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A Review On Development And Physio-Mechanical Analysis Of Bio-Friction Brake Pad Material

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Abstract

Environmental pollution caused due to automobile vehicle is a major concern in the world. Brakes are a very important component that should have good stability, and braking efficiency, and provides safety to humans. The development of brake pads using asbestos as a friction material has caused so many environmental problems and human health issues. The researchers have found synthetic fiber, and copper as an alternative for asbestos. Copper causes so many environmental problems and majorly affects aquatic species. Synthetic fibers such as Kevlar, glass fiber has high processing cost than other fibers which also produces greenhouse gases. Recent studies are carried out to use the fibers for making a composite that is biodegradable, lightweight, less costly, renewable, non-toxic, and environmentally friendly. Majorly the commercial brake pads are made up of polymer composite with various ingredients including phenol-formaldehyde. These days, various natural fibers are used to develop the natural fiber-reinforced brake pad by using hemp, jute, kenaf, banana, ramie, flax, etc. The major drawback of natural fiber polymer composite was that it has poor moisture resistance, low thermal stability, non-homogeneity of fiber and matrix, and highly anisotropic properties. This review is on the recent work in natural fiber-reinforced composite used for brake pads. The review includes various types of fibers, chemical treatments, manufacturing processes, physio mechanical, and thermal tests performed on natural fiber-reinforced composite.

Index Terms- Biodegradable, Hemp fiber, Natural fiber, Thermogravimetric Analysis, Mechanical testing.

1. Introduction

The brake system in automobile vehicles mainly consists of two components are drum and a brake pad. The huge amount of heat generated while braking increases the temperature of the brake pad so a brake pad with good thermal stability and good thermal conductivity is required. The materials used as reinforcement in brake pad composites are different types such as metallic, ceramic, non-metallic, and cellulosic. Synthetic fibers such as glass, carbon, and aramid fiber are the most common reinforcement material in polymer composites due to their better mechanical properties in various applications. But the major drawback of synthetic fiber is that they are non-biodegradable and causes so many ecological problems.[1]. In the previous study, Kevlar fiber with phenolic resin was used as the friction material. The researchers reported that the increase in aramid fiber content, tensile strength, and tensile modulus enhanced, while elongation at break was reduced. The carbon fiber processing cost is much more and also produced greenhouse gases.[2]. The semi-metallic materials have been used in the development of brake pads including steel, iron, and copper, but it is being aggressive in the braking system mostly on the rotor. They also produce dust. But ultimately semi-metallic materials and ceramics are much more expensive than other natural fibers.[3]. Some of the ingredients present in metallic brake bad get oxidized and produce toxic gaseous.[4]. Hence according to the demand of properties, natural fiber reinforcement composite is an alternative to metallic, semi-metallic, and synthetic fibers. The comparison properties of natural fibers and synthetic fibers are given in table.1. The degradability of natural fibers would strongly support the recyclability characteristic of fiber composite which also inspires the fabrication of natural fiber reinforced polymer (NFRP) composites.[1]. Nowadays natural fibers used to development of composites are bamboo, banana, cotton, flax, hemp, and jute. The composite has been made by using the short as well as long (continuous) fiber. The development of continuous fiber-reinforced composite has high production cost and difficulty in processing these composites led to getting attraction towards the development of natural discontinuously reinforced composite. The properties of composite greatly depend upon parameters such as reinforcement particle distribution, size, volume fraction, orientation, and matrix microstructure.[5]. are used

as structural materials because of their advantages of easy manufacturing and good mechanical properties. ROFRC is used in various applications such as automotive, aerospace, construction, and biomedical applications.[6]. It has been proven that the mechanical properties of composite get improved as the interfacial strength between fibers and matrix is increased, also due to the use of the natural fibers, the composite becomes lighter as compared to synthetic fibers.[7]. The reinforcement is the major constituent of composite material which takes most of the load applied to it. For taking a high load the reinforcement should have high sufficient hardness and high tensile strength.[8].

Table.1. The advantages of natural fibers over synthetic fibers.[20][20]

Properties	Natural Fibers	Synthetic Fibers
Density	Low	High
Processing cost	Low	High
Renewability	Renewable	Non-Renewable
Recyclability	Yes	No
Health issues	No	Yes
Disposal	Biodegradable	Non-biodegradable

(ROFRC) The extraction of biofibers has played a very vital role that affecting the characteristics of the reinforcements. Biofiber contains more amount of cellulose, hemicellulose, pectin, lignin, etc, which make them hydrophilic and result in poor interfacial bonding when emerging into the hydrophobic polymer. Because of these, the final properties of bio-composites such as mechanical and thermal stability are affected. The modification has been done to overcome hydrophobicity that surface modification through chemical treatments.[9]. The physical properties of natural fibers are given in table2. There are different molding techniques for manufacturing natural fiber-reinforced composites (NFRC) such as compression molding, resin transfer molding, injection molding, and vacuum infusion molding.

