ARCN International Journal of Sustainable Development
ISSN: 2384-5341. Volume 14, Issue 1, (January, 2024) pages 11 – 23
DOI: 2726-4-573-1-1412
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https://arcnjournals.org

Composites Made from Natural Fiber Materials: A Review

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Abstract: *In the recent time, a lot of research has been ongoing on composite development as a replacement to most engineering materials. The need for the production of environmentally friendly and biodegradable materials to reduce the environmental effect of non-biodegradable materials has led researchers to investigate the use of natural fibers as reinforcements in polymer composites. There is a rising interest in the use of these natural fibers because of their attractive features such as superior mechanical, physical and thermal properties and advantages such as worldwide availability and their biodegradable nature. An increase in the use of natural materials in composites could lead to a significant reduction in greenhouse gas emissions and carbon footprint of composites. However, there are some limitations associated with the use of natural fibers which can be overcome by subjecting them to morphological changes by various physical or chemical treatment methods. The overall objective of this paper is to provide a comprehensive overview of the need to use natural fibers as reinforcements in polymer composites.*

Keywords: *natural fibers, polymer, fiber treatment, composite, biodegradable, mechanical properties.*

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1. Introduction

Composite materials are defined as multiphase materials comprising two or more components possessing special properties. The reinforcement and matrix are the two main components of any composite material. Reinforcement is the principal component of composite and is the part that takes most of the load applied to the composite material. As reinforcement has to take the load, it must be hard, stiff and have high strength. A matrix is that component (a binder) of composite that surrounds the reinforcement. It protects, supports and holds the reinforcement in place at the desired orientation. It protects the reinforcements from environmental damage *(Yashas Gowda et al.,* 2018). These two components work together to give the composite a special property different from the properties of the individual components. Fiber reinforced composites are most generally employed in the automotive and aircraft industries due to its excellent properties like high strength, light weight, water resistance, chemical resistance, high durability, electrical resistance, fire resistance and corrosion resistance. They are also used in the infrastructure and structural applications. Fiber reinforced composites uses different types of fibers as reinforcements such as glass fiber, carbon fiber or natural fiber and polymer such as matrices namely plastic, resin, rubber or metal (Kerni *et al.,* 2020). However, the increasing demand for environmentally sustainable materials has prompted the use of natural fiber as a reinforcement in composite materials. The natural fiber in composite 9has continuously attracted the attention of researchers and scientists due to their many advantages over synthetic materials such as glass fibers and carbon fibers (Sai Shravan Kumar & Viswanath Allamraju, 2019). Natural fibers are being considered as an environmentally friendly alternative to synthetic fibers in fiber-reinforced polymer composites amongst other several advantages they offer such as light weight, easy availability and economic considerations. Natural fibers have proven to play an important role in developing biodegradable composites to resolve the current ecological and environmental problems. The use of environmentally friendly materials, which are recyclable, biodegradable, and renewable, has been recently considered to decrease the environmental impact of non-biodegradable synthetic materials (Gholampour & Ozbakkaloglu, 2020).

2. The need for natural fiber reinforced polymer composite

In the past, only synthetic fiber based reinforced composites were used due to low cost and good mechanical properties. These composites use the glass fiber or carbon fiber as reinforcement for composite materials. One major concern of all manufacturers and researchers, in this recent time is sustainability. To achieve a sustainable development goal, there is a great need as well as challenge for every industry to replace the non-sustainable products with the sustainable ones (Kerni *et al*., 2020). All natural plant fibers are sustainable. This is a suitable replacement for non-sustainable synthetic materials. Another major reason why we need to use natural fibers are to protect our environment from the use of non-biodegradable fibers which could in turn cause ecological and environmental problems. One of the main advantages of these natural fibers is that at the end of their life, they can be degraded by composting or other methods which does not proof any threat to the environment. Moreover, they are cheap and available as long as we continue to have a rich agricultural sector that continues produce. Also, the use of natural fibers would create employment opportunity in rural and less developed regions thus helping in achieving the sustainable development goals by the United Nations in eliminating poverty, building inclusive and sustainable industrialization and fostering innovation, creating sustainable cities and communities and responsible production and consumption.

