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A Review on Mechanical Characterization of Natural Composites

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***Abstract*— As people become more aware of the environmental harm caused by conventional products, eco-friendly materials are being created. Researchers have shown a strong desire to create products that can replace synthetic materials. As a result, there has been a growth in demand for natural fiber-based composites for consumer use in various industrial sectors in recent years. Natural fibres are long-lasting fabrics that are abundant in nature and provide benefits such as low cost, lightweight, renewability, biodegradability, and high unique properties. Composite materials have seen uses in mechanical, architecture, aerospace, vehicle, pharmaceutical, maritime, and many other industrial sectors due to their broad variety of diverse properties. The performance of composite materials is primarily determined by their constituent elements and manufacturing techniques. As a result, the functional properties of various fibres available worldwide, their classifications, and the manufacturing techniques used to fabricate composite materials must be investigated in order to determine the material's optimal characteristic for the desired application. In this paper, a comprehensive review about the properties, application and the manufacturing techniques of different natural fiber reinforced composites is presented.**

Keywords*— Synthetic materials, Natural fiber, Composite materials, manufacturing technique

I. INTRODUCTION

Over the decade, composites of polymers reinforced with natural fibers have received ever increasing attention, from various industries. Because of their endurance and resilience in combination with low density, natural fibre composite materials have been used in sports items such as surfboards and snowboards, as well as in the furniture industry as structural materials. Natural fibre composites have also found favour in the car industry, where lighter weight means greater transport capability and lower fuel consumption. In reality, several automakers are aiming to substitute glass fibre composites with recyclable or biodegradable natural fibre composites. Natural fibres such as jute, flax, hemp coir, and sisal are fine thermoset and thermoplastic matrices reinforcement and are used in vehicle, building, and packaging industries with few drawbacks(Mohanty et al 2000)[1]. Natural fibre is defined as fibrous plant material produced as a result of photosynthesis. These fibres are sometimes referred to as vegetable, biomass, photomass, phytomass, agromass, solarmass or photosynthetic fibres. In terms of use, there are two general classifications of plants containing natural fibres: primary and secondary. Primary plants are those that are grown for their fibre content, while secondary plants are those that provide fibre as a by-product of another primary use. Primary plants include jute, hemp, kenaf, sisal, and cotton, while secondary plants include pineapple, cereal stalks, agave, oil palm, and coir. Botanical type is the most general classification for natural fibres. Bast fibres, leaf fibres, seed fibres, core fibres, grass and reed, and all other varieties such as wood and roots are the six basic forms of natural fibres according to this type[2]. After vegetable or plant fibres, animal fibres are the most commonly used natural fibres. Proteins make up the most of them, and they may act as insulation in composites. Wool fibre from horses, goats, lamas, chickens, musk oxen, and other animals is an example of this fibre. Silk, feathers, and hair are also derived from a variety of sources[3].

II. TYPES OF NATURAL FIBERS

Natural fibres can be categorised based on their origin. Cotton, sisal, flax, jute, etc., are among the essential fibres in the plants, or cellulose-base, category. Wool, mohair, chicken feather fiber, silk, etc., are examples of animal, or protein-based, fibres. Asbestos is a mineral fibre that is very significant.

A. Plant Fibers

Sisal fibre is a vegetable fibre with properties similar to glass fibre in terms of strength and stiffness. Synthetic resins, on the other hand, are generally more costly than sisal fibre, making these composites less appealing for low-tech applications[4]. Jute fibres are totally biodegradable and recyclable, which makes them environmentally safe. Jute fibres have excellent thermal and acoustic insulating properties, with mild moisture resorption and no skin irritations [5]. Some other examples of plant fibers are Areca fiber. Areca fibers are extracted from areca sheath which is a ripen leaf from the tree. It is not useful for farmers and does not create any problem to the environment. It is purely natural sheath which can be used in composites[6].