2. Natural Fibers

There are various types of natural fibers available for use for reinforcement. The most widely used plant fibers include cotton, sisal, jute, bamboo, Hemp, Kenaf, coir, and Banana Fiber.

Table.2. Physical properties of natural fiber.[1], [20].

Fibers	Tensile strength (Mpa)	Young's modulus (Gpa)	Density (g/cm^3)	% of Elongation
Bamboo	290	17	1.25	1.4
Banana	529 – 914	27 – 32	1.35	2.6 – 5.9
Cotton	400	12	1.51	0.3 – 10
Flax	800 – 1500	60 – 80	1.4	1.2 – 1.6
Hemp	550 – 900	70	1.48	1.6 – 4.0
Jute	410 – 780	26.5	1.48	1.16 – 1.80
Kenaf	930	53	-	1.6
Sisal	610 - 720	9 – 24	1.34	2.3 – 2.5

2.1. Jute fiber

Jute fiber is produced from plants in the genus Corchorus family Malvaceae. Jute is a lignocellulosic fiber that is partially a textile and practically wood. It is one of the cheapest natural fibers and is a good fiber with a higher production rate volume. India, Bangladesh, and china provide the best condition for the growth of Jute.[10]. The world production of Jute fiber is about 2300 $*10^3$ tons, with their application in the door frame, shutter, and clipboard.[8]. The physical and mechanical characteristics of Jute fiber have a Density of 1.3-1.46 (g/cm^3), The cellulose about 41-48%, lignin 21-24%, hemicellulose 18-24 %., Ash 0.8%. [11] .

2.2. Hemp fiber

The hemp fiber belongs to the family of bast fibers. It is one of the most dominant and strong members of natural fiber. It is taken out from the hemp plant with its species of cannabis. The production of hemp fiber in the world is around 214 (10^3 tons), with their wide utilization in the field of electrical, paper industries, furniture, Cordage, etc.[8]. The chemical composition of the hemp fiber includes Cellulose 57-77% and lignin 3.7-13%. Hemicellulose 14-22.4%, Ash 0.8%, wax of 0.8 %.[11].

2.3. Banana fiber

Banana belongs to the genus Musa family Musaceae. This plant is usually referred to as a tree but it is actually a giant herb. It is a tropical plant that is growing in sheltered positions. The fiber of banana is widely used and is extracted from the trunk of the plant.[12]. The overall production of bananas only in India is about 13.5 million per annual with a wide variety mainly in southern India.[13]. In Kanyakumari, Kerala, and Tamil Nadu the banana as a

natural fiber is utilized for the making rope, mats, paper cardboard, lightweight composite, string yarn, natural absorbent, etc. The Chemical composition of the banana fiber contains cellulose of 60-65%. lignin 5-10% hemicellulose 19%. [11], [12].

2.4. Kenaf fiber

Kenaf is a family of Malvacea. It is one of the non-wood fibers which can be used in the composite as reinforcement or fillers. Kenaf fiber is a traditional third-world crop after wood and bamboo which originated from Asia and Africa. The production of kenaf fiber around the world is about 970 (10^3 tons), with their application in packing materials, mobile cases, and insulations.[8]. The Kenaf plant can divide into parts including a long stem that provides long fiber according to its length. The Yarn can be taken out from the kenaf for production of the product they show another application in cloth material carpets, sacks.[14]. The chemical composition of kenaf fiber contains cellulose of 31-57%, lignin 9-21·2%, Hemicellulose of 20.3- 33.9 %, and Ash of 2-5%.[14].

3. Methods and composition

3.1. Fiber treatment by chemical modification

Fiber treatment and modifications are used to improve the adhesion between matrix and fibers. This method tends to increase the water resistance, improve wetting and dispersion, and be easier to handle.[9]. chemical treatments are used to improve the fiber/matrix bonding, and resistance to moisture of composites.[9].

3.1.1. Alkalization

Alkalization is the process that is used as an economic process and is commonly used for fibers. The results of the alkalization process depend upon various parameters such as alkaline solution, and time of reaction temperature. If the alkali concentration is increased more than the critical level the causes the damage to the fiber. Alkalization process cause to through away the oil, wax, lignin, and hemicellulose before manufacturing the biocomposites. As the unwanted materials are removed the biofibers become rough and enhance the interlocking, and adhesion at the fiber/matrix interface.[9].