3. Sources and types of fibers

Natural fibers are hair-like or thread-like naturally existing substances with a high aspect ratio (Sinha et al., 2017) produced from plant or vegetable, animal, and mineral-based sources (Verma *et al*., 2016), (Gholampour & Ozbakkaloglu, 2020). Fibrous plants are abundantly available in agricultural crops and tropical areas. Plant fibers are mainly composed of cellulose, whereas protein is the major component of animal fibers (Gholampour & Ozbakkaloglu, 2020). Among these fibers, plant–based fibers are most frequently used in a number of applications and are of very high commercial importance (Thakur *et al.*, 2014). Natural plant fibers include different classes of fibers such as seed, fruits, bast, leaf, wood pulp, stalk and grass fibers (Hamidon et al., 2019).

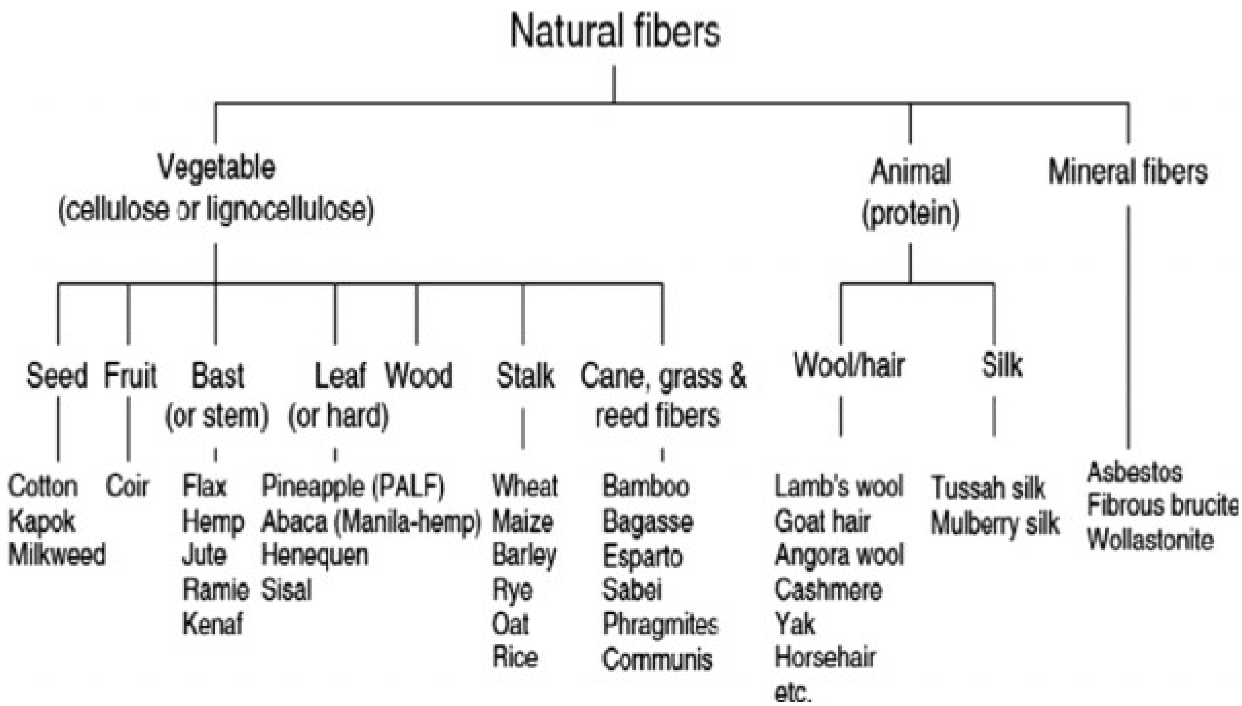

Figure 1: Classification of natural fibers (Hamidon et al., 2019).

