International Journal on Applications in Mechanical and Production Engineering
Volume 1: Issue 7: July 2015, pp 5-7. www.aetsjournal.com ISSN (Online) : 2395-3500

Development of Pineapple Leaf Fiber Reinforced Plastic Composites

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***Abstract*—** Pineapple leaves have become agricultural wastes after harvesting. Pineapple leaf fiber consists of about 70-80 % wt cellulose giving its high specific modulus and strength. Pineapple leaf fibers offer significant cost advantages and benefits associated with processing, as compared to synthetic fibers such as glass, nylon, carbon, etc. In the present work, pineapple leaf fiber reinforced plastic composites have been manufactured by hand layup method and their mechanical properties are studied. The tensile test was conducted in a Universal testing machine as per ASTM: D638 standard. The flexural test was conducted in a Universal testing machine as per ASTM: D790. The double shear test was conducted in the Universal testing machine as per ASTM: D5379 standard.

***Keywords*—** Woven pineapple leaf fiber mat, Chemical treatments, Hand layup method, Mechanical properties.

I. INTRODUCTION

Fiber reinforced polymers (FRPs) are structural materials, specifically designed for lightweight constructions, for which extremely high mechanical performances are generally expected (Ashby, 2005) [1]. Fiber reinforced plastic (FRP) composites possesses interesting properties like high specific strength and stiffness, good fatigue performance and damage tolerances, low thermal expansion, non-magnetic properties, corrosion resistance and low energy consumption during fabrication (Jawaid, et al, 2011) [2]. Fiber reinforced composites have become the alternatives of conventional structural materials such as, steel, wood or metals in many applications. Typical areas of composite applications are car industry, aircraft fabrication, wind power plant, boats, ships, etc. During the human history, composites made occasionally large breakthroughs in construction and other materials. Nowadays, the situation has been the same with modern fiber reinforced composites for which mass production of polymers provided stable background (Varga et al, 2010) [3].

Natural fibers, such as flax, cordenka, hemp, jute, ramie, kenaf, bamboo, caraua and sisal, have been employed as reinforcement to prepare green composites and are basically composed of cellulose, hemicelluloses and lignin. The resulting composition of those elements varies depending on the harvesting area and agricultural conditions. Cellulose and hemicelluloses comprise polysaccharides, whereas lignin consists of amorphous polyphenolic macromolecules (i.e., three kinds of phenylpropanes) (Jang et al, 2012) [4]. Environmental awareness and sustainability concept attracts researchers and scientist towards utilization of natural fibres as a reinforcement of polymer-based composites. Natural fibre reinforced composites have been in considerable demand due to their lower cost, light weight, high strength to weight ratio, renewability, lower density, less wear and tear in processing, lower energy requirements for processing, biodegradability, wide availability and relative non abrasiveness over traditional reinforcing fibres such as glass and carbon. Application of natural fibre reinforced composites has been restricted due to its hygroscopic nature, poor wettability, low thermal stability during processing and poor adhesion with the synthetic counterparts (Jawaid et al, 2012) [5]. Natural fibre composites represent an environmentally sustainable alternative to conventional glass and carbon fibre composites. Fibres derived from plants are renewable and have low levels of embodied energy compared to synthetic fibres. They are also low cost, low density, have high specific properties, are non-abrasive and less harmful during handling. Composite materials offer higher specific strength, stiffness and energy absorption than metals which is driving their use across many industry sectors. They are used extensively in motorsport and increasingly in the automotive sector because of their potential to reduce mass. The mechanical properties of a composite are dependent on the strength of the bond between fibre and matrix. The strength of a fibre–matrix interface is dependent upon the degree of mechanical, chemical and electrostatic bonding and level of inter-diffusion between the matrix and fibres (Meredith et al, 2012) [6].

Fibre reinforced plastic composites have played a dominant role for a long time in a variety of applications for their high specific strength and modulus. Recently, there has been an increasing interest in the completely biodegradable composites reinforced with natural fibres, because they are renewable, biodegradable and environmentally friendly, not withstanding their use in low-cost applications. The advantages of natural fibres over traditional reinforcing materials have been due to their acceptable specific strength properties, low cost, low density, good thermal properties, enhanced energy recovery and biodegradability. Natural fibres such as jute, sisal, pineapple, abaca and coir have been studied as a reinforcement and filler in composites. In general, the shortcomings of natural fibre-reinforced composites have been their high moisture absorption, poor wettability and poor fibre–matrix adhesion. In order to improve the mechanical properties of these composites, alkali treatment has been

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considered as a good technique to modify the fibre surface to obtain better adhesion between the fibre and the matrix (Cao et al, 2006) [7].

