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Determination of Volume Fraction of Coir Fiber, Chicken Feather and Egg Shell Powder in an Epoxy based Hybrid Composite for Maximum Tensile Strength

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Abstract: The mechanical properties of an hybrid composite depends on the type and size of reinforcements selected, volume fraction of the reinforcements and manufacturing technique used. In this research epoxy based composite of varying volume fractions of chicken feather, egg shell powder and coir fiber are fabricated. This research describes the determination of optimum volume fraction of reinforcements for the development of natural fiber based hybrid polymer composite with chicken feather, coconut coir and egg shell powder as reinforcements and epoxy resin as the matrix. The optimum volume fractions of the reinforcements are determined for obtaining maximum tensile strength of the resulting hybrid composite.
Keywords: Epoxy Resin, Chicken feather, Coir fiber, Egg shell powder, Hybrid Polymer Composite.

I. INTRODUCTION

Composites consist of a bulk material (matrix) and reinforcement which is added primarily to increase the strength and stiffness of the matrix. Composites with single fiber reinforcement improve the property of the base material. But at particular percentage limit the reinforcement to the base material fails to improve the property to further extent, rather it decrease its strength which made the researches to go for hybridization of composite which considerably increase and improves the performance of the material beyond the single fiber reinforced composite that is intended to be developed for suitable application. A composite material is made by combining two or more materials to give a tailored combination of properties. The matrix material is a base material and the reinforcement may be natural or synthetic depending upon the property requirement and on the application where it is used and most importantly economical and eco friendly. If the composite has more than one reinforcement, it is said to be a hybrid composite material.

Hybrid composites are more advanced composites as compared to conventional FRP composites. Hybrids can have more than one reinforcing phase and a single matrix phase or single reinforcing phase with multiple matrix phases or multiple reinforcing and multiple matrix phases. They have better flexibility as compared to other fiber reinforced composites. Normally it contains a high modulus fiber with low modulus fiber. The high- modulus fiber provides the stiffness and load bearing qualities, whereas the low-modulus fiber makes the composite more damage tolerant and keeps the material cost low. The mechanical properties of a hybrid composite can be varied by changing volume ratio and stacking sequence of different plies. The purpose of hybridization is to extend the concept of 'tailoring' the material's properties to suit particular design requirements, and to offset the disadvantages of one component by the addition of another.

Feathers represent 5 to 7% of the total weight of mature chickens. As a result, poultry processing plants produce a substantial amount of feathers as waste by-product and represent a sizable waste disposal problem. Although land application is an option, continued application can result in extreme high soil nitrogen levels with run-off contaminating streams and ground water with both chemicals and bacteria. A current value-added use for feather is its conversion, following treatment at high temperature and milling, to feather meal/ animal flour and used as a protein supplement into feed mixtures of domestic animals. This mammoth size of discarded feather, apart from polluting the soil or air, also causes various human ailments including chlorosis, mycoplasma and fowl cholera. The poultry feathers pollute the soil, or when burnt pollutes the air. Chicken feathers are a complex and branched structure resulted from the biological evolution and they cover approximately 10 % of the chicken's weight. In general, they consist of three main units called rachis also known as quill, barbs and barbules. The barbules are considered as the tertiary structures which are attached to the secondary structures called barbs. Barbs are then attached to the rachis which is the primary structure of the feather.

The presence of honeycomb structures of chicken feather is the main reason for the low density of barbs which also provides air and heat insulating capabilities different to any other natural fiber. None of the natural or synthetic fibers commercially available have a density as low as that of chicken feathers which is around 0.8 g/cm^3. Coir is a versatile natural fibre extracted from mesocarp tissue, or husk of the coconut fruit. Mature brown coir fibres contain more lignin and less cellulose than fibres such as flax and cotton and so are stronger but less flexible. The coir fibre is relatively waterproof and is the only natural fibre resistant to damage by salt water. Egg-shell waste is potentially a suitable candidate for an ecological filler material for reinforced biopolymeric composites owing to improving their mechanical properties and the heat stability

The objective of this study is to determine the optimal volume fraction composition of coir fiber, chicken fiber and egg shell powder for maximum tensile strength of the resulting epoxy based hybrid composite and to explore the areas of application for the resulting composite.