4. Properties of natural fibers

The constituents of almost all natural fibers contains hemicelluloses, cellulose, pectin, lignin, waxes and water-soluble substances except for cotton which contains cellulose, waxes, protein and pectin (Dochia *et al.*, 2012). The chemical composition of fibers may vary even within the same plant species, as a function of condition of growth of the plant, geographical factors and the method of fiber extraction. (Hamidon *et al.,* 2019), (Thakur *et al*., 2014), (Vijayan & Krishnamoorthy, 2019). The amount of cellulose in a given fiber determines the strength and stiffness of the fibers, which is provided by hydrogen bonds and other linkages in the cellulose. The amount of hemicellulose controls moisture absorption, biodegradation, and thermal degradation properties of all the natural cellulosic fibers, while lignin has been reported to be the most thermally stable among all three constituents, but is very sensitive to UV radiation and is responsible for the degradation of fibers under ultraviolet radiation. Among the constituents present in any cellulosic fiber, cellulose is the most essential component (Thakur et al., 2014) because it is primary component of the cell wall which provides strength, rigidity and support (Aldred, 2009).

Fiber properties are determined by the physical, mechanical and chemical properties of its constituents and their interfaces (Rohan *et al.*, 2018). These properties are dependent on the shape, size, crystallite content, orientation, and thickness of the cell walls (Gholampour & Ozbakkaloglu, 2020). Different properties of natural fibers, especially mechanical properties, depend upon the type of cellulose present in the fiber. The mechanical properties depend upon the degree of polymerization of the cellulose, total cellulose content in the fibers, and the microfibril angle (Thakur *et al.*, 2014).

5. Application of natural fiber composite

Natural fiber-based composites are extensively used in automotive applications. This is due to their light weight which leads to lesser fuel consumption and reduced emissions of harmful gases. Natural fiber reinforced composite even has extensive application in electronics and sporting fields. There are various other products like bicycles, tennis rackets, laptop cases that may be manufactured using natural fiber composites. Research in composites in recent times, has been shifted from synthetic fiber based composites to natural fiber reinforced composites ones, because of all the aforementioned properties and applications of natural fiber based polymer composites (Kerni et al., 2020). Natural fibers are considered as a suitable alternative to synthetic fiber, due to their numerous advantages such as worldwide abundance and availability, high strength -to-weight ratio, low cost, high toughness, reasonable specific strength, non-abrasive nature, renewability and biodegradability (Balaji & Senthil Vadivu, 2017). Most of the plant fibers are categorized as eco-friendly fibers because they are biodegradable and have no negative effect on the environment. (Gholampour & Ozbakkaloglu, 2020). The effective utilization of natural fibers as reinforcement fibers in diverse polymer matrices provides a number of positive benefits, including environmental benefits. Some of these fibers are reported to have healing and antibacterial properties. Natural fiber–reinforced composites are recently finding their use in a number of commercial applications such as deck surfaces, door components, windows, sports facilities, packaging and automotive industries, and furniture (Thakur *et al.*, 2014).

Societal and governmental needs have challenged several industries such as automotive, construction, energy and aerospace, among others to make products that are more durable, environmentally friendly and product that would reduce dependence on fossil fuels. The European commission issued a press release this year on proposed regulation, replacing the current directives on end-of-life vehicles on reusability, recyclability and recoverability and is expected to have substantial environmental benefits. In this light, the adoption of natural fiber as reinforcement in composite production is a needed development and attractive option for industries to meet socio-economic and environmental challenges. Therefore, natural fibers will play a vital role in socio-economic development of our society (Peças *et al.*, 2018). Despite the wide application of natural fiber composites in automotive sector, other fields of applications of natural fiber composites include textiles, medical, healthcare and pharmaceuticals, home and personal care, food and feed additives, construction and furniture, packaging, pulp and paper, bioenergy and biofuels and so on (Peças *et al.*, 2018).

6. Limitations and modification of natural fibers

Despite the many advantages of natural fibers, there are some issues within the development of these composites. Hydrophilic nature of natural fibers reduces the application of natural fibers as reinforcement in polymer composites. This is because it results in swelling of fibers and the production of voids at the interface between the matrix and fiber, decreasing the bonding between them. Fast degradation, and low resistance to higher temperatures are also some disadvantages associated with it use. These limitations would have a major effect on the mechanical properties. Natural fibers also possess the tendency to make aggregates during manufacturing of composites. This limits the application of natural fibers in manufacturing of composites. Lesser dimensional stability is also a disadvantage of natural fiber reinforced composite. Thermal stability of natural fibers limits their use as reinforcement in composites to some extent ones (Kerni et al., 2020).