A pre-requisite of most engineering materials is that they have good stiffness and strength along with adequate toughness. Man-made composites usually fill this requirement, especially since they exhibit crack-stopping capability which makes them very attractive for structural or semi-structural applications. On the other hand, over the recent years there is an increasing interest in natural fibers as a substitute for glass fibers mainly because of their low specific gravity, low cost, as well as their renewable and biodegradable nature. However, natural fiber reinforced materials have substantially inferior mechanical and water resistance properties than conventional glass fiber reinforced composites. The presence of polar groups in natural fibers is responsible for their good adhesion with thermosetting matrices. Several fiber treatments conducted on the natural fibers (i.e., alkali treatment, silane treatment, acetylation, and acrylonitrile treatment) exist. They not only modify the interphase but also produce morphological changes on the fibers. The alkali treatment promotes removal of impurities such as waxes, pectin, mineral salts and some hemicellulose and lignin. Extensive structural changes which strongly depend on the parameters of the alkali treatment (i.e., NaOH concentration, temperature and time of treatment) are also induced (Stocchi et al, 2007) [8]. Natural fibers have the advantages of low density, low cost, and biodegradability. However, the main disadvantages of natural fibers in composites are the poor compatibility between fiber and matrix and the relative high moisture sorption. Therefore, chemical treatments are considered in modifying the fiber surface properties Chemical treatments including alkali, silane, acetylation, benzoylation, acrylation, maleated coupling agents, isocyanates, permanganate and others aimed at improving the adhesion between the fiber surface and the polymer matrix may not only modify the fiber surface but also increase fiber strength. Water absorption of composites is reduced and their mechanical properties are improved (Li et al, 2007) [9]. The alkali treatment produces a rough surface; hence the number of anchorage points increases offering a good fiber–matrix mechanical interlocking, depending on the treatment condition (Mwaikambo and Ansell, 2002) [10]. Alkali treatment removes the hemicelluloses, splits the fibres into fibrils, and leads to a closer packing of cellulose chain due to the release of internal strain which in turn enhance the mechanical properties of fibre (Bledzki and Gassan, 1999) [11]. The steam and short durations of oxalic acid treatment significantly improved the mechanical properties and dimensional stability of rice straw particleboards (Li et al, 2011) [12].

The mechanical method was chosen to extract PALF from fresh leaves due to this method gave high yield of fiber, short extraction time, and environmental friendly. Green composites from pineapple leaf fiber (PALF) and polylactic acid (PLA) were manufactured (Kaewpirom and Worrarat, 2014) [13]. Vegetable fiber reinforced polymer composites have enormous potential to replace materials originated from non-renewable resources. Fibers from 12 different varieties of pineapple (Ananas genus) were characterized on their morphology, structure, chemical composition, mechanical and thermal properties. The elastic modulus ranged from 37 to 86 GPa, the tensile strength from 629 to 1309 MPa, and the onset oxidation temperature from 240 to 272 °C; indicating the potential of using all selected pineapple fibers as reinforcing fillers (depending on the polymer matrix and processing method). Direct correlations were observed between the thermo-mechanical properties of the fibers and their chemical features, such as holocellulose and cellulose contents, and also the cellulose crystallinity index. The mechanical properties showed an inversely proportional relation with the lignin content and diameter of the fiber bundle. These correlations provided indexes for the direct selection and/or for a genetic improvement program of the Ananas genus for the development of pineapples whose fibers may be adequate as mechanical reinforcement in polymer composite. An example of methodology is presented, aiming to help with materials selection within the group of vegetable fibers used in composites (Sena Neto et al, 2015)

