Engineering and Technology Journal e-ISSN: 2456-3358
Volume 06 Issue 04 April-2021, Page No.-855-860
DOI: 10.47191/etj/v6i4.03, I.F. – 6.39

Review on the Mechanical Properties of Pineapple Leaf Fiber (PALF) Reinforced Epoxy Resin Based Composites

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ABSTRACT: Synthetic materials possess with several drawbacks as most of the cases they are not environmental friendly where the scientists and researchers are very much concern about the environmental issues. That's why alternatives should be replaced in place of synthetic materials. Using natural fibers in polymeric composite materials have opened up a new dimension as natural fibers are eco-friendly and available. Moreover extracting natural fiber from abundant source can add an extra value to the fibrous composite world. Pineapple leaf fiber in short PALF or PLF is an example of such fiber that is envisaged as agricultural waste. We have studied several research articles on the mechanical properties of pineapple leaf fiber reinforced epoxy resin based composites and their different aspects have been discussed in this review paper with some promising applications such as alternative of wood, knee prosthetic sockets, replacement of glass fiber, building construction and so on.

KEYWORDS: Natural fiber, Pineapple Leaf Fiber (PALF), Epoxy Resin, Composites, Mechanical Properties.

INTRODUCTION

Composite materials, a wonder of modern science can be defined as a mixer of two or more distinct elements in order to get a resulting material having Superior properties from its parental materials [1, 2].Composite materials have a verity of implementations such as: automotive sector, marine industries, furniture, civil construction, military applications, aerospace, medical applications and many more. Fiber reinforced polymer based composite materials can be made by using both natural and man-made or synthetic fiber [3-5]. Synthetic fibrous composites have a bunch of disadvantages like expensive, more density, difficult to processing and not health friendly. Moreover, they are not biodegradable which means not environmentally safe where the whole world is very much concern about the environmental issue. These disadvantages peddled the scientists to think about alternative [6, 7]. On the other hand, Natural fibrous composites avails with light weight, cost effectiveness, low density, better mechanical behavior, renewability, non-frictional to materials, minimize the wreck of energy and more importantly biodegradability and many more [8,9].

Jute, flax [10], kenaf [11], ramie [12], pineapple leaf fiber [6, 13] can be classified as natural fiber which have been used for composite fabrication. Among those Pineapple leaf fiber (PALF) is considered as agricultural waste which are disposed by burning. PALF is available, white in color, sleek and shiny. PALF contains 70%-82% cellulose, 5%-12% lignin and 1.1% ash. PALF is ahead of other fibers due to its high cellulose content. Moreover they have better mechanical strength compared to other natural fibers along with biodegradability. These positive aspects of PALF have been made it superior to be chosen for composite fabrication [14, 15, 16, 17].

Polymer matrix is a very vital part of fibrous composites. Polypropylene (PP), polyethylene (PE), unsaturated polyester resin (UPR), Epoxy resin etc are widely used polymer matrix for fiber reinforced composite materials. Among those epoxy resins are used as a thermoset polymer for various engineering and structural applications now a days. Electrical industries, commercial and military aircraft industries are the application field of epoxy resin. Besides, it is very familiar for its better mechanical and thermal properties. Easy process ability and less moisture absorbency make it different from other polymer matrix. Moreoverit has excellent chemical resistance [18, 19, 20].

In materials science, ameliorating of mechanical properties of natural fiber reinforced composites is very significant research. Different approaches are adopted by scientists and researchers to improve the mechanical properties such as insertion of filler, modify or treat the fiber surface and so on. Mechanical properties of pineapple leaf fiber reinforced epoxy resin based composites were tried to depict in this review article.

MATERIALS AND METHODS

Materials

Several sort of natural (Jute, flax, kenaf, ramie, pineapple leaf fiber etc) and man-made fiber (E-glass, polyester, carbon, alginate etc.) fibers can be used as fortified element in composite materials. Polypropylene (PP), polyethylene (PE), unsaturated polyester resin (UPR), epoxy resin have been used as matrix material in various research study. But this review article will be confined to pine apple leaf fiber reinforced epoxy resin based composites.

Methods

Composite fabrication

Fiber reinforced composite materials can be fabricated by several ways such as hand lay-up technique, compression molding, pultrusion, injection molding, spray up etc. They are described below:

Compression molding: Compression molding is mostly used technique for fabrication of composite. High temperature and pressure are employed in this technique. Temperature ranges from 110-200°C are applied depending on the type of matrix materials which aim is to melt the matrix material. The operating temperature should be in between the melting temperature of the matrix materials and melting point of reinforcing materials. To give the composite proper shape pressures ranges from 1 to 5 tonsare deployed to the composite materials along with high temperature. It has to be affirmed that temperature and pressure won't affect the reinforcing materials. Generally two steel plates are used outside of the composite after wrapping with silicon paper prior to applying high temperature and pressure [21-26].