These problems can be overcome by modifying the fiber structure by physical or chemical treatment before use (Rohan *et al.*, 2018).

The physical modification of a cellulosic natural fiber refers to the changing of the surface properties such as surface energy, polarity, surface area, cleanliness and wettability. Corona treatment, plasma treatment, ultraviolet (UV) treatment, fiber beating and heat treatment are some of the remarkable techniques for physical modifications of fiber without altering the chemical structure of fibers. In the case of the corona, plasma and UV treatment, fiber surface energy is changed using a high voltage at low temperature and atmospheric pressure. Consequently, wettability and fiber–matrix interfacial bonding is improved, which enhances the composite strength. Active surface area is enlarged by the process of fiber beating which allows a good interfacial interaction between fiber and matrix. The heat treatment process removes the non-cellulosic components of plant fibers, such as pectin, lignin and hemicellulose, along with other dirt from the fibers, and allows the cleaned fiber to react with the matrix more actively. The chemical treatment is mostly carried out to deteriorate the inherent hydrophilic nature of the natural fibers, which eventually assists in enhancing the interfacial bonding between the fibers and the matrix (Syduzzaman et al., 2020). During the treatment of fibre, the waxy layers and impurities present in fibres would be drastically reduced. Due to the removal of waxy layer and impurities, twisting and bundling of natural fiber are achieved, which enhances the tensile, flexural, and impact strengths of the composite (Sinha *et al.*, 2017).

Chemical methods improve fiber/matrix adhesion by introducing new groups between incompatible fibers and matrices. These group enable bonding between fibers and matrices. Silane treatment is an efficient method to improve fiber/matrix adhesion using SiH_4. Some researchers applied silane treatment to the Kenaf fiber to improve the bonding between the fiber and the matrix by increasing the degree of cross-linking in the interface region. The silane treatment also contributes to stronger bonding between the fiber and the matrix by increasing the fiber surface area. Silanes are applied as coupling agents to fibers in order to ensure that they effectively adhere to a polymer matrix, which stabilizes the composite material (Hamidon *et al.,* 2019). Maleated coupling improves a composite's strength by improving the fiber/matrix interface. Another method is a bacterial modification, which improves fiber/matrix adhesion through better mechanical interlocking. The use of cellulose produced from bacteria is considered a green method for surface modification and provides new means to modify fibers. Alkali treatment or the Mercerization process is used to induce rough surfaces at the fiber/matrix interface. The alkaline treatment works by altering hydrogen bonding in the structure and removing some lignin, waxes, and oils to expose short-length crystallites. Alkaline-treated fiber has an increased concentration of exposed cellulose and surface roughness for better interlocking. High alkali concentration has adverse effects on fibers, which can weaken and damage the fiber. Optimum concentration must be ensured to have most of desired mechanical and physical properties. Benzoyl treatment is also used to improve fiber/matrix adhesion (Zwawi, 2021). The composite materials made out of chemically treated natural fiber have high tensile, bending, impact, and interlaminar shear strength as well as hardness values compared to the untreated composites (Sathish *et al.*, 2021). Moreover, the enhancement in the overall properties of natural fiber composites occurred after improved fiber selection, extraction, treatment and interfacial engineering as well as composite processing (Sai Shravan Kumar & Viswanath Allamraju, 2019). Currently, there is still quite a great discrepancy between the strength of natural fibers and that of conventional reinforcing fibers, such as glass fibers. The difference in strength is one of the main reasons why natural fibers cannot fully replace the glass fibers. Thus, researchers started investigating the hybridization of composites by combining two or more types of fibers as reinforcements to produce an hybrid composite with improved characteristics as compared to those of single fiber composition (Hamidon *et al*., 2019).

7. Matrices for natural fiber composites

A matrix is used in composites to hold the reinforcing materials together by surface connection. The main responsibilities of the matrix are the environmental tolerance, surface appearance, and durability of the composite. As the matrix is stressed, it transfers the external load uniformly to the fibers, and it is applied to resist the propagation of cracks and damage (Gholampour & Ozbakkaloglu, 2020). The polymer matrix used in the preparation of composites are classified into thermoplastics and thermosetting based on the type of bonding present in them (Yashas Gowda *et al*., 2018) and the detailed classifications are shown in the Table 1 .

