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REVIEW OF NATURAL FIBER REINFORCED WOVEN COMPOSITE

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Abstract. This paper reviews the research works carried out in the field of woven natural fiber composites with special reference to weave pattern, chemical modification and the theory behind it.

1. INTRODUCTION

Agricultural or biodegradable material plays important role in human life. The advantage of using such resource is that, they are widely distributed all over the world, its multifunctional, strength and biodegradable [1-2]. Natural fibers are used natural fibers are used in different forms such as continuous, random oriented and woven fabric for reinforcing composites. Further, there is growing interest in the use of natural fiber composites for structural and automotive applications. [3-4] In the case of aircraft structures, woven or braided composites are used for a wide variety of cross-sectional forms such as stiffeners, truss members, rotor blade, spars, *etc.* to reduce the fabrication costs [5-6]. Various processes such as weaving, braiding or knitting, *etc*. form reinforcement of these composites. Woven fabric composites, in particular, are constructed by weaving two fiber tows into each other to form a layer. These layers are then impregnated with a resin or matrix material, stacked in a desired orientation, and cured to obtain a composite laminate. The interlacing of fiber bundles has several advantages such as increasing the strength of the lamina, greater damage tolerance, as well as providing a possibility to produce near net shape structural components. Such capabilities are very important for producing thick laminates. However, these advantages come at the expense of some loss in the in-plane stiffness and strength, which depends upon the weave architecture [7]. There is certainly a need for sound engineering data as well as efficient analytical/design methodologies to evaluate different parameters. These design methodologies must account for processing parameters and micro structural/geometrical features for accurate modeling of such composites.

There are several geometries/architectures for woven composites. In the case of two-dimensional woven fabric composites, two sets of mutually orthogonal sets of yarns of the same material (non-hybrid) or different material (hybrid) are interlaced with each other. The various types of architectures can be formed depending on how the pattern in the interlaced regions is repeated. Plain weave is a special case of two-dimensional woven fabric composites. In the case of plain-woven composites, a “warp” or longitudinal fiber tow are interlaced with every second “fill” or width fiber tow. A woven fabric contains fibers oriented on at least two axes, in order to provide great strength and stiffness [8]. Study on

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various randomly oriented natural fibres like coir, bamboo, jute, palmyra, sisal, coir, banana have been reported in the literature [9-25].

In this paper, two types of natural fibers, woven - banana and pandanus (Kenaf) were utilized as reinforcement is studied. These two types of natural fibers are taken for study is because of their ability to be produced in a continuous form, and hence able to produce into a woven mat form. Further, literatures on other types of natural fiber woven composites were discussed briefly.

2. WOVEN COMPOSITES

Woven composites is known to be complex systems, which have additional features such as, interlace spacing or gap, interlace point and unit cell (Lai et al., [26]). There are very few reports on woven fabric composites reported so far. The popularity of woven composites is increasing due to simple processing and acceptable mechanical properties (Jekabsons and Bystrom, [27]). Woven fabric composites provide more balanced properties in the fabric plane than unidirectional laminas. According to Khashabaa and Seif [28], the usage of woven composites has increased over the recent years due to their lower production costs, lightweight, higher fracture toughness and better control over the thermo-mechanical properties. The weaving of the fiber provides an interlocking that increases strength better than can be achieved by fiber matrix adhesion. Failure of the composite will require fiber breakage, since fiber pullout is not possible with tightly woven fibers [29].

In recent years, owing to the increased environmental awareness, the usage of natural fibers as a potential replacement for synthetic fibers such as carbon, aramid and glass fibers in composite materials have gained interest among researchers throughout the world. K.G.Satyanrayana et al. [30] on his investigation of banana fiber with polyester composites with out weathering test shows the specific modulus of the composites is 2.39 GPa which are of same order as that of glass fiber plastics. Further the Scanning Electron Microscope study of Banana fiber-cotton fabric shows the specific modulus of the composite also of same order of glass fiber reinforced plastic. A truck model “Manaca” was developed and tested by H.A. Al-Qureshi [31] using banana fiber mixed with epoxy resin and hardener. However some special and critical panels a hybrid composite of fibre glass/banana chopped fibre/epoxy was laminated. It went through many years of performance road tests and in conclusion has demonstrated excellent results.