Kishor S. Joshi and Sunita M. Bagewadi (2016) studied various properties of Chicken quill including density, tensile strength, specific modulus, % elongation and compared with other fibers. They concluded that chicken quill can be used as a reinforcing material using epoxy/polyester resin as matrix material [1]. Avwerosuoghene Moses OKORO, Isiaka Oluwole OLADELE, Moshibudi Caroline KHOATHANE (2016) studied the effect of chemical treatment (0.1 M KOH solution) on Brown chicken feather fibers (BCFF) in HDPE matrix composite. The composite samples from the chemically modified chicken feather fibers exhibited better mechanical properties in terms of tensile properties and flexural strength [2]. Isiaka O. Oladele, Jimmy L. Olajide and Adekunle S. Ogunbadejo (2015) studied the influence of chemical treatment on the mechanical behaviour of animal Fibre-Reinforced HDPE Composites. Chicken feather and cow hair fibres were used as reinforcement materials From the test results, it was observed that the chemically treated cow hair and chicken feather fibre reinforced high density polyethylene composites gave the best flexural properties for most fibre loading percentages [3]. Justin R. Barone and Walter F. Schmidt (2004) investigated the Polyethylene reinforced composite with keratin fibers obtained from chicken feathers. It is found that the yield strength and elastic modulus increases with the volume fraction. The keratin feather fibers can be directly incorporated into the polymer using standard thermo mechanical mixing techniques. The density of the composite upon introduction of keratin feather fiber is not increased, but reduced by 2% [4].

K .Velmurugan, A. Sanjaikumar, V.Saravanaraj and P. Rajesh Kumar (2017) studied the mechanical properties of bio material filler (egg shell), jute fiber, and feathers reinforced hybrid composite. The hybrid composites with different compositions of fibers and fillers were found to possess higher impact, tensile and hardness properties [5]. Antaryami Mishra (2017) conducted investigation of mechanical characteristics of chicken feather-teak wood dust filled epoxy composite. During these investigations it has been seen that the composite with 15 % teak wood dust and 5 % chicken feather is a good proposition for application as packing materials, instrument casings, light decorative fittings and other such applications as it has shown highest tensile strength amongst all the materials considered [6]. B. Sudharsan, Dr.S.Sunil Kumar Reddy and M.Lava Kumar (2014) studied the mechanical behaviour of eggshell and coconut coir reinforced composites. The results reveal that high compression strength is obtained for composition with largest eggshell content. The composition with largest coconut coir percentage showed increased tensile strength than egg shell powder. It is concluded that the tensile strength of composite depend on amount of coir fiber and compression strength of composite depend on eggshell quantity [7]. Shiv Kumar and Dr.B.Kumar (2012) performed the study on mechanical properties of coconut shell particle and coir fiber reinforced epoxy composite. Ultimate strength equal to 30 MPa and modulus of elasticity equal to 856 MPa is achieved for 20%wt shell particle reinforced composite. Ultimate strength of 48 MPa and modulus of elasticity of 920 MPa are achieved for 18%wt shell particle & 2%wt coir fibre and 17%wt shell particle & 3%wt coir fibre reinforced composite respectively. Elasticity decreases with increase of coir and ultimate strength decreases with increase of particle wt%. Ultimate strength and modulus of elasticity increase with addition of coir [8].

D. Chandramohan and A. John Presin Kumar (2017) studied the properties of natural fiber particle reinforced polymer composite material in which powdered coconut shell, walnut shell and Rice husk are used as reinforcements with bio epoxy resin to form hybrid composite specimens. The test result shows that hybrid composite has far better properties than single fibre glass reinforced composite under mechanical loads. However it is found that the incorporation of walnut shell and coconut shell fibre can improve the properties [9]. MD. Zyaoul Haque, Sikandar Yadav, Sunil Kumar and Sandeep (2016) studied the mechanical behaviour of coir/glass fiber reinforced epoxy based composite. It has been noticed that the various properties of the composites are greatly influenced by the fibre loading and fibre length. The void content of composites increases with increase in both the fibre

