. Variation of volume fraction of void% with different volume fractions

From the figure it is observed that as the reinforcement percentage of CSP increases in the epoxy the Volume fraction of voids % decreases gradually up to 30 %. Whereas comparing theoretical densities density is less at CSP-30%, FA-0%.

As the reinforcement percentage of CSP increases in the epoxy the Volume fraction of voids % decreases gradually up to 30 %.





3.2 Hardness Test

From figure 3.3 it is observed as the reinforcement of OP 10%, FA 20% hardness value be the maximum is 33.284 and then 27.219 hardness for composite of OP 30% volume fraction.

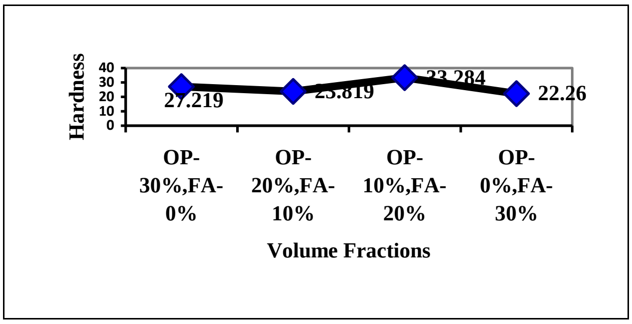
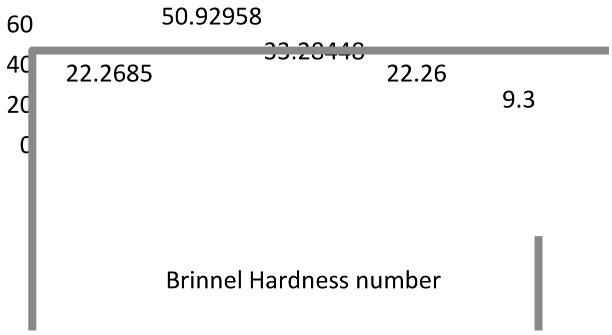
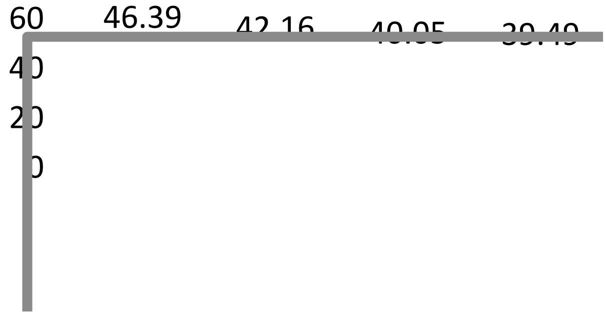


Fig: 3.3.Hardness of different samples

From figure it is observed as the reinforcement of CSP 20%, FA 10% hardness value be the maximum is 50.92958 and then 22.2685 hardness for composite of CSP 30% volume fraction.

Volume Fractions of Particulates (%)	Brinnel Hardness number
CSP-30%,FA-0%	22.2685
CSP-20%,FA-10%	50.92958
CSP-10%,FA-20%	33.28448
CSP-0%,FA-30%	22.26
CSP-0%,FA-0%	9.3





3.3 Tensile Test

From figure 3.4 it is observed that the tensile strength is maximum for the composite prepared with 10% OP and 20% FA. However, for 30% FA composite has also good tensile strength. with the help of figure:3.3.

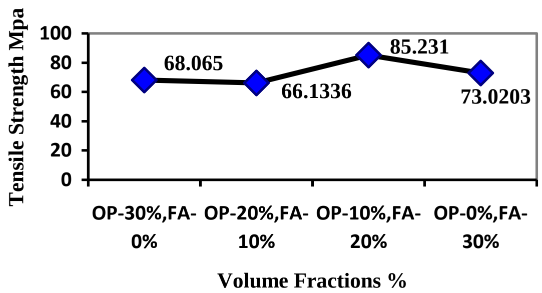
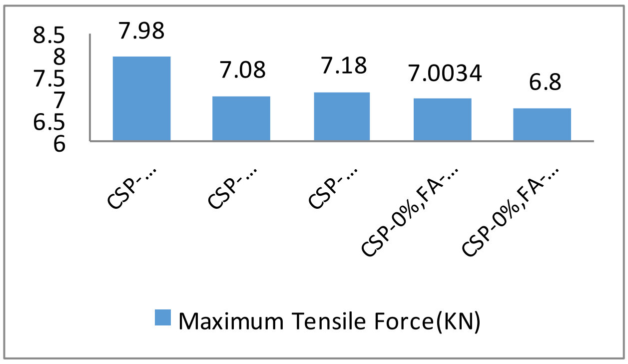


Fig: 3.4 Tensile strength with different volume fraction

From figure it is observed that the tensile strength is maximum for the composite prepared with 30% CSP and 0% FA. However, for 20% CSP and 10%FA composite has also good tensile strength.



3.4 Absorption Test

The water absorption results for various samples which are prepared with OP filler and FA with different volume fraction were plotted in figure 3.5. The water absorption graph illustrates that the minimum water absorption is for the composite prepared with 30% FA and 0% OP volume fraction. It is also observed that an increase of FA filler volume the corresponding water absorption percentage decreases and OP-30% reacts with water but remaining have less absorption and didn't react with water.

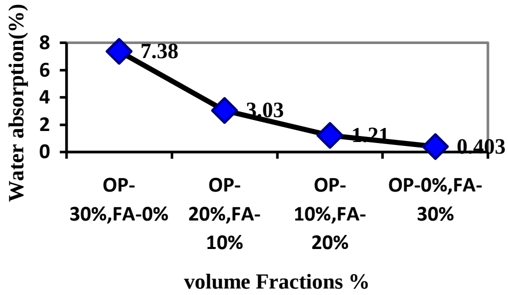


Fig: 3.5 Variation Water absorption % with different volume fractions

The water absorption for CSP and FA have water absorptioin values are below 1.45

IV. CONCLUSIONS

Based on the study of the mechanical behavior of fly-ash and orange peel fiber reinforced epoxy composites at various fiber volume fraction the following conclusions are drawn

- The density of the composite is found to be optimum and Volume fraction of voids (%) is found to be optimum with OP-10%, FA-20% volume fraction and CSP-0%, FA-30% volume fraction.
- The hardness value of the composite is found to be maximum at OP-10%, FA-20% volume fraction and CSP-20%, FA-10% volume fraction.
- The tensile strength of the composite is found to be maximum at OP-10%, FA-20% volume fraction and CSP-30%, FA-0% volume fraction.

- The water absorption% is low for orange peel-0%, fly ash-30% volume fraction.

Overall, OP-10% & FA-20% volume fraction and CSP-20% & FA-10% volume fraction best among other combinations of this composite material.

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