3.1.2. Silane Treatment

Silane is the hydride of silicon, which consists only of Si and H atoms silanes are used to enhance the adhesion and provide a strong bonding between fiber and matrix. Due to silane adsorption, the layer was formed on the surface of the fiber. There are various steps involved in silane treatment such as hydrolysis, self-condensation, Adsorption, and chemical grafting.[15].

3.1.3. Acetylation treatment

The hydrophilicity was removed by using acetylation, treatment and also enhances the interfacial bonding between fibers and matrix. The hydrophilic nature was removed and improves the dimensional stability of composites. This treatment causes a rough surface topology with less void substance and provides better mechanical bonding with the matrix.[15].

3.1.4. NaOH treatment

Sodium hydroxide (NaOH) has been used for fiber treatments due to its ease of application, and material availability. It has been true that sodium hydroxide has a bad impact on the environment, but the small amount of the NaOH that is used for the fiber treatments.[16].

4.0. Composite manufacturing

4.1. Hand lay-up process

The hand lay-up process is the simplest and most widely used for the development of composite. By using this process very large size of the composite was made such as a boat, and water tank.

Process: Select the mold according to the shape of the mold that can be fabricated. Apply the release gel on the surface of the mold that can avoid the polymer to stick to the mold. In the first layer, the polymer is applied and in the second layer, fiber is applied. Layer by layer polymer and fiber is applied to form the required thickness. As the laminate is formed pressure is applied by using consolidated rollers. The reason behind applying the pressure is that the void and air bubbles are removed from the composite. Because applying the pressure on the laminate polymer will spread throughout and become a homogeneous composite. Thermosetting resins are brittle so more resin present in one place causes increased brittleness of the fiber at that place. In this process, the direction of the fibers applied can be controlled.

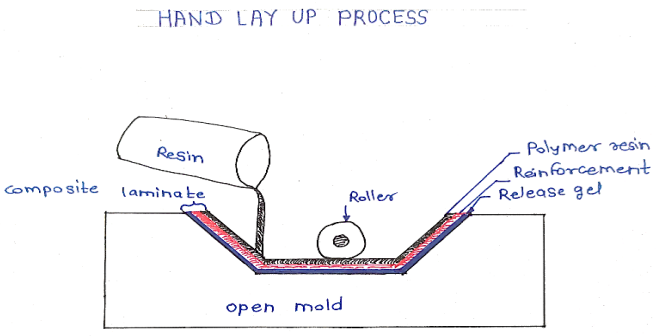

Figure.2. Hand lay-up process

4.2. Compression molding process

Compression molding is used for thermosetting as well as a thermoplastic polymer. The common process involved in the compression molding process is heating, melting, deforming, and finally cooling. It is a high-pressure closed molding process. Pressure is suitable for small to medium size parts by using this process complex shapes can be easily produced.

Process: The two matched molds are used for the manufacturing of composites. The release gel is applied to the mold to avoid sticking the composite to the mold. Craft paper can also be used and placed on the mold and release gel is applied. Then the mixture is kept on the mold and a whole assembly is put between the compression molder. Heat and pressure are applied as per the requirements for a definite period. The materials placed in between the molding

parts flow due to the applications of heat and pressure. The hardener is used for the thermosetting polymer to react the polymer and make it solidify the polymer. As the heat and pressure are applied the hardener and resin will become rigid and get our composite.

Figure.4. compression molding machine

Procedure	Condition
Mixing condition	Mixing of fibers and resin for 5 minutes. and mixing other ingredients for 5 minutes.
Molding condition	Temperature = 150°C, Time = 10 minutes, Pressure = 15 Mpa.
Oven curing condition	Temperature = 170°C, Time = 3 hours.

Table.5. Composite fabrication details. [17], [18]

4.3 Injection Molding process

The injection molding process is a closed molding process. This process is used for small fibers. The process is suitable for both thermoplastic and thermosetting polymer with short fiber-reinforced composites. This process is suitable for mass production.

