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Investigation on Mechanical Properties of Hybrid Fibre Reinforced Polymer Composites

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ABSTRACT
The main intention of this review is to learn the potential of agro-residues as reinforcements for composite materials as a substitute to natural and synthetic fibre. In recent times, there has been a rapid advancement in study and progress in the field of natural fibre composite. Attention is vindicated due to the remuneration of these materials compared to synthetic fibre composite, including unassuming environmental strength, inexpensive and hold up their prospective across a wide range of use. A lot of attempt has been made in ordered to examine the mechanical properties of composites made from these natural fibre materials. This study aims to offer a summing up the factors that influence the mechanical properties of natural fibre composites and their hybrid reinforced polymer composites.
Keywords: composite, hybrid, mechanical properties, natural fibre, polymer

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I. INTRODUCTION

1.1 Composites

A composite is combination of two materials in which one of the materials, called the reinforcing phase, is in the form of fibres, sheets, or particles, and is embedded in the other materials called the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Composites usually have a fibre or particle phase that is stiffer and stronger than the continuous matrix phase and serve as the major load carrying members. The matrix acts as a load transfer medium between fibres, and in less ideal cases where the loads are complex, the matrix may even have to tolerate loads transverse to the fibre axis. The matrix is more ductile than the fibres and thus acts as a source of composite toughness. The matrix also serves to protect the fibres from environmental damage before, during and after composite processing. When designed accurately, the new combined material exhibits superior strength than would each individual material. Composites are used not only for their structural properties, but also for electrical, thermal, tribological, and environmental applications. The following are a few of the reasons why composites are preferred for certain applications:

- High strength to weight ratio
  (Low density high tensile strength)
- High creep resistance
- High tensile strength at elevated temperatures
- High toughness [1].

1.2 Composite Materials

Composite materials make their way into all aspects of recent technological civilization, but above all so for applications requiring enormous strength and light weight such as in the aerospace industry. Because they are hybrid heterogeneous materials, they can be difficult to characterize with any one particular methodology [2]. Composite materials offer design engineers with advanced quality and long life cover. Higher strength, lower weight and less maintenance have led to many engineering applications, in particular in the transport segment for extensively reduced energy consumption and impact to the environment (CO2). Generally speaking, three types of composite materials are developed and usually used in various kinds of engineering applications: polymer matrix composites (PMC), metal matrix composites (MMC), and ceramic matrix composites (CMC) [3].

1.3 Polymer Matrix Composite Materials

Polymer matrix composite materials are a growing field in aerospace science. Their utilize is rising by reason of the weight saving compared to metallic parts for equivalent application but generally still concerned minor parts in aircraft currently. However, the aeronautic industry has been also fascinated in using composite materials for structural parts to diminish manufacturing costs. Continuous processing methods such as thermo plastic automated tow placement are a potential solution to achieve this target by manufacturing bulky parts such as fuselage parts [4].

Polymer matrix composites are being progressively more considered for different applications ranging from coatings, load-bearing implants or biosensors. Examples of polymers proposed as matrices in biomedical composites include poly methyl meth acrylate (PMMA), poly sulfone (PSU), poly ether ether ketone (PEEK) or Epoxy resins. The necessities for a polymer material to be used in those applications comprise fatigue resistance, resistance to ageing in saline aqueous media, biocompatibility, dimensional stability, absence of migrating harmful additives and being sterilisable by standard methods without loss of properties. The biocompatibility requirement includes that the material and its additives are established by the surrounding tissue without toxic, inflammatory or allergic reaction [5].

1.4 Natural Polymers

Natural polymers are generally biocompatible, whereas synthetic polymers can include a residue of initiators and other compounds/impurities that do not permit cell expansion. Synthetic polymers have good mechanical properties and thermal stability, much better than several naturally occurring polymers. There is also a limitation in the performance of several natural polymers in comparison to synthetic polymers. Synthetic polymers can be processed into a wide range of shapes, whereas for natural polymers several shapes are not easily obtained; for example, high temperatures imposed in processing can destroy their indigenous structure. Newly developed polymeric materials based on the blends of natural polymers and artificial ones should be biocompatible while, at the same time, possess good thermal and mechanical properties for use in biomedical applications [6].