B. Animal Fibers

After vegetable or plant fibres, animal fibres are the most commonly used natural fibres. Proteins make up the most of them, and they may act as insulation in composites. Wool fibre from horses, goats, lamas, rabbits, musk oxen, and other animals is an example of this fibre. Silk, feathers, and hair are also derived from a variety of sources[3]. Wool fibres have different properties than each other. Alpaca fibre is lighter and colder than sheep fibre and is almost white in colour, while angora fibre is thin and fluffy and comes from the Angora rabbit. Cashmere fibre is a luxury soft wool fibre obtained from the cashmere goat, while quiviut wool obtained from the musk ox is a more costly smooth fibre. Despite the fact that the above fibres have different properties, sheep fibre is the most commonly used fibre due to its broader availability and lower cost. Silk is another essential natural protein fibre that can be woven into textiles and can be obtained from a variety of sources. The fabrics come from a variety of insects, with the majority of the silk coming from butterfly larvae. Feathers from chickens can be found in vertebrates. They have a complex integumentary structure, are produced in small follicles on the chicken's outer skin layer, and contain keratin proteins. Chicken feathers have certain special properties, such as low density and superb thermal and acoustic insulation. They are composed of 91% keratin (protein), 1% lipids, and 8% water, and can be used as reinforcement materials in composites[3].

III. NATURAL FIBERS AS A REINFORCEMENT

Natural fibres were used in lines, ropes, and other one-dimensional objects in the early 1800s and into the nineteenth century; other uses included early suspension bridges for on-foot river crossings and rigging for naval ships. Many different types of textiles, cords, canvas, and chapter made from natural fibres are used today. Natural fibres have been phased out due to the low cost and the efficiency of technical plastics and, most importantly, synthetic fibres. In the 1990s of the twentieth century, a revival in the use of natural fibres as reinforcements in technological applications began. Natural fiber-reinforced polymer composite materials are attracting a lot of attention, both in terms of industrial applications and fundamental research. They are a sustainable, low-cost, completely or partly recyclable, and biodegradable source of lignocellulose fibres. Plants such as flax, cotton, hemp, jute, kenaf, pineapple, ramie, bamboo, banana, and others, as well as wood, have been used as insulation in composites since the dawn of time. Their affordability, renewability, low density, and price, as well as satisfactory mechanical properties, make them an appealing ecological alternative to glass, carbon, and man-made fibres used in composites manufacturing. Natural fiber-based composites are more environmentally friendly and are used in vehicles (automobiles, train buses, aerospace), military applications, the architecture and construction industry (ceiling panelling, partition boards), packaging, consumer electronics, and other applications[7].

IV. APPLICATIONS OF NATURAL FIBRE COMPOSITES

Natural fibre parts for interior components have been actively manufactured by the automotive and aircraft industries (Sanjay et al., 2016; Puttegowda et al., 2018)[8,3]. Natural fibres are also used to make insulation components for a variety of applications, including blowing insulation, pouring insulation, effect sound insulation materials, and ceiling panels for thermal and acoustic soundproofing (Akin, 2010)[9]. Natural fibres have a bright future in construction, with a wide range of architectural styles, forms, and also the ability to improve on already existing materials. In the world of construction, synthetic fibres could be replaced with natural fibres. Sunscreens, cladding, walling, and flooring are all made of it[10]. Flax, cotton, sisal, and wool, among other natural fibres, are now used in Mercedes-Benz parts (Holbery and Houston, 2006)[11]. The mirror casing, paperweights, voltage stabiliser cap, projector cover, helmet, and roof were all made of coir/polyester-reinforced composites[12]. The flax fibres were used in the construction of the GreenBente24 voyage[13]. Rice husk fibre, cotton, ramie, jute fibre, and kenaf are used in a variety of applications such as construction, furniture, clothes, ropes, sewing thread, fishing nets, packaging materials, and paper manufacturing (Sen and Jagannatha Reddy, 2011b)[14]. The use of natural fibre composites in the automotive industry, especially in car interiors, has received a lot of attention. It is also used to make external auto body components, in addition to car interior parts (Shuit et al., 2009; Monteiro et al., 2010; Shinoj et al., 2011; Mohammed et al., 2015)[15,16,17,18].

