Composites of Polymer Blends and Their Applications Using Natural Fibres: A Review

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Abstract. Study on new composite materials in engineering products with promising physical and mechanical properties has been considered as one of the fields of concern in recent decades. Strength, hardness and fatigue properties make engineering structural more flexible. They are extensively used in the aerospace industry, mechanical engineering applications and parts, electronic packaging, vehicle and aircraft structures, process industry equipment, as well as in biomedical equipment. Disposing of composite wastes however, are very difficult because of its structure and compositions. Hence, composite materials recycling has become one of the major measures of the future. This study seeks to analyse the present state of engineering plastics using natural fibers in their properties and manufacturing techniques. The effects of various chemical treatments on natural fibres’ mechanical and thermal properties have been studied in strengthening thermosetting and thermoplastics composites. The mix ratio of polymer waste used from the industry sector with natural fiber is expected to rise in the future, thus issues regarding recycling need to be tackled. It concluded that chemically treated natural fibre improved the adhesion between fibre surface and polymer matrix, which gradually increased the properties of natural fibres incorporated composites.

1. Introduction

In the recent years, the awareness of environmental and consumer’s awareness towards new products subjected to strictly regulation and law enforcement, the environmentally friendly used materials adopting natural fibers become more popular [1][2]. Natural fiber offered good properties and environmental user friendly compared to synthetic one when developing a new product which aiming quality and sustainable values [3]. The growth of natural fiber applications in composites industries are considerably fast over 5 years (2011 – 2016) by 10% worldwide [4].

The variety of mechanical properties and lack of knowledge for such fibres created major problems for end users in the widespread implementation of methods for collecting, handling, processing and post-processing natural fibres. Natural fibres are clearly defined fibres that are not synthetic or manmade and may be derived from animals or plants. [5]. The use of natural fibre with renewable and non-renewable polymers from both origins, such as oil palm, kenaf and jute, to manufacture composite materials, has attracted considerable attention in recent decades.

Plants producing cellulose fibres can be categorised as fibres of bast (kenaf, hemp, ramie, flax, and jute), fibres of seed (kapok, coir, and cotton), fibres of leaf (abaca, pineapple, and sisal), fibres of grass and reed (rice, corn, and wheat),
fibres of core (jute, hemp, and kenaf) and all other types of fibres (roots and wood) [6]. Table 1 indicates the world and world production of the most common and commercially natural fibres.

| Fiber Source      | World Production (10^3) |
|-------------------|-------------------------|
| Bamboo            | 30,000                  |
| Sugar cane bagasse| 75,000                  |
| Jute              | 2300                    |
| Kenaf             | 970                     |
| Flax              | 830                     |
| Grass             | 700                     |
| Sisal             | 375                     |
| Hemp              | 214                     |
| Coir              | 110                     |
| Ramie             | 110                     |

Table 1: Natural fibers in the world and their world production [4]

The problems of natural fibres are the scattered data and the variations in mechanical properties described. Furthermore, the absence of instructions on methods for the collection, storage, processing and post-processing of natural fibres creates a difficulty for both the producers and consumers of these products. These issues are in reality, important deterrents to the widespread use of natural fibres in different applications. The fibre reinforced polymer matrix received considerable attention in terms of its comparatively low weight, low cost, less harm to processing equipment, good relative mechanical properties such as tensile module and flexural module, improved surface finish of moulded composite parts, renewed composite parts due to the good properties and superior benefits of natural fibre over synthetic fibres [7].

Moreover, the mixing of natural fibres and polymers is argued since the chemical compositions of both fibres and the matrix are distinct, it was considered a challenge. Such reasons for the ineffective transferring of stress during interface of the composites produced. Therefore, natural fibre modifications using unique treatments are definitely necessary. Typically, these improvements are focused on the use of groups of functional reagents that have the capacity to react and modify the composition of the fibre structures. As a result, fibre modifications make it possible to minimise the absorption of moisture by natural fibres, resulting in excellent Incompatibility across the polymer matrix and the fibre [8]. Kabir et., al. [9] agreed in a review of chemical treatments of natural fibres that treatment is a main factor to be taken into account mostly in processing of natural fibres. It was found that fibres lose hydroxyl groups due to various chemical treatments, which decreases the hydrophilic characteristics of the fibres and enhances the mechanical strength and dimensional stability of natural fibre reinforced composites.