1.5 Matrix

The role of the matrix in a fibre reinforced composite is to transfer the load to the stiff fibres through shear stresses at the interface. This process requires a good bond between the polymeric matrix and the fibres. Poor adhesion at the interface means that the full capabilities of the composite cannot be exploited and leaves it susceptible to environmental attacks that may weaken it, thus sinking its life span. Inadequate adhesion between hydrophobic polymers and hydrophilic fibres consequence in poor mechanical properties of their specific properties, particularly stiffness, are comparable to the stated values of glass fibres. In addition, natural fibres are about 50% lighter than glass, and normally cheaper [7].

1.6 Natural Fibres

Natural fibres have many benefits compared to synthetic fibres, for example low weight, and they are recyclable and biodegradable. They are also renewable and have fairly high strength and stiffness and cause no skin irritations. Alternatively there are also some drawbacks i.e. moisture uptake, quality variations and low thermal stability. Many investigations have been made on the prospective of the natural fibres as reinforcements for composites and in numerous cases the results have shown that the natural fibre composites acquire good stiffness but the composites do not achieve the same level of strength as glass fibre composites. The manufacturing methods of natural fibre thermoplastic composites have been modified lay-up/press moulding (film stacking method), pultrusion, extrusion and injection moulding [8].

1.7 Types of Natural Fibres

Natural fibres are grouped into three types: seed hair, bast fibres, and leaf fibres, depending upon the source. Some examples are cotton (seed hairs), ramie, jute, and aflax (bast fibres), and sisal and abaca (leaf fibres). Of these fibres, jute, ramie, flax, and sisal are the most commonly used fibres for polymer composites. Natural fibres in the form of wood flour have also been often used for preparation of natural fibre composites [9].

1.7.1 Bagasse Fibre

The sugarcane bagasse (SCB) is a residue extensively generated in high extent in the agro-industry. A fibrous residue of sugarcane stalks is surplus after the crushing and extraction of juice from the sugarcane. This sugar industry by-product is almost fully used as fuel for the boilers by the sugarcane factories. The bagasse is a natural fibre generally constituted by cellulose i.e. glucose-polymer with relatively high modulus [10].

1.7.2 Coir Fibre

The coconut husk is obtainable in bulk as remainder from coconut in most of the places, which is the coarse coir fibre. It is obtained from the outer shell of coconut, or husk of the coconut. The husk comprises of 30 wt% coir fibres and 70 wt% pith. Coconut coir is the most attractive products as its lowest bulk density and thermal conductivity. The addition of coconut coir in composite reduces the thermal conductivity of the composite and produce a light weight product.

Development of composite materials for buildings is using natural fibre as coconut coir with low thermal conductivity and biodegradability [11].

1.8 Methods Used for Making Fibre Composites

The emergent need for lighter, stronger and reasonably low cost materials has led to the growth of low cost composite materials with better mechanical properties, viz. higher specific strength and stiffness. In this perspective, the use of natural fibres in polymer composites has gained attention from the research society all over the globe. The efforts are being made to substitute synthetic fibres with natural fibres to develop natural fibre reinforced composites. The use of recycled polymers such as polyolefins (Polyethylene and Polyproplyene) [12–15] as matrix in biofibre reinforced composites is rising and minimizing the troubles associated with plastic disposal and depleting fossil fuel resources and exploring a variety of way to recycle plastic waste to minimize environment pollution.

In recent time, major efforts have been directed to investigate the use of natural fibres as reinforcement in thermoplastics. Natural fibres, for example wood fibre, bagasse fibre, coir fibre, wheat straw, jute fibre and rice husk have several benefits i.e. low cost, low density, high toughness, acceptable specific strength, biodegradability and enhanced energy recovery. The natural fibre uses in plastic matrix have a lot of benefits, for instance low cost, increase of stiffness of thermoplastics, increase of heat deflection temperature, and improvement of surface exterior [16].

Design of experiments (DOE) using scientific technique is an emerging area of research these days. It may be used to find the set of experiments to recognize the optimum setting for the factors that affect the constituents of the composites. Design of experiments is useful because an optimal design reduces the cost of experimentation by allowing statistical models to be estimated with fewer experimental runs. It can accommodate several types of factors, such as process, mixture and discrete factors [17, 18].