Seena Joseph et al. [32] in their work compared the mechanical properties of phenol formaldehyde composites reinforced with banana fibers and glass fibers predicted that the optimum fiber length for maximum value of tensile stress for banana fiber and glass fiber are 30 and 40 mm, respectively. Also found that the tensile strength and young’s modulus value of banana/PF composites increases to 400 and 320%, respectively when fiber loading is 48% when compared with neat resin. By increasing, the fibre loading to 45% the flexural modulus is increased to about 25% for banana/PF composites. Laly.A.Pothan et al. [33] studied the static and dynamic mechanical properties of Banana and glass fiber–reinforced polyester composites. The composite was prepared in woven form and found out that high tensile strength can be obtained using two layer of fabric and four layer of fabric shows two peaks and one shoulder. Increasing the number of layers made the second relaxation peak visible and damping values are found to be lowered by the incorporation of more number of layers.

S.M.Sapuan et.al [34] investigated the Mechanical properties of woven banana fiber reinforced with epoxy composites. From the result of tensile test, it is found that the maximum value of stress in *x*-direction is 14.14 MN/m^2 and in *y*-direction is 3.398 MN/m^2. The results of three point bending test predict that the maximum load applied is 36.25 N to get the deflection of 0.5 mm. Statistical analysis has also been carried out using analysis of variance-one way (ANNOVA).

Tensile, flexure, impact and fracture surface study of woven pseudo stem banana fibre reinforced with epoxy composite was investigated by M. A. Maleque et al. [35]. Tensile test results show that the ultimate strength of banana-reinforced epoxy is increased from 45 MPa to 47 MPa when compared with unreinforced epoxy. In addition, the Young’s modulus is increased from 1300 MPa to 1850 MPa. Similarly, the flexure strength increased to 75 MPa from 45 MPa and Young’s Modulus in Flexure is increased to 1825 MPa from 1525 MPa. The fracture surface study through Scanning electron microscope shows the banana fiber composite exhibit ductile type of failure with minimum plastic deformation.

S.M.Sapuan et al. [36] has designed and fabricated a multipurpose table-using composite of epoxy and banana pseudo-stem fibers. In this paper the design concept, detail design and fabrication of woven banana fabric composite telephone stand are presented. The fabricated telephone stand is unique in presentation and aesthetically pleasing, golden brown in colour and can easily be matched with typical colour of furniture. H. Y. Sastra et al. [37] analysed the results from the flexural tests of Arenga pinnata fiber reinforced epoxy composite showed the highest value for maximum flexural properties. The flexural strength and flexural modulus values for 10 wt.% of woven roving Arenga pinnata fiber composite are 108.157 MPa and 4421.782 MPa respectively. The results of present study have showed that using Arenga pinnata fibers as a reinforcement for the epoxy matrix could successfully develop a beneficial composite particularly in term of strong and rigidity. Zouari B(2007) carried out yarn process by varying parameter for the simulation in fact to apply the mechanical law behavior in tension along their direction (warp and weft).

Boisse P.H et al. [38] discussed the principal deformation mode of woven fabrics is the plane shear and could be estimated by measurement of angle between yarns, during the process.

Ala Tabiei et al. [39] reviewed modeling of Process Induced Residual Stresses in Resin Transfer Molded Composites with Woven Fiber Mats. Significant change in the elastic properties is observed as a result of the scissoring effect and fiber reorientation in woven fabric composites. Sabeel Ahmed et al. [40] discussed the elastic properties and notch sensitivity of untreated woven jute and jute–glass fabric reinforced polyester hybrid composites was determined analytically and experimentally. Elastic properties were determined by using the rule of hybrid mixture and classical lamination theory (CLT).His investigation reveals that jute composites undergo more transverse strain and less longitudinal strain than jute–glass hybrid composites.