Table 1. Major polymers used as matrix for composites

Thermoplastics	Thermosets
Nylon	Phenolic
Cellulose acetate	Epoxy
Polystyrene (PS)	Polyester
Polypropylene (PP)	Polymide
Polyethylene (PE)	Polyurethane
Polycarbonate (PC)	
Polyvinyl chloride (PVC)	
Polyether–ether ketone (PEEK)	
Acrylonitrille-butadiene-styrene (ABS)	

Table 2. Some major properties of thermoplastics matrix materials

Thermoplastics	Density (g/cm^3)	Tensile modulus (GPa)	Tensile strength (Mpa)	Melting temperature (°C)
Polypropylene (PP)	0.90–0.91	1.1–1.6	20–40	175
Polyethylene (PE)	0.91–0.95	0.3–0.5	25–45	115
Polyvinyl chloride (PVC)	1.38	3.0	53	212
Polystyrene (PS)	1.04–1.05	2.5–3.5	35–60	240
High density PP	0.94–0.97	0.5–1.1	30–40	137

Table 3. Some major properties of thermoplastic matrix

Thermosets	**Density (g/cm^3)**	**Tensile modulus (GPa)**	**Tensile strength (Mpa)**	**Elongation at break (%)**	**Compression strength (Mpa)**
Polyester	1.0–1.5	2.0–4.5	40–90	< 2.6	90–250
Epoxy	1.1–1.6	3.0–6.0	28–100	1–6	100–200
Vinyl ester	1.2–1.4	3.1–3.8	69–86	4–7	86
Phenolic	1.29	2.8–4.8	35–62	1.5–2.0	210–360

7.1 Thermoplastic based natural fiber composites

Thermoplastic resins are polymers that can be shaped easily in the viscous state and solidified by cooling (physical change). In the melted condition, the viscosity of thermoplastic resins is approximately 500–1000 times higher than that of uncured thermoset resins. They are solid at room temperature and can be reformed and reshaped when heated without chemical reactions. Thermoplastic resins have higher impact resistance (approximately 10 times), more reformability, higher damage tolerance, and higher processing temperature pressures than thermoset resins (Gholampour & Ozbakkaloglu, 2020). Natural fiber thermoplastic matrix composites have unique characteristics such as low density, high damping and specific mechanical properties, biodegradability, and recyclability. They have been widely used in applications including automotive and construction because of these advantages. The environmentally friendly natural fiber thermoplastic composite consists of natural fibers, such as hemp, kenaf, and flax, and matrix such as polyethylene and polypropylene. The low densities of both natural fibers and thermoplastics often result in a composite with a density ranging from 1.04 to 1.45 g/cm3 depending on the types of fiber and matrix and fiber percentages (Ning et al., 2019).

Among various thermoplastic polymers, polypropylene is perhaps one of the most widely used because of its moderate to good mechanical properties. Hence, it is an obvious choice as the matrix material in the preparation of natural fiber–reinforced composites. These materials possess moderate dimensional stability, high temperature of thermal deformation and flame resistance. The recyclability of these materials is an advantage which will reduce disposable waste and therefore economical. Recycled polypropylene showed higher density, lower porosity and water absorption property with a high dimensional stability relative to the composites and native polypropylene, which also showed excellent mechanical properties such as strength and tensile strength (Yashas Gowda *et al.,* 2018). Polypropylene composites have excellent flowability, mechanical characteristics, weatherability, and chemical resistance, and are economical considering cost aspects. Such composites are used widely as an important raw material especially in automobile parts. The automobile bumper is one of the major applications of PP composites (Nomura *et al.*, 2018). Fiber Reinforced Polypropylene composites are mainly fabricated by extrusion, injection or by compression molding. Extrusion method is widely used to fabricate short fibers composites. Injection molding refers to a process that generally involves forcing or injecting a plastic material into a closed mold of desired shape. This method is normally used for high-volume and low-cost component manufacturing. This method is normally used for high-volume and low cost component manufacturing (Shubhra *et al.*, 2013).