1.9 Applications of Natural Fibre Composites

- The use of natural fibre as reinforcement in polymer matrix focused the attention towards environmental awareness among all over the globe. A hybrid composite is a combination of two or more different types of fibre in which one type of fibre balance the deficiency of another fibre [19].
- Natural fibre reinforced polymer composites have been verified substitute to Synthetic fibre reinforced polymer composites in many applications [20,21].
- Several Natural fibre composite products being developed and marketed, very few natural fibre composites have been developed, with most of their technologies still in the research and development stages. Natural fibre composites in automobile incorporate for parcel shelves, door panels, instrument panels, armrests, headrests and seat shells [22].
- Plastic/wood fibre composites are being used in a large number of applications in decks, docks, window frames and molded panel components [23].
- The passenger car bumper beam is manufactured by kenaf/glass epoxy composite material [24].
- Recently, banana fibre reinforced composites are coming into in attention due to the innovative application of banana fibre in under-floor shield for passenger cars [25].
- Automobile parts such as rear view mirror, visor in two wheeler, billion seat cover, indicator cover, cover L-side, name plate were fabricated using sisal and roselle fibres hybrid composites [26].

1.10 Advantages of Natural Fibre Composites

With the growing worldwide population, environmental problems are becoming more frequent. Now, in the 21st century, it is clear that we are paying the price for our high utilization, advanced technologies and rapid growth, in the form of ecological problems and sometimes even natural disasters. It is in our interest to look for solutions. As a consequence, there is a growing interest in green, environment-friendly materials. As far as composites are concerned, one solution could be to use natural fibres instead of more traditional glass and carbon fibres. Natural fibres are renewable; they are biodegradable in appropriate circumstances and use a bio polymer as matrix. Subject to a Life Cycle Analysis (LCA), the potential advantages of such Bio Hybrid Composites (BHC) would be:

- Less energy used than with traditional materials;
- Lower pollution levels during production;
- CO2-neutral processing and burning;
- Photosynthesis of the plant growth fixates CO2 and produces oxygen;
- No need to use fertilizers and pesticides;
- Lower cost.

In composites, natural fibres can compete with synthetic fibres because of their lower density and because they are healthier to work with and less abrasive to the tooling equipment. Their low density and bonded energy makes it possible to recycle laminates. This is the main reason for the automotive industry's great interest in BHC. Interfacial strength (adhesion) is key to efficient reinforcement. Bio fibres have an advantage in the design and manufacture of BHC laminates: compared with pure carbon laminates, which have a "linear" flexural modulus, BHC laminates have a "non-linear" flexural modulus, i.e. better flexural and impact. In composites, natural fibres can compete with synthetic fibres because of their lower density and because they are healthier to work with and less abrasive to the tooling equipment. Their low density and bonded energy makes it possible to recycle laminates. This is the main reason for the automotive industry's great interest in BHC [27].

II. LITERATURE REVIEW

Favero et al [28] investigated chemically modified high-density polyethylene (PE) and 5 or 10 wt.% rice husk prepared by extrusion. Rice husk was mercerized with a Na-OH solution, acetylated, FTIR & 13C NMR spectroscopy characterized and analyzed by SEM. PE/rice husk composites present improved flexural and impact performance but no changes in the tensile strength comparatively to the pure polymer matrix.

Oza et al [29] investigated the effect of chemical treatment on thermal and mechanical properties of hemp fibre (20-40%) composites with recycled high density polyethylene. The surface modification was analyzed by Fourier transform infrared spectroscopy (FTIR) and the thermal stability was studied by thermo gravimetric analysis (TGA). The mechanical properties of the composites were tested in accordance to ASTM D-790, the maximum flexural strength of 44.6MPa was observed 40% fibre volume fraction.

Kord [30] investigated the interfacial adhesion in wood plastic composites consisting of polypropylene and sawdust flour at 50% wt. ratios, with maleicanhydride as a coupling agent (0, 1 and 2%) were fabricated by melt compounding and then injection molding. Results indicated that the tensile, impact properties increased with increase of coupling agent. Also, in presence of maleicanhydride the mechanical properties of the wood plastic composites were improved.

Lu and Oza [31] investigated the effect of silane and Na-OH treatments on the thermal and thermo-mechanical properties of hemp-high density polyethylene composites. The results indicated that thermal stability of composites decreased with increase in fibre loading and treated composites had higher thermal stability in comparison to untreated hemp composites. Dynamic mechanical analysis revealed an increase in the storage modulus of the treated composites compared to untreated ones. The increase in storage modulus was observed up to 40% fibre volume fraction, but at 50%, it dropped drastically.