This paper is organised as follows in four areas: first, we give an overview of natural fibres, focusing on their benefits and practical characteristics. Next, we identify the relevant applications and potential trends. Finally, with some final remarks, we discuss and conclude the reviewed.

2. Natural Fibre Polymer Composites (NFPCs)
Natural fibre polymer composites can be classified as a composite material with a polymer matrix incorporated with natural high-strength fibres such as oil palm, jute, sisal, flax and kenaf [10] (NFPC). Polymers can typically be broken down into two classifications: thermoplastics and thermosets. The thermoplastic matrix material composition tends to make their properties weaker at an elevated heat range and roll back when cooling, consisting of one or two-dimensional molecular. Polymer thermosets can, meanwhile, be recognised as highly cross-linked polymers that recover only using heat, heat and pressure and/or light irradiation. Therefore, its composition gives the thermoset polymer excellent properties such as high flexibility, good strength and modulus [11, 12].

In general, depending on the nature of the constituents, bio-based composites can be graded either as partially eco-friendly or green. Green composite means all the components come from renewable sources, potentially reducing carbon dioxide emissions and depending on petroleum-based materials. On the other hand, if one of the components is partly environmentally friendly, either the fibre or the matrix is not derived from renewable resources [13]. In accordance with length, dimension and orientation, natural fibre reinforcement can be split, as shown in figure 1. The fibre itself is classified as continuous or discontinuous according to its length to diameter ratio (l/d) (i.e. chopped). Generally, the fibre-reinforced phase structure is known as woven or non-woven. A woven fabric is characterised by continuous interlacing of perpendicular yarns in a regular pattern.

![Figure 1. Classification of bio-composite [13–15].](image)

Due to the nonlinear mechanical behaviour of natural fibres, under the influence of tensile shear loads, the fracture activity of composites is also affected [16]. Table 2 demonstrates the mechanical properties of common forms of natural fibres in the world [17].

Composite properties [19] are also affected by the hydrophilic character of the natural fibre [18] and by the mixing of the fibre. In order to achieve good NFPC properties, high fibre loading is typically required [20]. It should be remembered, in general, that the rise in the fibre content contributes to enhancement of the composites' tensile properties. [21].
Table 2. Physicomechanical properties of natural fibers [17].

| Fiber  | Density (g/cm³) | Tensile strength (MPa) | Young's modulus (GPa) | Elongation at break (%) |
|--------|-----------------|------------------------|-----------------------|-------------------------|
| OPEFB  | 0.7–1.55        | 2                      | 3.2                   | 2.5                     |
| Flax   | 1.4             | 88–1500                | 60–80                 | 1.2–1.6                 |
| Hemp   | 1.48            | 550–900                | 70                    | 1.6                     |
| Jute   | 1.46            | 400–800                | 10–30                 | 1.8                     |
| Ramie  | 1.5             | 500                    | 44                    | 2                       |
| Coir   | 1.25            | 220                    | 6                     | 15–25                   |
| Sisal  | 1.33            | 600–700                | 38                    | 2–3                     |
| Abaca  | 1.5             | 980                    | —                     | —                       |
| Cotton | 1.51            | 400                    | 12                    | 3–10                    |
| Kenaf  | 1.2             | 295                    | —                     | 2.7–6.9                 |
| Kafir  | 0.21            | —                      | —                     | —                       |
| Bagasse| 1.2             | 20–290                 | 19.7–27.1             | 1.1                     |
| Henequen| 1.4           | 430–580                | —                     | 3–4.7                   |
| pineapple | 1.5          | 170–1672               | 82                    | 1–3                     |
| Banana | 1.35            | 355                    | 33.8                  | 53                      |

Table 3. Equilibrium humidity content of various natural fibres relative humidity (RH) at 65 percent and 21°C [22].

| Fiber  | Equilibrium humidity content (%) |
|--------|----------------------------------|
| Abaca  | 15                               |
| Pineapple | 13                            |
| Jute   | 12                               |
| Sisal  | 11                               |
| Coir   | 10                               |
| Hemp   | 9                                |
| Ramie  | 9                                |
| Bamboo | 8.9                              |
| Bagasse| 8.8                              |
| Flax   | 7                                |

In the meantime, temperature can also influence the percentage of the composites’ water absorption. The equilibrium moisture content of certain natural fibres can be observed in Table 3 at 65 percent humidity at 21 °C [22].

