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Fabrication and development of natural fibres reinforced epoxy composites using fly ash as filler material

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Abstract: The present study on the development of natural fibres reinforced epoxy composites using fly ash as filler material. Fabrication of composites based on Taguchi L9 orthogonal array design of experiments by using three factors fibre type, fibre weight % and fly ash % with three levels of each factor. Paddy- Paddy fibre gives high elasticity to the fibre composite due to presence of approximately hexagonal structure of cellulose present in paddy fibre. Coir- Coir fibre gives less tensile strength than paddy fibre as Coir fibre is brittle in nature when it pulls breakage occurs showing less tensile strength. Banana- Banana fibre has the least tensile strength in comparison to the paddy & coir fibre due to less cellulose content. Higher fibre weight leads to reduction in tensile strength due to increased nuclei of air pockets.The Optimization of composition of natural fibre reinforces composites using ANOVA for obtaining maximum tensile strength on fabricated composites revealed that the natural fibres along with fly ash can be successfully used with epoxy resin to prepare polymer matrix composites with good mechanical properties.
Keywords: Natural fibres, tensile strength. Fly ash and epoxy resin

I. INTRODUCTION

Natural fibres may be utilized instead of glass fibres as reinforcement because they need low thickness and are biodegradable with good reusability So there is dire need fordevelopment and fabrications of natural fibres reinforced epoxy composites to utilize difficult to dispose agriculture waste to control the environmental issues successfully. Additionally natural fibres are renewable crude materials and they have good strength and stiffness. The Composites materials are available in nature from long time. Composite materials are the combination of materials to overcome their deficiencies and gain advantage in terms of desired properties [1].

A composite material is formed by the combination of two or more phases or materials. This combination gives the properties that are different from the properties of individual phases..

Composite materials basically consist of two phases. A continuous phase called as matrix and a dispersed phase called as reinforcement. The reinforcement material may be in the form of fibres, particulate or flakes. The reinforcement phase is imbedded into the matrix material. By using different combinations of matrix and reinforcement the composite materials of various properties can be made [2].

II. MATRIX MATERIAL

Matrix material is the primary phase in a composite material. Matrix holds the fibres together and also transfer the load to the fibres. Matrix also protects the fibres from environmental damage. The common materials used for matrix are metal, ceramics and polymers. Each of these materials has their own advantages and disadvantages [3].Reinforcement is the secondary phase in a composite material. Reinforcement provides the strength and other mechanical properties to the composite material Metals can be reinforced with fibres, particulates or flakes e.g. aluminum reinforced with silicon carbide, boron reinforced aluminum etc. Metal matrix composites have many advantages over monolithic metals including a higher specific strength, higher specific modulus, better properties at elevated temperatures, lower coefficients of thermal expansion and better wear resistance [4].

III. LITERATURE SURVEY

Ferreira et. al. studied the mechanical properties of woven mat Jute/Epoxy composites [5]. The composites were reinforced by coarse, medium, and fine mats of jute and are processed by vacuum bagging. Mechanical tests were performed to study bending strength and impact strength. It was observed from the results that fine mat composites have lower strength as compared to coarse mat composites also the strength increases with increasing grammage of mats. Sanjay et.al**.**investigated the mechanical properties of Jute/E-Glass fibre reinforced epoxy hybrid composites [6]. The epoxy resin used was LY556 and hardener used was HY951.

Different combinations of glass and jute fibre were taken for different samples. The properties of the composites were studied by tensile, flexural, impact, and inter laminar shear strength tests as per ASTM standards. From results it was observed that hybrid composites have better properties as compared to composites made separately from single fibre.

Cerbuet. al. (2015)investigated the mechanical characterization of flax/epoxy composite materials [7]. The mechanical properties of flax/epoxy composites were analyzed by using tensile test, flexural test, and impact test. The 40 weight % of flax fibre was used for composite preparation. Different samples with wrap and weft direction of flax fibre were used with epoxy resin. From the results it was concluded that the mechanical characteristics in weft direction are better than wrap direction.

Pattanaiket.al. studied the dry sliding wear behavior of epoxy fly ash composite with Taguchi optimization[8]. The composites were prepared by using epoxy as matrix and fly ash as reinforcement. The ultrasonic stirring method was used for composite preparation. The fly ash weight % used was 10, 20, 30, and 40% with different time, speed, load and track diameter on pin-on-disk machine. From the experiments it was concluded that applied normal load is most influencing factor for increase in wear also fly ash can be successfully used in future as filler material in composites.