loading and fibre length. The micro-hardness value increases with increase in fibre length. As far as the effect of fibre loading is concerned, composites with 5wt% fibre loading shows better hardness value as compared to 10wt% irrespective of fibre length except for 20 mm length. A gradually increase in tensile and flexural strength can be observed with the increase in the fibre length up to 15 mm of composites. However, further increase in fibre length beyond 20 mm there is a decrease in the strength properties. It can be observed that with the increase in fibre length, the tensile modulus increases irrespective of fibre loading [10].
Senthil.J and Madan Raj.P (2015) conducted experiment on characterization of reinforced egg shell polymer composites. GP Polyester resin, calcium carbonate and egg shell powder have been utilized successfully in preparing using two different % wt. of 15% and 20% polymer composites. The tensile strength and flexural strength of the composite specimen was found to increase with increase in egg shell powder contents, and decrease in filler particle [11]. Stanislav Petrasek and Miroslav Muller (2017) studied the polymeric particle composites based on filler from hen egg shells. Polymeric particle composites, i.e. structural two-component epoxy resins CHS EPOXY 324 Lepox 1200 filled with micro particles from hen egg-shells of 10, 20, 30 and 40 wt. % concentrations, were used. The tensile strength was increased to 22 % at 10 wt. % egg-shell micro particle filler [12].
It can be concluded that there is a scope to develop a hybrid composite material by judiciously selecting the composition of Chicken feather, Coir fiber and Egg shell powder as reinforcements resulting in enhanced properties. The aim of this research paper is to optimize the composition of reinforcements for higher tensile strength of hybrid composite.

II. MATERIALS AND METHODOLOGY

A. Materials Used

The reinforcement, matrix materials and processing chemicals used in the present research are shown in Table I

TABLE I
SPECIFICATIONS OF THE MATERIALS USED IN THE RESEARCH

S.No	Materials	Specification
01	Epoxy resin (HSC 7600) Hardener (HSC 8210)	Density: 1.1 g/cm^3 UTS: 50MPa
02	Coir fiber	Density: 1.2g/cm^3
03	Chicken feather	Density :0.82g/cm^3
04	Egg shell	Density: 0.5 g/cm^3
05	Sodium Hydroxide (NaOH)	-
06	Ethanol	-

B. Chemical Treatment

The reinforcements used in the development of hybrid composite including chicken feather and egg shell powder are subjected to chemical treatment to improve the bonding between the reinforcements and the matrix material. Chicken feather was washed with water and treated with 2% of Ethanol and 1% of NaOH solution and dried in sunlight for 48 hours to remove moisture. It is then heated in an oven at 110 degree celsius to remove traces of moisture. Coir fiber is dried in sunlight for 48 hours to remove the moisture and heated in an oven at 110 degree Celsius to remove any moisture traces. Egg shell was washed with water and treated with 5% NaOH solution to protect from bacterial growth and dried in sunlight for 48 hours to remove moisture. It is then heated in an oven at 110 degree celsius to remove any moisture traces and powdered by ball milling to uniform size of 100 microns. Figure 1 shows the chemically treated chicken feather and Figure 2 shows the Coir fiber and Figure 3 shows the Egg shell powder used for the composite fabrication.

Fig. 1 Chemically treated chicken feather

Fig. 2 Coir fiber

Fig. 3 Egg shell powder

C. Hand Layup Method

Hand layup method is used in the fabrication of chicken feather, coir fiber and egg shell powder based hybrid composite. The process flow chart of hand layup technique is show in Figure 4.