Natural fiber-reinforced high-density polyethylene composite hybridized with ultra-high molecular weight polyethylene was developed with kenaf through compression molding. A less ultrahigh molecular weight composite was achieved with polyethylene fiber reinforcement added. A low density composite with an increase tensile strength was achieved. (Ning *et al*., 2019). Agave fibers was used as reinforcement for preparation of polystyrene composites. Composites produced exhibited high mechanical properties as well as a high thermal stability in composites with particles and shorter fibers than that of the longer fibers which is attributed to the strong fiber/matrix adhesion due to greater surface area of particle reinforcement (Singha & Rana, 2012).

7.2 Thermoset based natural fiber composites

Thermoset resins are infusible and insoluble materials that are cured by heat or a catalyst. Thermosets are completely different from thermoplastics, they cannot be melted and reshaped by heating. Owing to three-dimensional covalent bonds between the polymer chains, this type of resin has a higher modulus, improved creep resistance, higher thermal stability, and higher chemical resistance than thermoplastic resins. They are also brittle at room temperature and show low fracture toughness (Gholampour & Ozbakkaloglu, 2020).Thermoset polymers are used as a matrix material for most structural composite materials. The main advantage of thermoset polymers is that they have a very low viscosity and can thus be introduced into fibers at low pressures. Thermosets are processed by simple processing techniques such as hand lay-up and spraying, compression, transfer, resin transfer, injection, compression injection, and pressure bag moulding operations (Yashas Gowda *et al.*, 2018).

Coconut fiber and mahogany wood dusts were used as reinforcements in polyester matrix and has been found to be s are good alternatives to synthetic fibers as they are cost effective, abundantly available and environmentally friendly and possess good mechanical properties. These exhibited properties would makes this composites find their applications in building and construction industries and in applications where strength are of paramount importance (Omiwale et al., 2017). The mechanical properties exhibited by epoxy composites reinforced with NaOH treated fiber shows that they are suitable for low load applications such as window panels, decorative items, cushioning pad, fishing rod, internal parts of aeroplane, lampshades, food trays & interior paneling etc. Thus these composites can replace the most conventionally used materials in those applications and enhance the overall quality of the product (Parbin *et al*., 2019).

8. Mechanical Properties of the Natural fiber reinforced polymer composite

The interfacial adhesion between the cellulosic fiber and polymer matrix influences the composite properties. The composites show better physicochemical properties if suitable interactions between the fiber and the matrix are provided. Furthermore, natural fiber composites exhibit reasonable mechanical properties such as stiffness, strength, flexibility, and young's modulus. Fiber type, fiber orientation, microfibril angle, treatment type, physical properties, and adhesion between the fiber and the matrix are essential characteristics in composites to determine mechanical properties. The microfibril angle determines the stiffness of the fiber. Natural fibers act as reinforcements to improve mechanical properties. Fiber/matrix adhesion is the most critical factor for the determination of mechanical properties. Better adhesion improves the stress/load transfer between fiber and matrix. Tensile strength is mostly dependent on matrix properties, while modulus is dependent on fiber properties (Zwawi, 2021).

Table 1: Mechanical properties of some natural fibers (Vijayan & Krishnamoorthy, 2019), (Syduzzaman et al., 2020).

S/N	Types of Natural fibers	Moisture content (wt. %)	Density (g/cm^3)	Elongation at break (%)	Tensile strength (MPa)	Young's modulus (GPa) Cotton
1.	Abaca	5-10	1.5	3-10	430-980	12
2.	Oil palm	12-15	0.7-1.55	25	248	3.2
3.	Pineapple	14	1.5	1-3	413-1627	82
4.	Cotton	7.85-8.5	1.5-1.6	7-8	287-597	5.5-12.5
5.	Jute	12.5-13.7	1.3-1.49	1.16-1.8	393-773	13-26.5
6.	Flax	8-12	1.5	27.6	345-1035	27.6
7.	Hemp	6.2-12	1.47	1.6	690	70
8.	Ramie	7.5-17	1.55	1.2-3.8	400-938	61.4-128
9.	Sisal	10-22	1.45	3-7	511-635	9.4-22
10.	Coir	8	1.15-1.46	15-40	131-220	4-6
11.	Silk	9.91	-	20-25	252-528	7.32-11.22
12.	Banana	8-10	1.35	53	500	33.8
13.	Wool	13.8	-	25-35	122-175	2.34-3.42
14.	Bagasse	20-28	1.2	1.1	290	19.7-27.1
15.	Bamboo	11-17	0.9	5.6-8.6	575	9.8
16.	Kenaf	6.2-12	1.2	1.6-6.9	295	53