3. Application

NFPC applications are growing quickly in various engineering fields. In various automotive applications, structural components, packaging and construction components, various types of natural fibres such as oil palm, jute, kenaf, hemp, and bamboo reinforced polymer composites have been given great importance [23, 24]. Society and governments are challenged by many sectors, including automotive, manufacturing, electricity and aerospace, to generate more environmentally sound products and, among others, to reduce their dependency on fossil fuels [25, 26, 27].

In tables 4 and 5, respectively, the application of natural fibres in general and also specifically in the automotive industry is presented. Due to its low specific weight, relatively high strength, relatively low manufacturing costs, corrosion resistance and fatigue resistance, the widespread use of NFPCs in polymer composites.
Table 4. Natural fibre composite applications in industry [28 – 31].

| Fibre          | Application in building, construction, and others                                   |
|----------------|-----------------------------------------------------------------------------------|
| Hemp fibre     | Construction products, textiles, cordage, geotextiles, paper & packaging, furniture, electrical, manufacture bank acts, and manufacture of pipes |
| Oil palm       | Fiber building materials such as windows, door frames, structural insulated panel building systems, siding, fencing, roofing, decking, and other building materials [32] |
| Wood fibre     | Window frame, panels, door shutters, decking, railing systems, and fencing         |
| Flex fibre     | Window frame, panels, decking, railing systems, fencing, tennis racket, bicycle frame, fork, seat post, snowboarding, and laptop cases |
| Rice husk fibre| Building materials such as building panels, bricks, window frame, panels, decking, railing systems, and fencing |
| Bagasse fibre  | Window frame, panels, decking, railing systems, and fencing                       |
| Sisal fibre    | In construction industry such as panels, doors, sliding plate, and roofing sheets; also, manufacturing of paper and pulp |
| Stalk fibre    | Building panel, furniture panels, bricks, and constructing drains and pipelines    |
| Kenaf fibre    | Packing material, mobile cases, bags, insulations, clothing grade cloth, soilers potting mixes, animal bedding, and material that absorbs oil and liquids |
| Cotton fibre   | Furniture industry, textile and yarn, goods, and cordage                           |
| Ramie fibre    | Use in products as industrial sewing thread, packing materials, fishing nets, and filter cloths. It is also made into fabrics for household furnishings (upholstery, canes) and clothing, paper manufacture |
| Jute fibre     | Building panels, roofing sheets, door frames, door shutters, transport, packaging, geotextiles, and chip boards |
| Coir fibres    | Building panels, flush door shutters, roofing sheets, storage tank, packing material, helmets and postboxes, mirror casing, paper weights, projector cover, voltage |

Table 5. Applications of natural fibres in automotive industry [33, 34, 35, 36, 37, 38].

| Natural Fibres | Component/Description                                                                 | Other Constituents       | Reference(s) |
|----------------|--------------------------------------------------------------------------------------|-------------------------|--------------|
| Basil fibres (flax, hemp, kenaf, jute, sisal, etc.) | Carrier for covered door panels, covered components for instrument panels, covered insets, carrier: for hard and soft armrests, seat back panels, door panels, door bolsters, headliners, side and back walls, seat backs, rear deck trays, pillars, centre consoles, load floors, trunk trim | Polypropylene (PP) and polyester | [34] |
| Abaca          | Under-floor panel and body panels                                                   | –                       | [33,36]      |
| Coconut        | Seat bottoms, back cushions and head restraints, interior trim and seat cushioning, seat surfaces/backrests | Natural rubber          | [34,35,38] |
| Banana         | Wapping paper                                                                       | –                       | [37]         |
| Coir           | Car seat covers, mattresses, doormats, rugs                                         | –                       | [38]         |
| Cotton         | Soundproofing, trunk panel, insulation                                              | PP/PET                  | [33,35]      |
| Flex           | Seatbacks, covers, rear parcel shelves, other interior trim, floor trys, pillar panels and central consoles, floor panels | Mat with PP (floor panels) | [33,35] |
| Fitrowood recycled | Plastic retainer for seat back panel                                                | PP granules, thermoplastic | [34]         |
| Flex or Hemp   | Carrier for covered door panels                                                     | Epoxy resin             | [34]         |
4. Future Trends