V. MANUFACTURING PROCESSES

All the natural fibers extracted from their natural sources should be treated with some chemicals and washed using tap water for better properties as it may contain some foreign materials like dust in jute, areca, cotton, sisal, etc, and blood, skin and flesh in chicken feathers. The fibers are cleansed in running water and dried. The fibers were dried for 10 hours in natural light. Advantage of chemical treatment (with NaOH preferably) is to get rid of moisture content from the fibres thereby increasing its strength. Also, chemical treatment enhances the flexural rigidity of the fibres and stabilizes the molecular orientation.[19] To convert the raw materials into the final shape without creating any defects in the component, a suitable manufacturing method must be used. Design and manufacturing engineers rely on a variety of factors for the correct fabrication selection process with biodegradable polymer based composites, including desired properties, size and form of the resulting composites, raw material handling characteristics, production speed, and manufacturing expense. Because of their versatility and quick processing time, injection and compression moulding are favoured for small to medium sized parts. Some techniques used for fabricating the natural fiber composites are:

A. Hand Lay-up Process

In the study of Dynamic Vibrational Analysis on Areca Sheath fibre reinforced bio composites by Fast Fourier Analysis[6], Hand layup technique was used to fabricate the composites of areca fibers where the mould is prepared with Mild steel of size 320 x 320 x 4 mm. In another study of Investigation of the Mechanical Properties of Glass Fiber – Chicken Feather Hybrid Composite, Hand layup technique was used to prepare hybrid composite consisting of chicken feather and glassfiber. The technique of laying down fabrics made of reinforcement and painting with the matrix resin layer by layer until the desired thickness is obtained in hand lay-up molding.

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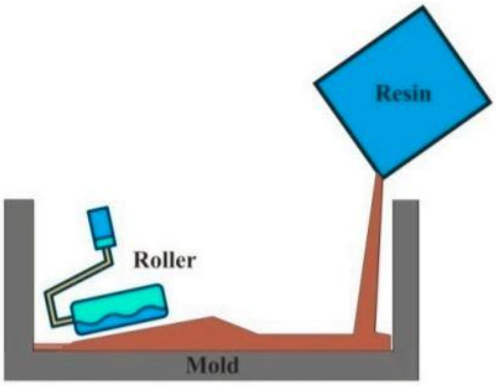

Fig 1[27]

B. Spray-up Process

Kenaf fiber composite was manufactured using Spray-up process in the study of Manufacturing and Processing of Kenaf Fibre- Reinforced Epoxy Composites via Different Methods [20]. By using a spray gun and a fiber cutter, spray-up molding is much less labor intensive than the hand lay-up process. However, it is only possible to create short fiber reinforced composites. Through the blade, a continuous fiber is fed and chopped. With the resin mist stream and catalyst supplied through separate nozzles, the chopped fiber is sprayed onto a mold. The sprayed fiber and resin mixture will soon cure the mold at room temperature and the product will be made. Large and complex-shaped objects can be easily produced because of the spraying process.

There are many other manufacturing techniques used. We have reviewed two manufacturing techniques.

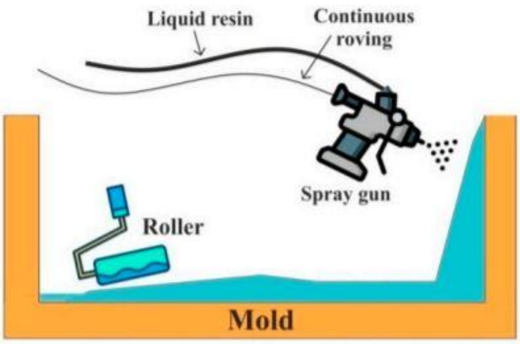

Fig. 2[27]

VI. MATRIX MATERIAL

The common matrix material used for the fabrication of most of the natural fiber composites contains low temperature curing epoxy resin LY556 and corresponding hardener HY951. Epoxy resin and hardener are mixed in a ratio of 10:1 as suggested [21]. The Epoxy Resin LY556 was used as a reinforcing material because of its medium viscosity and chemical resistance. The hardener HY951 was the acceptable hardener for the epoxy resin used.