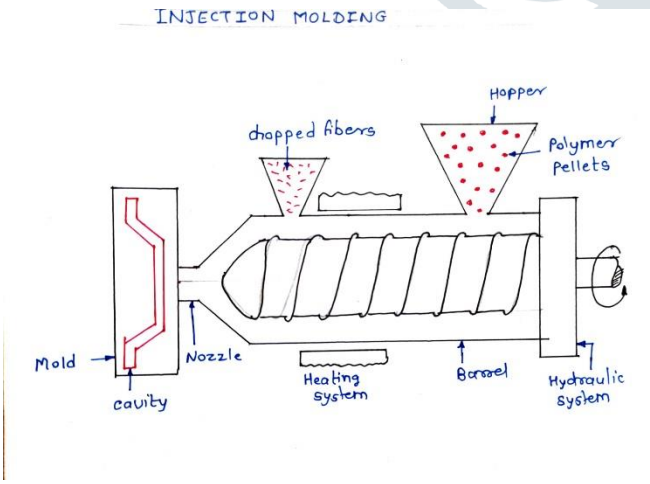

Figure.6. Injection molding machine

Process: Firstly puts the polymer pellets into the hopper and through the hopper, they will be coming into the barrel. The heating of the polymer will be done by using the heater surrounding the barrel. Due to heating, the polymer pellets will melt and they will move forward by screw. The screw will rotate and it will push the melt polymer towards the mold. Then small size fibers will be mixed with polymer and uniform distribution of fiber and matrix will form.

Then the mixture will enter the cavity to form the final composite. The chopped fiber will be introduced just before the nozzle because as the fiber will be introduced near the pellets the degradation of the fiber will start due to heating.

5.0. Testings of composite

5.1. Density test

The density of a material is mass per unit volume. It is based on the ASTM standard D7920-00. The procedure for performing the density test contains obtaining the weight of the specimen in the air (a) and the weight of the specimen in the water (b). The density is calculated by getting the weight of air and water. Whereas the density of air is negligible and the density of water is 1 g/cm^3. The density of composite material at 23°C can be calculated as follows.

$$\rho = \frac{a}{a + w - b} \times 100$$

$\rho = density$ (g/cc)

a= weight of the specimen in air

b= apparent weight of fully immersed specimen and partially immersed wire.

W= apparent weight of partially immersed wire alone density if distilled water at 23°C (g/cc).

5.2. Water absorption test

The water absorption test gives us the water content in the composite laminate. Firstly the specimen weight before the immersion (W_d) is taken down then after the immersion (W_n) the sample is removed from the water and carefully clean with filter paper to remove the excess water on the surface. The described ASTM D570 standard method is used for the water percentage of the composite.[19]. To get the proper percentage of water absorption the specimen should be immersed in water until equilibrium water condition. (Nearly 48 h).[16].

$$\text{Water absorption (\%)} = \frac{Wn - Wd}{Wd}$$

5.3 Tension test

It is the simplest and widely used uniaxial mechanical test. This test gives the values of an elastic module, tensile strength, and Poisson's ratio of the material. While performing the tensile test of the composite material then flat specimen having a dog-bone shape with straight-sided is generally used. This commonly used ASTM standard D3039/D3039M-00 for tension tests.[19]. The method is designated for the test of fiber composite. In the recording data, it records the applied load and strain in parallel and perpendicular to the load. The applied load is measured by the load cell which is generally fit in the machine and strain can be measured by an extensometer or electrical-resistance strain gauge.

5.4. Compression test

The compression test is quite similar to the tension test. There are several loading fixtures and specimen configurations used to determine compressive strength. The

ASTM standard D 6641/D 6641M-01 describes the test method of compressive strength of polymer matrix composite using fixture. By this test elastic moduli and Poisson's ratios of composite material can be determined and the stress-strain curve in compression can be plotted.

5.3. Thermogravimetric analysis.

It is an experimental technique in which the mass of a sample is measured as a function of sample temperature or time. The sample is heated at a constant heating rate or held at a constant temperature. There is some loss of weight or gain of weight due to the temperature applied. In the thermogravimetric analysis, the sample is heated in an environment of carbon dioxide, air, and nitrogen.[2].The TGA analysis can be performed in the range of temperature of 20-1100 C. The main applications for TGA are constant analysis, thermal stability, and evaporation behavior. This data is used to produce the component with excellent face resistance concerning this data there can be stability in thermal conditions.[16].

6.0. Conclusion and future perspective

This review article aims to present an overview of biocomposite materials, surface modification techniques, properties of fibers, and processing techniques. This review article is devoted to producing a strong understanding of the processing techniques, and testing of biocomposites. To replace the synthetic fibers biocomposites that are lightweight, biodegradable, non-toxic, abundant availability, health benefits, and sustainable, low cost has become a great attraction. Taking the review of conventionally employed fibers such as jute, hemp, flax, sisal, etc. shows that there is the possibility of taking another fiber with biopolymer to enhance the properties of biocomposites that can be used in various applications. The commercial demand for these materials and their use in the future will be increasing due to the need for various applications, and environmental awareness among the people.[9].

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