II. EXPERIMENTAL

In the present work, first the woven pineapple leaf fiber mat (WPALFM) was made by hand weaving. Woven pineapple leaf fiber mat (WPALFM) (Pineapple leaf fiber plain weave fabric) of size 280 mm x 280 mm (80 yarns in warp direction and 30 yarns in weft direction per 280 mm each), of 640 gsm and an average thickness of 30 mm woven by hand weaving was used as reinforcement material. The WPALFM was subjected to different surface treatments with water, sodium hydroxide, oxalic acid and sodium hydroxide + oxalic acid respectively. The plain WPALFM was soaked in a stainless steel vessel containing distilled water for 1 hour, 5% sodium hydroxide (NaOH) solution for 1 hour, 5 % oxalic acid solution for 1 hour and 5% sodium hydroxide (NaOH) solution + 5 % oxalic acid solution for 1 hour separately. Then the respective specimen were washed with distilled water and dried in hot air oven for 3 hours at 70 °C.

The methyl ethyl ketone peroxide hardener and cobalt naphthenate accelerator were mixed into the polyester resin by mechanical stirring, to form the mixed polyester resin. The fiber reinforced plastic (FRP) composites were manufactured by hand layup method with one (1) layer of WPALFM. Initially a releasing agent is spread over a flat mould to enable easy removal of the manufactured FRP. Above this releasing agent layer, a thin layer of the mixed polyester resin is applied. Reinforcement in the form of WPALFM cut as per the mould size is then placed at the surface of mould. The mixed polyester resin is then poured onto the surface of WPALFM already placed in the mould and it is uniformly spread with the help of brush. A roller is moved with a mild pressure on the WPALFM - mixed polyester resin layer to remove any air trapped. Finally a thin layer of the mixed polyester resin is applied. A weight is placed over the manufactured FRP specimen and the entire setup is left for 24 hours. Thus the 4 types of woven pineapple leaf fiber mat (WPALFM) reinforced plastic composites FRP specimens with WPALFM (water treated), WPALFM (NaOH treated), WPALFM (oxalic acid treated) and WPALFM (NaOH + Oxalic acid treated); were manufactured separately. The total thickness of the entire manufactured FRP specimen was 35 mm.

The tensile test was conducted in the Universal testing machine as per ASTM: D638 standard. The three point flexural test was conducted in the Universal testing machine as per ASTM: D790. The double shear test was conducted in the universal testing machine as per ASTM: D5379 standard.

III. RESULTS AND DISCUSSION

The hand woven pineapple leaf fiber mat (WPALFM) is presented in figure 1.

Figure.1.The hand woven pineapple leaf fiber mat (WPALFM)

The photographs of WPALFM fiber reinforced plastics tensile test specimen, flexural test specimen and shear test specimen are presented in figures 2, 3 and 4 respectively.

Fig.2.Tensile test specimen

Fig.3.Flexural test specimen

The mechanical properties for the different types of of woven pineapple leaf fiber mat (WPALFM) reinforced plastic composites FRP specimens are presented in table 1. The mechanical properties of tensile strength, flexural strength and shear strength of specimens of WPALFM (NaOH treated) are higher than that of WPALFM (NaOH + Oxalic acid treated), which are higher than that of WPALFM (Oxalic acid treated), which are higher than that of WPALFM (Water treated).

Table 1. Mechanical properties of the WPALFM fiber reinforced plastics

Specimen Code	Tensile strength, MPa	Flexur strength, MPa	Shear strength, MPa
WPALFM (Water treated)	31.15	58.73	13.06
WPALFM (NaOH treated)	48.59	96.86	23.48
WPALFM (Oxalic acid treated)	35.65	69.86	17.79
WPALFM (NaOH + Oxalic acid treated)	41.19	83.70	19.31

IV. CONCLUSION

In the present work, woven pineapple leaf fiber mat (WPALFM) fiber reinforced plastics were manufactured by hand layup method and their mechanical properties are studied. The mechanical properties of tensile strength, flexural strength and shear strength of specimens of WPALFM (NaOH treated) are higher than that of WPALFM (NaOH + Oxalic acid treated), which are higher than that of WPALFM (Oxalic acid treated), which are higher than that of WPALFM (Water treated). The mechanical properties are highest for the WPALFM (NaOH treated) specimen. The development of woven pineapple leaf fiber mat (WPALFM) fiber reinforced plastics revealed that these materials can be used to the advantage for many applications.

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