L. A. Pothan et al. [42] studied composites of woven sisal in polyester matrix using three different weave architectures: (plain, twill, and matt) were prepared using a resin transfer molding technique with special reference to the effect of resin viscosity, applied pressure, weave architecture, and fiber surface modification. His study provide the information that weaving architecture and the fiber content were both found to have an effect on the composite mechanical properties. W.L. Lai et al. [42] investigated betel palm woven hybrid composite characteristics and testing features. It is found that the alkaline treatment of fibers effectively cleans the fiber surface and increases the fiber surface roughness. In general, mechanical properties of the woven composites made from alkali treated fibers were superior to the untreated fibers.

3. CHEMICAL TREATMENT OF WOVEN FIBER COMPOSITE

N.Srinivasababu et al. [43] presented new natural fiber namely okra for the preparation of okra fiber reinforced polyester composites. Chemically treated (chemical treatment-2) okra woven FRP composites showed the highest tensile strength and modulus of 64.41 MPa and 946.44 MPa respectively than all other composites investigated in the present research. Specific tensile strength and modulus of untreated and treated okra FRP composites is 34.31% and 39.84% higher than pure polyester specimen.

Edeerozey et al. [44] carried out the chemical modification of kenaf fibers. Different concentrations of NaOH were used and SEM. examined the morphological changes. The authors observed that treated kenaf fibers exhibited better mechanical properties than untreated fibers. In addition, the optimum concentration of NaOH was found to be 6%. A decrease in impurities was observed in the case of treated fibers. Fiber bundle tests were also performed and the strength of 6% NaOH-treated fiber bundles was found to be higher by 13%. Shinji Ochi. (2008) reviewed biodegradability of kenaf/PLA composites was examined for four weeks using a garbage-processing machine. Experimental results showed that the weight of composites decreased 38% after four weeks of composting.

S.H. Aziz et al. [45] discussed the effect of alkalization on fiber alignment. Maldas et al. [46] investigated the influence of chemical treatment. Nishino et al. (2006) investigated the influence of silane coupling agent (glycidoxypropyl trimethoxysilane) on kenaf fiber-reinforced PLA. The stress on the fibers in the composite under transverse load was monitored in situ and nondestructively using X-ray diffraction. Pothan et al. [47] investigated the influence of chemical modification on dynamic mechanical properties of banana fiber-reinforced polyester composites. A number of silane coupling agents were used to modify the banana fibers. The damping peaks were found to be dependent on the nature of chemical treatment. Thiruchitrambalam et.al [48] studied the effect of NaOH and SLS treatment on Banana/kenaf woven composite. It was found that the composites made using SLS (Sodium lauryl sulphate) treated fibers has higher strength then the composites made using alkali treated fiber.

Rozli Zulkifli et al. [49] studied the effect of chemical treatment on the interlaminar fracture toughness of woven silk composite. The results give the indication of the effect of the fiber surface treatment and number of layers because the thicknesses of all the specimens are the same. In order to increase the interlaminar fracture toughness of woven silk/epoxy composites, surface treatment using silane based coupling agent gives a slightly improve properties and usage of multiple layers of woven silk fiber has proven to be effective. Rafah [50] investigation reveals that the chemical treatment improved the dielectric strength and thermal conductivity by about 29.37% and 139% respectively compared with untreated fiber composites. Finally, the dielectric constant value of the treated fiber composite was found to be lower than the untreated fiber composite and virgin unsaturated polyester.

4. CONCLUSION

The use of woven natural fiber, especially banana and kenaf as reinforcing agent in polymer-based composites were reviewed from the point of weave pattern, chemical modification and other factors and the factors which affects the mechanical properties. At present, these fibers are used for non load bearing automotive components. Thus, we conclude that the systematic and persistent research in the future will increase the scope and better future for woven banana/kenaf fiber and its composites.

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