Lei et al [32] studied the effects of the fibres and coupling agent type/concentration on the properties of composite based on recycled high density polyethylene (RHDPE) and natural fibres (wood and bagasse) made through melt blending and compression molding. The use of maleated polyethylene (MAPE), carboxylated polyethylene (CAPE), and titanium-derived mixture (TDM) improved the compatibility between the bagasse fibre and RHDPE, and mechanical properties of the resultant composites compared well with those of virgin HDPE composites. The modulus and impact strength of the composites had maxima with MAPE content increase. The composites had lower crystallization peak temperatures and wider crystalline temperature range than neat RHDPE, and their thermal stability was lower than RHDPE.

Fang et al [33] measured the moisture absorption properties of the treated hemp fibre/polyethylene (PE) composites prepared by varying the fibre shape (hemp flour and hemp fibre from thermo-mechanical refining), coupling agent (maleicanhydride grafted and copolymerized onto PE), coupling agent loading method (during fibre treating process in the thermo-mechanical refiner and compositing process in twin screw extruder), and compositing method (twin screw extruding and batch mixing). The loading of coupling agent during fibre treating process decreased the water uptake but also decreased the flexural yield strength, consequently resulted in lower flexural yield strength after water exposure. The composites prepared by batch mixing method were better than by twin screw extruding for the water resistance and mechanical properties.

Ramesh et al [34] evaluated the tensile and flexural properties of hybrid glass fibre-sisal/jute reinforced epoxy composites and analyzed the interfacial characteristics of materials, internal structure of the fractured surfaces and material failure morphology by using SEM. The results indicated that the incorporation of sisal fibre with GFRP exhibited superior properties than the jute fibre reinforced GFRP composites in tensile properties and jute fibre reinforced GFRP composites performed better in flexural properties.

Thombre et al [35] experienced the study of the mechanical behaviour of hybrid natural fibre composites. Samples of several Jute-Bagasse-Epoxy & Jute-Lantana camara-Epoxy hybrids were manufactured using hand layup method where the stacking of plies was alternate and the weight fraction of fibre and matrix was kept at 40% - 60%. Specimens were cut from the fabricated laminate according to the ASTM standards for different experiments. For Tensile test & flexural test samples were cut in Dog-bone shape and flat bar shape respectively.

Siddika et al [36] investigated the tensile, flexural, impact and hardness properties and conducted Fourier transform infrared spectroscopic analysis of jute-coir fibre reinforced hybrid polypropylene (PP) composite and observed the effect of chemical treatment (5% and 10% Na-OH solutions) of fibre manufactured using hot press machine at four levels of fibre loading (5, 10, 15 and 20 wt%) with varied fibre ratio's (jute : coir = 1:1, 3:1 and 1:3) for 20% fibre loaded composites. Composites were also prepared using treated fibre with jute-coir fibre ratio of 3:1. The composite showed a decreasing trend of tensile strength and increasing trend of the Young's modulus with increase in fibre loading. The flexural strength, flexural modulus, impact strength and hardness values were found to be increased with increase in fibre loading. All these properties enhanced with the enhancement of jute content except impact strength. 5% Na-OH treatment provided an improving trend of properties whereas, 10% Na-OH treatment showed the reverse one. The FTIR analysis of the composites indicated decrease of hemicelluloses and lignin content with alkali treatment.

III. CONCLUSIONS

Natural fibre composites comprise, high specific strength and stiffness and low density. Fibres are a renewable resource, for which production requires small energy, carbon dioxide absorption, and oxygen returning to the environment. Cost of production of fibres is lesser than synthetic fibres. Hazard in manufacturing processes is less. When subjected to heat and during incineration at end of life emitted low toxic fumes. Natural fibres compared to synthetic fibre composites have less abrasive damage to processing equipment.

To a great extent research and developments has occurred on progress of bagasse and coir fibre composites and their mechanical performances. Improvement has occurred due to improved fibre selection, extraction, treatment and interfacial engineering as well as composite processing. This paper has reviewed the research that has focused on improvement of tensile strength, flexural strength, impact strength and hardness of bagasse and coir based hybrid composites.

The review reflects that the studies have been carried out to investigate the effect of varying fibre content on the mechanical properties, viz. tensile and flexural strengths, of NFPMCs. However, the work done on NFPMCs using recycled polymer as matrix material is still limited. Further, in most of the studies the researchers have employed only one kind of natural fibre in polymer matrix. Some of the studies observed that the hybrid NFPMCs containing two different kinds of natural fibres show improved mechanical properties compared to NFPMCs containing single type of bio-fibres.

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