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A REVIEW ON ENGINEERING MODELING AND PROCESSING OF NATURAL FIBER REINFORCED POLYMER COMPOSITES

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Abstract

The Contemporary and advanced trends in the field of polymeric materials composite towards the sustainability is a great challenge to the engineers and researchers. In the present scenario a vast and broad research and development is sustained in the field of polymeric and natural fiber composite field due to its better formability, abundant, renewable, cost-effective & eco-friendly features. This paper exhibits an anatomization study on manufacturing process for processing of polymeric and natural fibers & their potential applications in present and past few decades with the future development of different kinds of engineering and domestic products. In this review, many articles and literatures were related to the processing and applications of natural fiber reinforced polymer composites. As a result, it helps to provide details about the potential use of natural fibers and its composite materials, mechanical and physical properties and some of their applications in engineering sectors.

Key words: Polymer, composite, Natural fiber, Hand lay-up, Physical properties, Engineering application

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1. Introduction

In the past few years, there has been a dramatic increase in the use of natural fibers such as flax, jute, pineapple, areca, banana, bamboo, rice, kenaf, hemp, palm and sisal for making a new type of environmentally–friendly composites. Recent advances in natural fibre development, genetic engineering, and composites science offer significant opportunities for improved materials from renewable resources with enhanced support for global sustainability. Table-1shows the mechanical properties of different types of potential natural fibers for composite applications[1]. A material that can be used for medical application must possess a lot of specific characteristics, which are different with that for the general domestic-used plastic products. As matrix most of the researches were carried out on epoxy resin of different grade. Also to obtain different quality, hybridization was considered by different researchers. For instance to increase the tensile strength and density (decreasing the micro voids and cracks), hybridization is one of the method[2].Also to improve some properties, chemical treatment and surface treatment of the fibers were done [3 & 4]. High-temperature polymer blends (HTPBs) are typically used at T $\geq 140^0$C.

Table 1. Mechanical properties of natural fibre

Natural fibres	**Tensile strength (MPa)**	**Elongation at break (%)**	**Young modulus (GPa)**
Flax	300–1500	1.3–10	24–80
Jute	200–800	1.16–8	10–55
Sisal	80–840	2–25	9–38
Kenaf	295–1191	3.5	2.86
Pineapple	170–1627	2.4	60-82
Banana	529–914	3	27–32
Coir	106–175	14.21–49	4–6
Oil palm (empty fruit)	130–248	9.7–14	3.58
Oil palm (fruit)	80	17	

Ramie	348–938	1.2–8	44–128
Hemp	310–900	1.6–6	30–70
Wool	120–174	25–35	2.3–3.4
Spider silk	875–972	17–18	11–13
Cotton	264–800	3–8	5–12.6
Human tissues	130–160	1–3	17–20

It has some great application in the military, aerospace, transportation, electronic, health care and oil and gas industries, they need to have good process ability, high mechanical performance, chemical resistance, and fire retardancy and so on FRPs are very sensitive to intrinsic damage, matrix cracking and fatigue damage. Several approaches have been adopted to tackle these which include improving the fracture toughness of the ply interfaces via epoxy elastomer blends and reducing the mismatch of elastic properties (and stress concentrations) at the interfaces between the laminated plies. The innovation and advances in the engineering material is that the improvisation in the properties for the specific application. That is alloy and heat treatment as internal improvisation and as external change is the [5] reinforcement with fibers, rods, whiskers, and particle. There are some difference between alloys and composite Alloy is the solid solution of two or more materials with one principal element which has more volumetric percentage and for better quality (specific) we use other elements in that particular composition. In the other hand the composite can be defined as a mixture of two or more distinct constituents or phases. Having the following criteria, first, both constituents have to be present in reasonable proportions, say greater than 5%. & Secondly, it is only when the constituent phases have different properties, and hence the composite properties are noticeably different from the properties of the constituents, that we have come to recognize these material as composites. We know that composite have two or more phases on a macroscopic scale, separated by a distinct interface. The constituent that is continuous and is often but not always, present in greater quantity in the composite is termed as Matrix. A composite have ceramic, metallic or a polymeric matrix. Reinforcement is the part of the composite that provides strength, stiffness, and the ability to carry a load. In many cases the reinforcement is harder, stronger and stiffer than the matrix[6].