VII. PROPERTIES OF NATURAL FIBRE COMPOSITES

A. Mechanical Properties

In recent years there have been extensive studies on the mechanical properties of natural fiber composites. The exploration of mechanical properties of Palmyra natural fiber reinforced composite was done by using analytical method and experimental method. ANSYS12 software was used to solve the analytical method and tensometer machine was used to determine experimental results. They concluded that the error percentage between these two were comparatively less[22]. Kumar [23] measured the tensile strength, flexural strength, and surface stiffness of bamboo – epoxy composites in a thesis concerning the analysis of bamboo natural fibre composite. On the bamboo epoxy composite, the influence of fibre loading on tensile strength, flexural strength, and surface hardness was also investigated. The maximum value tensile strength, flexural strength, and micro surface stiffness of bamboo–epoxy composite were found to be achieved at 25% wt of fibre loading in this study using the hand layup technique. Saba et al [24] investigated the mechanical properties of kenaf fibre. They discovered that the kenaf fibre has strong tensile and flexural strength, as shown by numerous mechanical tests, allowing it to be used in a wide range of applications, including auto-industrial, light-weight constructional applications, and traditional goods such as yarns, fabrics, and ropes. He also discovered that kenaf/epoxy composites had greater mechanical properties than polymeric matrix composites.

B. Biodegradability

As opposed to non-renewable petroleum-based goods, natural fibre reinforced PLA composites are a truly renewable material with effective degradability. PLA and natural fibres are both hydrophilic, and it is thought that this property will help with adhesion[25].

C. Free Vibration Properties

The natural frequency and damping factor of a banana and sisal fibre randomly directed reinforced polymer composite were investigated. The effects of various weight percentages on banana, sisal, and hybrid composites are investigated. In comparison to other types of composites, 50 percent composite has the highest natural frequency. And the stiffness of the substance is increased[26].

VIII. CONCLUSION

The primary goal of this review is to give a overlook of the mechanical characterisation of different natural fibre reinforced composites. Global innovations in renewable materials are throwing light on the possibility of using natural resources like natural fibres to reinforce base matrix materials. Flax, sisal, jute, and bamboo are examples of cellulosic fibres of high specific strength and low density. Since all natural fibres are biodegradable, the fabrics can be safely disposed of at the end of their useful life. Composite materials are made using a variety of methods, each of which is specific to a particular type of material. Since each substance has different physical properties, such as melting point, hardness, and tensile strength, the effectiveness of the processing method is determined by the combination of form and amount of matrix or fibre material used. As a result, manufacturing methods are determined by the material chosen. Some of the experimental analysis of natural fibers which are reviewed in this paper. The hybrid composite of 10% chicken feathers with synthetic glassfibers had maximum tensile strength (193 MPa), flexural strength (148 MPa), and impact strength (3.65 Joules) were determined the investigation of mechanical properties of Glass fiber-Chicken Feather hybrid composite[28]. In the Experimental Investigations on Mechanical Properties Of Jute Fiber Reinforced Composites with Polyester and Epoxy Resin Matrices, it was was found that Jute-epoxy and jute-polyester composites had tensile strengths of 12.46 N/mm2 and 9.23 N/mm2, respectively[29]. Natural fibre is being used as an important reinforcement medium in polymer matrix composites as a result of increased environmental consciousness. Natural fibres are effective fabrics that can be used to supplement synthetic fibres. The fibres that are normally harvested from plants and animals have low moisture tolerance, and the incompatibility of the fibres is the major downside. As a result, material properties have been modified by chemical treatments of natural fibres, which increase fiber-matrix adhesion and improve the mechanical properties of composites. Natural fibre will soon become one of the most sustainable and renewable options in the composites industry, capable of replacing synthetic fibres in a variety of applications.

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