Bisariaet. al. (2015)studied the effect of fibre length on mechanical properties of randomly oriented short jute fibre reinforced epoxy composites [9]. The tensile strength, flexural strength and impact strength was studied in this work. The composites were prepared with 30 wt% of jute fibre in various lengths of 5, 10, 15, and 20 mm into epoxy resin using hand lay-up method. From the results it was concluded that tensile and flexural properties were found maximum for 15 mm fibre length composites whereas the impact strength was found maximum for 20mm length of fibres.

Himanshu Bisariaet.al. investigated the tensile, flexural and impact properties of epoxy and randomly oriented short jute fibres reinforced epoxy composite [9]. The prepared composites using Hand and lay-up method with 30 wt.% of jute fibre in the various lengths of 5,10,15 and 20 mm into epoxy matrix. The results presented that the tensile and flexural properties were found maximum for the composite with 15 mm length of fibre whereas the intact properties were found maximum for the composite with 20 mm length of fibre

Gopinathet.al.investigated the mechanical properties of jute fibre reinforced composites with polyester and epoxy resin matrices [10]. In this study jutefibre of length 5-6 mm is used as reinforcement. The matrix material used was polyester and epoxy resin. Different composite samples were prepared for both epoxy and polyester. The prepared composites were tested to study mechanical properties such as tensile strength, flexural strength, impact strength and hardness. The result of the study showed that jute-epoxy composites have better properties as compared to jute-polyester composites.

Camelia Cerbustudied the mechanical characterization of the epoxy resin. Reinforced with flax fibre[10].The mechanical behavior of flax/epoxy composite material was analyzed by using tensile test, flexural(bending) test and intact (Charpy Method). After the statistical processing of experimenting data for all specimens tested , the average values of the following properties determinate: Youngs modulus E intention, tensile normal stress at failure, tensile normal strain at failure, youngs modulus in bending, flexural normal stress at failure, strain energy in all tests (tension, bending ,Charpy) , resilience recorded in Charpy test. Thus reported the average values of the mechanical properties of the flax/epoxy composite material tested. The results presented that the average values of the mechanical recorded on the weft direction of the flax. Fabric were greater than the ones recorded on the warp direction.

Pantamanatsopaet. al. (2014)studied the effect of modified jute fibre on mechanical properties of green rubber composites [11]. The jute fibre of 0, 10, 20, and 40 wt% were used for reinforcement and composites were prepared by using two roll mills and then molded by hot compression molding technique. The results showed that with increasing fibre content the modulus and hardness increased but tensile strength decreased. Also comparison between untreated jute and treated jute fibre showed that mechanical properties improve more in case of untreated fibres.

Berhanuet. al. (2014)studied the mechanical behavior of jute fibre reinforced polypropylene composites[12]. The composites were prepared by compression molding process with the fibre weight percent of 30, 40, and 50. The effect of fibre weight percent on mechanical properties was studied using UTM. Also the Scanning Electron Microscope (SEM), X-ray Diffraction (XRD), and Thermal Analysis (TA) was done to understand the behavior of composites. The results revealed that the mechanical properties were improved significantly on addition of jute fibre up to 40% weight. Also the dispersion of fibre into the matrix is better for 40% fibre weight composites.

Deshpandeet. al. (2014)studied the effect of fillers on E-Glass/Jute fibre reinforced epoxy composites[13]. The composites were fabricated by hand lay-up technique. The fillers of bone and coconut shell powder in varying concentrations were used in composites. Mechanical properties such as ultimate tensile strength, flexural strength, inter laminar shear strength; tensile modulus, impact strength, and hardness of composites were tested. From the results it was concluded that mechanical properties of composites increase with increase in filler content. The flexural strength, inter laminar shear strength, tensile modulus and hardness were found maximum for 15% volume of coconut shell powder. Impact strength was found maximum for 15% volume of bone powder.

M. Ramesh et.al. (2014) Fabricated Banana fibre reinforced composites and found that the maximum tensile strength was 112.58 MPa which was held the 50% Banana fibre and 50 % Epoxy resin composites [16]. The maximum flexural strength was 76.53 MPa and held by the same combination of the composites samples. The maximum impact strength held by the 60 % Glass fibre 40 % Epoxy Resin composites was 11.22 Joules fallowed by 50 % Banana fibre and 50 % Epoxy Resin composites with stood the impact load of 9.48 Joules. From the SEM Analysis, the nature of fibre fracture due to Mechanical loading, Crack formation in the Matrix layer and Matrix failure were observed. From their experimental study they suggested that , the 50 % Banana fibre and 50 % Epoxy Resin composite materials could with stand the higher loads when compared to the other combinations and used as an alternate materials for conventional fibre reinforced polymer composites.