Hand Lay-up: Among the composite fabrication methods hand lay-up is the oldest but simplest method. In this method, fiber is distributed uniformly onto a mold and the resin matrix is dispersed over the fiber. Then it is rolled by hand roller for the uniform distribution of resin matrix. The hand rolling also ensures better interaction between the reinforcement and the matrix and help to get required thickness [27, 26].

Pultrusion: Pultrusion is an automated process used for the production of composite materials into continuous, constant cross sectional profile. Instead of forced out the product by pressure the products are pulled from the dice. Rods, tube, different types of structure are made with pultrusion process [28, 29, 26].

Injection Molding: Injection molding method is used to produce large scale of composite materials. Both thermoplastic and thermoset composites are possible to produce in this method. Composites are fed into a heated barrel, mixed and forced into a mold cavity where it is cooled and harden to desired shape [30].

Spray-up: The spray-up method forms composite at a rapid rate with uniform surface. Hand lay-up method and spray up method are a bit of similar. Moderate mechanical properties are obtained by spray up method which can be can be categorized as drawback. Another disadvantage includes it is unable to use continuous fiber in the reinforcement. Liquid resin and the chopped fiber are sprayed by separate sprayer and composite is formed [31,26].

Mechanical properties

Universal Testing machine (UTM) is used to figure out the tensile properties (tensile strength, elongation at break and tensile modulus) of the composites with different cross-head speeds. Generally ASTM-D638-01 is very common to prepare tensile specimens. Tensile Strength can be calculated by following formula-

$$\text{Tensile Strength} = \frac{\text{Applied Load}}{\text{Cross Sectional Area}} \quad \ldots\ldots\ldots\ldots (1)$$

It can be revealed in the unit of Nm^2 or in MPa or GPa. Elongation at break is expressed in the terms of tensile strain in percentage basis. Tensile strain can also be computed according to ASTM-D638-01. The difference between the final length and the initial length of the composite materials on the basis of the initial length can be defined as tensile strain. Young modulus can be ascertained by the ratio of stress to strain using universal testing machine [32, 33]. Bending properties (Bending strength and bending modulus) can also be calculated by using the same machine as described for the tensileproperties [34].

RESULT AND DISCUSSION

A lot of research works have been conducted on pineapple fiber reinforced epoxy resin based composites. The researchers used different fiber percentage in composites and figure out their mechanical properties.

Jyoti Jain et al. have conducted an experiment on 0-25 wt% of pineapple leaf fiber (2 to 5 mm fiber length) reinforced epoxy based composite and found better mechanical properties at 10 wt% fiber composition. They reported that better transfer of stress through fibers all over the matrix was obtained at 10 wt% fiber loading resulting in better interfacial adhesion between the fiber and matrix [35].

M. Indro Reddy et al. experimented a comparative study on Jute, pine apple and glass fiber (1:1:1 ratio) reinforced thermoset composites. They used epoxy and polyester resin as matrix material. The fiber content in the composite was varied from 0.18 to 0.42 by volume fraction. In their study, they have reported epoxy resin based composites revealed better mechanical properties than polyester resin based composites at maximum fiber content (0.42 volume fraction of fiber). The mentioned values of tensile strength in their paper were 68.24 MPa for Jute, pine apple and glass fiber reinforced polyester resin based composites and 71.66 MPa for jute, pine apple and glassfiber reinforced epoxy resin based composites [36].

M. Mittal et al. reported that, PALF reinforced epoxy resin based composites gained 61.2% and 49.5% higher tensile strength and tensile modulus respectively compared to COIR/Epoxy composite respectively. Inherently PALF has better tensile properties than that of COIR fiber. Moreover, the diameter and microfibrillar angle of PALF is less compared to COIR fiber resulting in higher surface area and reinforcement effectiveness of PALF than COIR [37].

Santosh Kumar D S et al. developed pine apple reinforced epoxy resin based composite with 10% to 30% fiber volume ratio and they came to know 30% pine apple fiber volume ratio exhibited maximum tensile, flexural strength and hardness. The numerical value of tensile strength, flexural strength and hardness were found in their study to be 65.95 MPa, 121.83 MPa and 80B respectively at 30% pine apple fiber volume ratio. They proposed to use pineapple leaf fiber reinforced composite materials as an alternative of wood [38].

J. K. Odusote compared pineapple leaf fiber epoxy composites with pineapple leaf fiber polyester composites and glass fiber polyester composited and they got to know pineapple leaf fiber epoxy composites had superior mechanical properties than those of pineapple leaf fiber polyester composites and glass fiber polyester composited at 40% fiber loading. The values they obtained for tensile, flexural and impact strengths of PLEC were 76.47 ± 3.85 MPa, 81.27 ± 1.77 MPa and 59.03 ± 0.99 k/Jm2, respectively. They claimed better fiber matrix adhesion at mentioned fiber loading percentage and suggested to exploit pineapple leaf fiber epoxy composites as a replacement for glass fiber in above-knee prosthetic sockets [39].