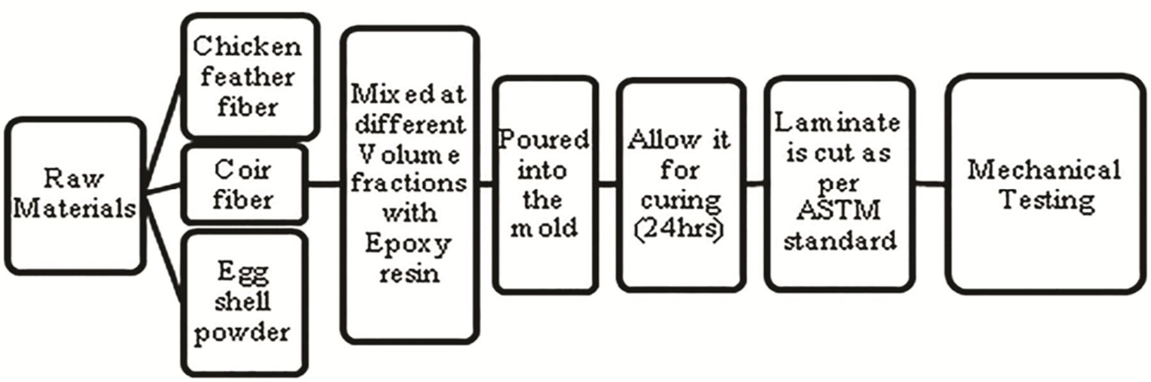

Fig. 4 Hand Layup Process flow chart

The objective of this study is to determine the optimal values of input parameters namely, volume fraction composition of coir fiber, chicken fiber and egg shell powder for maximum tensile strength of the resulting hybrid composite.

III. EXPERIMENTATION

A. Selection of volume fraction of reinforcements for Compliance test

To determine the range of various reinforcements used, tensile testing was conducted for various volume fractions of single fiber reinforced epoxy composite. Table 3.1 shows the volume fractions used to conduct compliance testing for chicken fiber epoxy composite and coir fiber epoxy composite. The optimum volume fraction of egg shell powder considered is 10% **[12].** The optimum volume fraction of chicken fiber and coir fiber are determined as follows by producing composites with composition as shown in Table II.

TABLE II
VOLUME FRACTIONS OF CHICKEN FEATHER AND COIR FIBER FOR COMPLIANCE TESTING

S.No	Volume Fraction of Chicken Feather (%)	Volume Fraction of Coir Fiber (%)
01	7	15
02	10	20
03	13	25
04	16	30
05	18	35

B. Development of Composite

For the volume fractions selected, chicken feather epoxy composite and coir fiber epoxy composite was fabricated using hand layup as shown in Figure 5, 6 & 7, and are subjected to tensile testing as per ASTM D3039. The ultimate tensile strength was calculated using the Equation 1

Ultimate tensile strength = $\frac{Maximum\ Load\ in\ Newton\ (N)}{\text{Cross sectional area in mm}^2}$ …………….(1)

Fig. 5 Mould filled with Epoxy resin and reinforcement

Fig. 6 Composites prepared and marked for cutting

Fig. 7 Specimen for Tensile Testing

C. Tensile Testing of Composite Specimen

Ultimate tensile strength, often referred to tensile strength is the maximum stress that a material can withstand while being stretched or pulled before fracture. The tensile test for the specimens was conducted according to ASTM D3039. The specimens of size 250 mm x 25 mm x 4 mm were tested with a cross head speed of 1 mm / min. The Universal Testing Machine, Instron 1195 used in this investigation is shown in Figure 8.

Fig. 8 UTM setup for Tensile test

IV. RESULTS AND DISCUSSION

A. Determination of Optimum Volume fractions of Reinforcements

Based on the tensile test conducted for various volume fractions of chicken feather epoxy composite and coir fiber epoxy composites, the test results are shown in Table III and Table IV.

TABLE III
TENSILE STRENGTH OF CHICKEN FEATHER

S.No	Volume Fraction of Chicken Feather (%)	Tensile Strength (Mpa)
01	7	57.62
02	10	62.24
03	13	65.21
04	16	67.24
05	18	51.32

TABLE IV
TENSILE STRENGTH OF COIR FIBER

S.No	Volume Fraction of Coir Fiber (%)	Tensile Strength (Mpa)
01	15	60.24
02	20	71.32
03	25	77.58
04	30	86.32
05	35	57.32

From Table III and Table IV, the optimum volume fraction of chicken feather and coir fiber for maximum tensile strength is identified and is shown in Table V.