P. Sashi Shankar et. al. Evaluated stress, strain and deflection of banana fibre reinforced Epoxy composites [17]. The ultimate tensile strength value was maximum at 15% and decrease started from 15-20 % of the fibre. The flexural strength value slightly decreased from 5% to 10% and after that the value increased from 10% to 20% of the fibre. The impact value was maximum at 15% (12J) of the fibre and the value decreased from 15% to 20% of the fibre.

Ramesh et.al. (2013)studied the comparative properties of hybrid glass fibre- sisal/jute reinforced epoxy composites[14]. The specimens were prepared by using epoxy resin as matrix and sisal (Agave sisalana), Jute (Corchorusoliotorus), and glass fibre as reinforcements. The specimens are prepared by using conventional hand layup technique. The tensile and flexural properties were studied and results based on SEM indicated that incorporation of sisal fibre with glass fibre shows better tensile properties as compared to jute fibre with glass fibre but flexural properties were better for jute fibre composites.

Veluet.al. studied the mechanical properties of glass-jute fibre epoxy composites [15]. The composites were prepared by changing stacking sequence of 4 layers of jute and woven glass fibre as reinforcement with epoxy as matrix material. The composites were prepared by hand lay-up method with 60:40 weight ratio of fibre to resin. The tensile, bending, and impact tests were carried on the prepared composites. It was concluded from the tests that tensile, bending, and impact strength increases with increase in fibre weight percent compared to pure resin.

IV. FIBRE REINFORCED POLYMER (FRP)

These are of two type'si.e Containing discontinuous fibres and Containing continuous fibres. Fibres are the reinforcements having length much greater than their cross-sectional area. Polymer materials can be used as matrix material with different types of fibres both synthetic and natural. If the properties of fibre vary with fibre length it is considered as a short or discontinuous fibre. Fibres are available in different forms like woven, unidirectional, bi-directional etc. Fibre provides the strength to a composite material. The matrix holds all the fibres together in shape and transfers stresses (load) between the reinforcing fibres. The major synthetic fibres used in polymers are glass fibre, carbon fibre etc. Natural fibres such as jute, flax, basalt etc. are also used with polymers. Natural fibres are available at less cost and also are safe for environment [7].

V. NATURAL FIBRES

The use of natural fibre as support in plastics has expanded drastically throughout previous Couple of years. Regarding the ecological viewpoints if natural fibres may will be utilized instead of glass fibres as reinforcement in some structural provisions it'd very interesting. Natural fibres have various points of interest
Contrasted with glass fibre, for example they need low thickness, and they are biodegradable and reusable. Additionally they are renewable crude materials and they have nice strength and stiffness. Natural fibres are classified on the basis of the origin of source, into three typesi.e Plant Fibres, Minerals Fibres and Animals Fibres Plant Fibres basically consists cellulose: examples cotton, jute, bamboo, flax, ramie, hemp, fibre and sisal. Cellulose fibres are employed in different applications. The class of these fibres is as following: seed fibres are those that we get from the seed e.g. Kapok and cotton. Due to superior tensile properties as compared to other fibres these are employed in several applications like packaging, paper and cloth. Fruit fibres are the fibres that we get fromthe fruit of the plant, e.g. banana fibre and coconut fibre. Similarly, stalk fibres are fibres that we get from the stalks (rice straws, bamboo, wheat and barley).

Mineral Fibres are the fibres which we get from minerals. Asbestos is the solely present mineral fibre that was used extensively for creating industrial product however is currently being phased out as a result of its suspected potential to cause cancer.

Animal fibres are natural fibres that consist mostly of explicit proteins. Instances are silk, hair/ fur (including wool) and feathers. The most common animal fibres wool from sheep and silk are used in both manufacturing world and by hand spinners. Alpaca fibre and mohair from Angora goats are also very popular. Other fibres like Angora wool from rabbits and Chiengora from dogs additionally exists, however are seldom used for production.

VI. MATERIALS AND MEDHODOLOGY

To Composites are made by reinforcing fibres or filler into the matrix material. For this study following materials will be used for preparing composites.

Matrix Material

The most common resin materials utilized in thermosetting composites are epoxy, phenlics, vinyl ester, polyester and polymides. Epoxy resins are distinctive among all the thermosetting resins as a result of many factors. The distinct properties of epoxy like high corrosion and chemical resistance, outstanding adhesion to various substrate, sensible thermal and mechanical properties, sensible electrical insulating properties, low shrinkage upon cure, and the ability to processed at a variety of conditions make it a perfect material for composites. Epoxy has been used for the making of polymer matrix composites by many researches.