H.S. Mahadevaswamy et al. carried out a research on effect of nano $CaCO_3$ on mechanical properties of pineapple fiber reinforced epoxy resin based composites. They inserted 1wt%, 3wt% and 5wt% N-$CaCO_3$ in pineapple epoxy composites whereas the formulation of fiber was 25 wt%. After experimenting mechanical properties they found that 3% N-$CaCO_3$ filler imparted highest mechanical properties compared to unfilled, 1wt% and 5 wt% N-$CaCO_3$ filled pineapple epoxy composites. They reported that tensile strength and tensile modulus of 3 wt% N-$CaCO_3$ filled Pineapple fiber epoxycomposite were augmented by 14.9% and 23.06% respectively when compared to unfilled Pineapple epoxy composites. They accused 5% N-$CaCO_3$ filler acted as space fillers after observing SEM image [13].

Jagadish et al. conducted a research work on short pineapple leaf fiber (≈ 1 mm to 2 mm) reinforced epoxy resin based composites whereas the fiber compositions were 0, 1, 5, 10, 15, and 20 wt%, with the composites specimen’s thickness of 3 and 5 mm and evaluated the mechanical properties.They revealed that improved mechanical properties were obtained at 10 wt% pineapple epoxy composites with 5 mm thickness compared to other combinations [6].

N. KrishnarjunaRao et al. fabricated pineapple and glass fiber reinforced epoxy resin based hybrid composites with varying pineapple and glass fiber compositions such as 8: 0, 6:2, 4: 4, 2: 6, 0: 8. Maximum tensile strength and modulus (171.18 MPa and 7087.07 MPa respectively) were achieved at 4: 4 pineapple and glass fiber reinforced epoxy resin based hybrid composites in their study. One of the important things they stated in their article is that about 50% to 75% glass fiber can be replaced by pineapple leaf fiber depending on the need for the application of mechanical properties [40].

N. Lopattananon performed a research on the influence of fiber modification on mechanical properties of pineapple leaf fiber reinforced epoxy resin based composites. They used three kind of solutions such as 5% w/v NaOH aqueous solution, the deposition of diglycidyl ether of bisphenol A (DGEBA) from toluene solution (1% w/v DGEBA), and the alkalization combined with the deposition of DGEBA (5% w/v NaOH and 1% w/v DGEBA) to treat the fiber surface. In all the cases they got almost 2–2.7 times improved mechanical properties compared to untreated pineapple leaf fiber that leads to greater interaction between the pineapple and epoxy resin matrix. But the maximum mechanical properties were obtained at combined alkalization (5% w/v NaOH and 1% w/v DGEBA) treated pineapple leaf fiber reinforced epoxy resin based composites [41].

BalaManikandanCheirmakani et al. added *ProsopisJuliflora* powder (PJP) as filler to pineapple fiber (PLF) reinforced epoxy resin based composites by using compression molding machine to evaluate the mechanical properties.They treated pineapple leaf fiber with 5% NaOH for 2 hours. The fiber formulations were 30 weight percentage (wt.%) of untreated PLF and PJP, 30 wt.% of treated PLF and PJP, 40 wt.% of treated PLF and PJP, 50 wt.% of treated PLF and PJP.They reported that 40 wt.% of treated PLF and PJP elicited better tensile strength and higher impact energy absorption. They also observed that 50 wt.% of treated PLF and PJPshowed better flexural strength.Due to increasing surface roughness of fiber by chemical treatment, pineapple fibers exhibited enhanced mechanical properties. They characterized pineapple leaf fiber reinforced epoxy resin based composites as low-weight, low cost and higher strength material appropriate for industrial applications [42].

CONCLUSION

A brief literature study on mechanical properties of pineapple fiber reinforced epoxy resin based composites has been gathered in this review paper. In every cases, it has been depicted explicitly that epoxy resin based composites gain improved mechanical properties due to insertion of pineapple leaf fiber in composites. So, it can be said that pineapple leaf fiber is very much promising as reinforcing element for fiber polymer composite materials. Having 70-82% cellulose content and lower microfibrillar angle make pineapple leaf fiber superior for composite fabrication lead to better fiber matrix adhesion.Moreover pineapple leaf fiber reinforced epoxy resin based composites posses with various advantages such as light weight, low production cost, stiffness, easy process ability and so on. Hence these composites materials can be implemented as as automobile parts, electronic packages, building construction etc. Finally it can be concluded thatpineapple leaf fiber reinforced epoxy resin based composites have a great future in the world of fibrous composites.

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