The broad benefits of natural fiber-reinforced composites, such as a high weight-to-weight ratio, light weight and biodegradability, make them ideal for various applications in the construction industry [39]. To a large degree, the capacity for the application of natural fibres, in particular as composite reinforcement, relies on the increase in regulations and their commercial requirements, including the setting of production and post-treatment.

Advancing the knowledge of natural fibre would make it possible to standardise the fibre type available on the marketplace and enable people to have a top level of trust in the mechanical and chemical properties. The scientific group has an important role to play in the release of specific and extensively characterised studies, for a robust increase in fundamental knowledge of natural fibres [40]. Van de Weyenberg et al. [41] have shown that good properties such as high tensile strength and compression strength, of thin-walled components made of sisal fibre reinforced composite, give it a wide range of applications, such as structural components, permanent shaping, and pipe reinforcement of existing structures. Green buildings are built to be a clean, fitting and environmentally friendly area to live and work. The main materials used at this time as part of green materials are biocomposites [42].

Table 6. Output (in tons) of composites based on wood and natural fibres in 2012 and their forecasts for 2020 [43].

| Bio-Composites                  | Production (in ton) |
|--------------------------------|---------------------|
|                                | 2012                | 2020 (without Incentives for Bio-Based Products) | 2020 (with Strong Incentives for Bio-Based Products) |
|                                |                     |                                                   |                                                      |
| Wood-Plastic Composites        |                     |                                                   |                                                      |
| Construction, extrusion        | 190,000             | 400,000                                          | 430,000                                             |
| Automotive, compression moulding and extrusion/thermoforming | 60,000 | 80,000 | 300,000 |
| Granulates, injection moulding | 15,000              | 100,000                                          | >200,000                                            |
| Natural Fibre Composites       |                     |                                                   |                                                      |
| Automotive, compression moulding | 90,000             | 120,000                                          | 320,000                                             |
| Granulates, injection moulding | 2000               | 10,000                                           | >20,000                                             |
Carus et al. have shown that the application of natural fibres will dramatically increase in the future as they begin to reach various sectors comparing to automotive sector. In table 6 for 2012 and 2020, the Production Forecast Scenarios are presented. There is a substantial difference in the amount of natural fibre and wood-based composites for this time. So, it can be claimed that in the absence of significant political incentives to increase the proportion of bio-based materials used in products, especially in the automotive sector, there would be no rapid growth [43].

5. Conclusion

When incorporating such natural fibres to the correct loading ratio, composite polymer blends are an efficient way to increase the quality of parts when it comes to cost-effective, technical and environmental characteristics. The benefits of getting the right polymer blend formulations along with the natural fibres give low density and fair price, offering great marketing advantages, such as the automotive and construction industries. It is possible to enhance the physical and chemical properties of a new material by introducing a binding agent as a bonding material between composite polymers with such fibres. This study showed that the properties of fibres are significantly affected by the manner in which they are handled and how the treatments are conducted. The chemical treatment of the fibre used has shown that it is possible to increase the physical and mechanical properties of composite polymers and to regulate the level of moisture by means of alkalinization and coupling agents. But the important point that needs to be discussed is that some fibres are very expensive compared to those with the same mechanical properties, such as cotton. Therefore, before withdrawing the rationale and recommendation, the selection of the required fibres along with the polymer blend for such application must be properly carried out using the relevant experimental method and review of the effects.

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