Fibre Material

There is increasing trend towards the use of natural fibres in composite materials due to their many advantages over the synthetic fibres. Natural fibres are available at less cost also these fibres are biodegradable which makes them environment friendly. For the present research work three different types of natural fibres paddy waste, banana fibre, and coir fibre have been used as reinforcement.

Banana Fibre

In India banana is cultivated in large amount. Banana fibre is obtained simply from the plants that are rendered as waste when the fruits have ripened. Banana fibre, a lignocellusic fibre, obtained from the pseudo-stem of banana plant, have good mechanical properties. Banana fibre possesses good specific strength properties resembling those of typical materials like glass fibres. Also these fibres have lower density as compared to glass fibre. Banana fibre has recognized for apparels and home furnishings. Banana fibre has good potential for paper making hand- crafted paper. It is used for making filter paper, paper bags, greeting cards, lamp stands, pen stands, ornamental papers, rope, mats and stuff etc. Banana fibre can be used by various researches as reinforcement in composites.

Coir Fibre

Coir fibre is used for making ropes, yarns, mattresses, mats, sacking, brushes, caulking boats. Insulation panels and floor tiles. It is a lign cellulosic fibre that extracts from the husk of cocnut. Coir fibre has low strength and young's modulus owing to its low cellulose and large lignin content. Coir fibre has high microfibrilar angle owing to that it posses low module. However the proportion of elongation of break and toughness of fibre is more than alternative natural fibres. Coir fibre is also have better resistance to weather, fungous and microorganism owing to its high lignin content. The addition of Coir fibre as an element in polymer matrix composites is undesirable in some perspective compared to different natural fibre due to its low cellulose content (36-43%). High lignin content (41-45%) and high microfibrilar angle. The Coir fibre polymer has several applicationin structural systems in housing, electrical panels, ducting etc. The coir fibre is selected for the present work due to its easy availability, good toughness and better resistance to moisture as compared to other natural fibre.

Paddy Fibre

Paddy fibre is used in outdoor deck floors, railings, fences, landscaping timbers, cladding and siding, park benches, moulding and trim, window and door frames, and indoor furniture.Utilization of biomass for green products is still progressing in the effort to provide alternative clean technology. The utilization of natural waste fibres from paddy as acoustic material. The paddy fibres are found to have good acoustic performance with high normal incidence absorption coefficient. Rice hulls are an inexpensive by product of human food processing, serving as a source of fibre that is considered a filler, ingredient in pet foods. Behalf of above composite made from paddy i.e. **fibre-reinforced composite** (FRC) is a composite building material. This is a type of advanced composite group, which makes use of rice husk, rice hull, and plastic as ingredients. This technology involves a method of refining, blending, and compounding natural fibres from cellulosic waste streams to form a high-strength fibre composite material in a polymer matrix. The designated waste or base raw materials used in this instance are those of waste thermoplastics and various categories of cellulosic waste including rice husk and saw dust.

Filler Material

Fly ash from thermal power plant will be used as a filler material. The addition of filler materials improves the properties of the composites. The use of filler materials by many researchers shows that filler materials helps in bonding between fibre and matrix also sometimes provide additional properties to the composites. Fly ash is a waste product of coal based thermal power plants. It is a harmful material to the environment due to its pollution aspects.

VII. TAGUCHI TECHNIQUE

The Taguchi methodology involves reducing the variation using design of experiments in a process. The objective of the strategy is to produce prime quality product at low cost to the manufacturer. The Taguchi technique was developed by Genichi Taguchi. He developed a way for designing experiments to study how completely different parameters have an effect on the mean and variance of a process performance characteristic that defines however well the process is functioning. The experimental style planned by Taguchi involves orthogonal arrays to arrange the parameters influencing the process and also the levels at which they need to be varied. Rather than having to test all attainable mixtures just like the factorial style. The Taguchi methodology tests pair of mixtures. Therefore saving time and resources. The Taguchi methodology is best used once there is intermediate variety of variables, few interactions between variables, and there are only few variables that contribute considerably.Control Factors and levels used in this investigation are shown in table 1.

Table 1 Control Factors and levels.