9. Fabrication of Natural fiber reinforced polymer composite

There are a wide variety of processing techniques used to fabricate the composite materials. Application conditions for each of these techniques are quite different. Different types of composite fabrication methods can be classified according to the methods of a polymer matrix and reinforcement application to the mould, or according to the curing methods (Syduzzaman et al., 2020). Fabrication processes play an important role in determining the mechanical properties of natural fiber reinforced polymers. The major fabrication processes that can be used include Compression Molding process, the Injection Molding process, the Extrusion Molding and hand lay-up technique.

Compression molding is a reliable method due to the high production rate and low processing time. Compression molding is used for bulk production, such as in automobile parts production. Compression molding decreases fiber strength due to the dependency on initial fiber length and various process parameters such as melt viscosity and screw speed and design. The incompatibility of natural fibers with matrices also reduces fiber strength and the strength (Zwawi, 2021). In compression molding, preheated materials are initially placed in the molding cavity. Then, they are compressed and deformed by the core side of the mold while subjecting the cavity to high pressure. Before opening the mold and removing the composite, the high pressure is maintained until the composite solidifies. The important parameters that must be considered with this technique are the amount of material, heating time, pressure applied to the mold, and cooling time (Gholampour & Ozbakkaloglu, 2020). The primary advantage of the compression molding is its ability to produce large number of parts with little dimensional variations (Shubhra et al., 2013).

Extrusion is a hot-melt technique used for the continuous production of composites (Zwawi, 2021). Extrusion molding is one of the most widely used procedures in the manufacturing process of natural fiber composites. This technique is preferred because of the high stiffness and strength of the composites and because the formation of the composites with this technique is very easy. This technique begins with storing the thermoplastic material in the form of pellets or granules in a hopper. Then, they are delivered to a heated barrel to be molten. The molten plastics are subsequently used for the required shape of the composite. The final stage is cooling the product (Gholampour & Ozbakkaloglu, 2020).

Injection molding refers to a process that generally involves forcing or injecting a plastic material into a closed mold of desired shape. The molding compound is fed into injection chamber through the feed hopper. In the injection chamber, the molding compound is heated and therefore it changes into liquid form. It is forced into the injection mold by the plunger. This method is normally used for high-volume and low-cost component manufacturing. Both thermoplastic and thermoset are subjected to injection molding. A thermoplastic material is first melted and then forced through an orifice into the mold which is kept relatively cool. The material solidifies in the mold from which it can then be removed. But in thermoset injection molding, high temperature is required for solidification. Therefore, a reaction material is forced into a generally warm mold in which the material further polymerizes into a solid part. This method is suitable for high-volume and low-cost component manufacturing. But the method is limited to short fibers (Shubhra et al., 2013).

Hand lay-up is the most common, simplest, and cheapest technique for production of composites. In this technique, a release agent as an anti-adhesive agent is initially applied to the open mold, and the fibers are then placed in the mold. Resins are applied to the fibers by pouring and brushing with a roller or brush. Lay-up is made by building layer upon layer till the desired thickness is achieved. Entrapped air in the laminate is removed manually with squeegees or rollers. Laminates are then left to cure under standard atmospheric conditions (Gholampour & Ozbakkaloglu, 2020).

Conclusions

Natural fibers amongst various natural materials have proven to be environmentally friendly, abundantly available and of a very low cost. Different kinds of natural fibers, due to their bio renewable nature and inherent eco-friendly characteristics, offer a number of advantages over synthetic fibers such as glass fibers and carbon fibers. These reasons have made natural fibers become an excellent alternative to synthetic fibers. However, there are still more researches that need to be done to overcome the limitations of natural fiber composites such as deterioration and moisture absorption.

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