TABLE V
OPTIMUM VOLUME FRACTION OF REINFORCEMENTS

Volume Fraction of Chicken Feather (%)	Volume Fraction of Coir Fiber (%)	Volume Fraction of Egg shell powder (%) [12]
16	30	10

Based on this result of volume fractions obtained by compliance testing, Taguchi analysis was conducted by selecting the range of volume fractions as shown in Table VI and the Optimum value of reinforcements found using Taguchi technique and the corresponding Ultimate tensile strength obtained for the optimum combination of reinforcements is shown in Table VII. [13]

TABLE VI
RANGE OF REINFORCEMENTS SELECTED [13]

PROCESS PARAMETERS	LEVELS		
	L1	L2	L3
Volume Fraction of Coir Fiber (%)	28	30	32
Volume Fraction of Chicken Feather (%)	14	16	18
Volume Fraction of Egg Shell Powder (%)	8	10	12

TABLE VII
OPTIMUM VALUE OF REINFORCEMENTS [13]

Parameter	Level	Optimum Value (%)	Ultimate Tensile Strength (MPa)
Volume fraction of Coir in %	2	30	100.39
Volume fraction of chicken feathe in %	1	14	
Volume fraction of egg shell in %	2	10	

B. Recommended Applications Based On Tensile Strength As Material Selection Criteria

The hybrid composite developed can be recommended for various applications if tensile strength of the material predominates the material selection criteria by the designer. Table VIII shows the properties of various epoxy based natural fiber composites and Table IX shows the applications of various natural fiber composites.

TABLE VIII
TENSILE PROPERTIES OF VARIOUS NATURAL FIBER COMPOSITES

S.No	Reinforcement Material	Matrix Material	Tensile Strength (Mpa) (MPa)	Ref
01	Banana, Coir	Epoxy	16.43	[14]
02	Banana, Pineapple	Epoxy	62.5	[15]
03	Coir, Human hair	Epoxy	18.5	[16]
04	Jute, Flyash	Epoxy	60	[17]
05	Kenaf, Banana	Epoxy	55.47	[18]
06	Kenaf, Neem	Epoxy	57.62	[18]
07	Silk, Flax	Epoxy	41	[19]
08	Sisal, Coir	Epoxy	17.92	[20]
09	Banana fiber	Epoxy	45.57	[21]
10	Bio-degradable Bark cloth	Epoxy	30	[22]
11	Jute	Epoxy	61	[23]

TABLE IX
APPLICATIONS OF VARIOUS NATURAL FIBER REINFORCED COMPOSITES

S.No	Reinforcement Material	Matrix Material	Applications	Ref
01	Jute	Epoxy resin	Door Panel of E-Class Mercedes Benz	[24]
02	Biodegradable Bark Cloth	Epoxy	Automotive Instrument Panels	[24]
03	Roselle, Banana, Sisal	Epoxy	Rear view mirror, visor in two wheeler, billion seat cover, indicator cover, Cover L-side, writing pen, name plate	[25]
04	Banana fiber	Epoxy	Telephone stand	[26]

V. CONCLUSION

The experimental investigation on the determination of volume fraction of chicken feather, coir fiber and egg shell powder for optimum tensile strength leads to the following conclusions:

1) The tensile strength of chicken feather epoxy composite increases until the volume fraction of chicken fiber reaches 16%, thereafter tensile strength decreases as the volume fraction of chicken fiber is increased. Similarly, the coir fiber reinforced epoxy resin composite shows an increasing tensile strength until the volume fraction of coir fiber reaches 30%. In case of egg shell powder, the volume fraction for optimum tensile strength is 10%
2) The hybrid composite developed using optimum volume fractions of chicken feather, coir fiber and egg shell powder has a tensile strength of 100.39Mpa.**[13**
3) The hybrid composite developed showed superior tensile property when compared with other hybrid composites including Banana- coir epoxy, banana - pineapple epoxy, coir –human hair epoxy, Jute-flyash epoxy, kenaf-banana epoxy, kenaf-neem epoxy, silk-flax epoxy, sisal-coir epoxy, banana fiber epoxy, bio-degradable bark cloth epoxy and jute epoxy composites
4) The developed hybrid composite can be considered during material selection by the designer to be used in automobile parts including door panels, door trim, mirror casing, bumper beam, instrument panel, helmets due to their superior tensile and impact properties over currently using natural/synthetic fiber reinforced composites including Coir polyester, Biodegradable bark cloth epoxy, banana fiber epoxy, wood flour polypropylene, kenaf polypropylene and Jute epoxy resin.

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