S. No.	Factors	Levels		
		1.	2	3
1.	Fibre Type	Paddy	Banana	Coir
2.	Fibre Weight%	4	8	12
3.	Fly Ash Weight%	0	2	4

Design of Experiment

The conventional experimental design is very complex to use when there are large number of variables. To overcome this difficulty Taguchi proposed experimental design using orthogonal arrays to study the effect of all variables with small number of experiments. The design of experiments for the present work is prepared by MINITAB 17 software using Taguchi methodology of L9 orthogonal arrays shown in table 2.

Table 2 Design of experiments based on Taguchi L9 orthogonal arrays

Sample No.	Fibre Type	Fibre Weight%	Fly Ash Weight %
S1	Paddy	4	0
S2	Paddy	8	2
S3	Paddy	12	4
S4	Banana	4	2
S5	Banana	8	4
S6	Banana	12	0
S7	Coir	4	4
S8	Coir	8	0
S9	Coir	12	2

VIII. COMPOSITE SPECIMEN FABRICATION

The composites were prepared by using hand lay- up process. The first step was to prepare a mould for the castings of composites. A mild steel match plate mould of size 300 mm x300 mm x 4mm was prepared for composite fabrication. For the easy removal of the prepared composite wax was used as a releasing agent on the inner side of the mould. Then the composites were prepared according to selected the design of experiments based on Taguchi technique.Composite Specimens are shown Fig. 1.

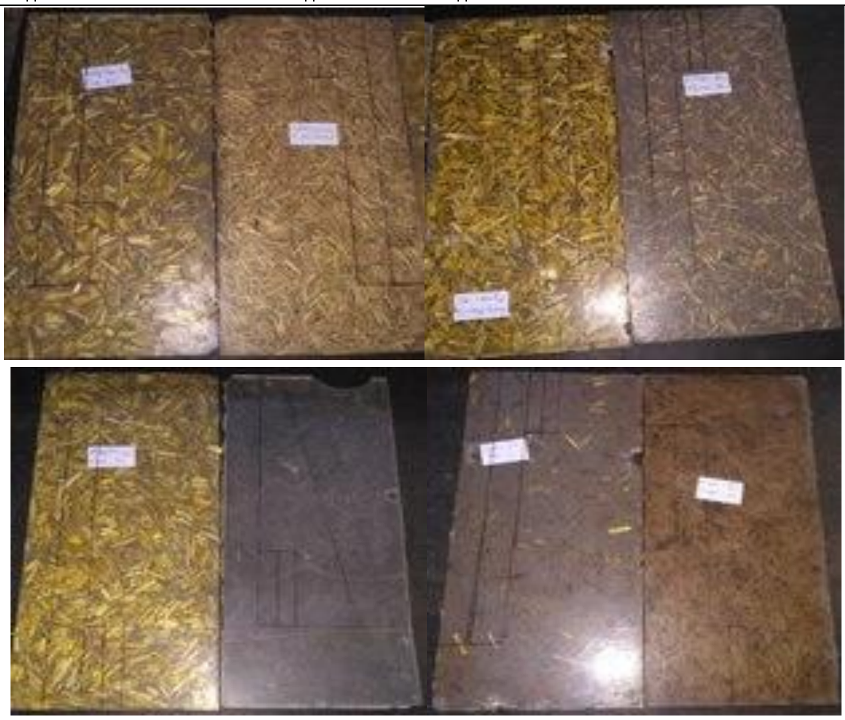

Fig. 1Composite Specimens

IX. CONCLUSIONS

From the present research work it is established that the natural fibres along with fly ash can be successfully used with epoxy resin to prepare polymer matrix composites with the following conclusions;.

- Paddy- Paddy fibre gives high elasticity to the fibre composite due to presence of approximately hexagonal structure of cellulose present in paddy fibre.
- Coir- Coir fibre gives less tensile strength than paddy fibre as Coir fibre is brittle in nature when it pulls breakage occurs showing less tensile strength.
- Banana- Banana fibre has the least tensile strength in comparison to the paddy & coir fibre due to less cellulose content.
- Higher fibre weight leads to reduction in tensile strength due to increased nuclei of air pockets.
- Increasing fly ash content reduces tensile strength due to nonbonding of fly ash particles with natural fibre. Fly ash is also not not very strong as compared to the epoxy resin leading to reduction in tensile strength.

The FESEM images show good bonding between fibre, fly ash particles and matrix. Also breakage of fibres shows the load transferred from matrix to the fibres. The use natural fibres and fly ash can be successfully done to prepare eco- friendly composites as fly ash is a waste material and its use in composites can reduce its pollution aspects. The use natural fibres and fly ash can be successfully done to prepare increase the refractoriness properties in the material.

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