2. Manufacturing process

There are generally two types manufacturing process i.e. primary & secondary which are applied for polymeric composites.

2.1. Primary processing of Polymer Composites

2.1.1. Extrusion

Extrusion is a high-volume manufacturing process. Plastic material is melted with the application of heat and extruded through die into a desired shape. A cylindrical rotating screw is placed inside the barrel which forces out molten plastic material through a die. The overheating of plastics should be minimized which may cause degradation in the material properties. A cooling fan or water-cooling system is used to maintain the temperature of the barrel during the process[7].

2.1.2. Compression Moulding

Compression moulding process is one of the low-cost moulding methods as compared to injection molding and transfer molding is a high-pressure forming process in which the molten plastic material is squeezed directly into a mould cavity, by the application of heat and pressure to conform to the shape of the mould. In compression molding of thermo sets the mould remains hot throughout the entire cycle; as soon as a molded part is ejected, a new charge of molding powder can be introduced. On the other hand, unlike thermo sets, thermoplastics must be cooled to harden. So, before a molded part is ejected, the entire mould must be cooled, and as a result, the process of compression molding is quite slow with thermoplastics. Compression molding is thus commonly used for thermosetting plastics such as phenolic, urea, melamine, an alkyd; it is not ordinarily used for thermoplastics. However, in special cases, such as when extreme accuracy is needed, thermoplastics are also compression molded[8].

2.1.3. Injection moulding

Injection molding is the one of the most commonly used processing technique for the plastic components. It is used to manufacture thin walled plastic parts for a wide variety of shapes and sizes. Plastic material is melted in the heating chamber and then injected into the mould, where it cools and finally the finished plastic part is ejected. Plastic materials usually in the form of powder or pellets are fed from hopper into the injection chamber. The "piston and cylinder/reciprocating screw" arrangement is used to forward the material inserted from the hopper in to the injection chamber. The material is heated in the injection chamber with the application of heating elements. The molten plastic material is then injected into the mould through a nozzle. The molded part is cooled quickly in the mould. Final plastic part is removed from the mould. The process cycle for injection molding is very short, typically between 2 to 60 seconds.

2.1.4. Resin Transfer Moulding

Resin transfer molding is a closed molding process. It is also known as liquid transfer molding process. As the name indicates, resin is transferred over the already placed reinforcement. The process is effective for production of structural parts with low cost in low to medium production quantities. Reinforcement in terms of either woven mat or chopped fiber mat form is placed on the surface of lower half mould. A release gel is applied on the mould surface for easy removal of the composite. The mould is properly closed and clamped. The resin is pumped into the mould through ports and air is displaced through other vents. The uniformity of resin flow can be enhanced by using a catalyst as an accelerator and vacuum application. After curing, the mould is opened and composite product is taken out.

2.1.5. Rotational Moulding

Rotational moulding, known also as retooling or roto casting, is a process for manufacturing hollow plastic products. For certain types of liquid vinyl, the term slush moulding is also used. Rotational moulding is a high temperature and low-pressure plastic forming process. Powder is inserted into the closed split mould and rotated in biaxial direction to produce a hollow part.

2.1.6. Blow Moulding

Blow moulding is a manufacturing process that is used to produce hollow plastic parts by inflating a heated plastic until it conforms to the mould shape and form the desired product. The blow moulding process begins with melting of the plastic and forming it into a parison or preform, it can be done by extrusion or injection moulding. The parison is a tube-like piece of plastic with a hole in one end in which compressed air can pass through. The parison is then clamped into a mould and air is pumped into it. The air pressure then pushes the plastic out to match the mould. Once the plastic has cooled and hardened, the mould opens up and the part is ejected.

2.1.7 Hand lay-up

Spray release gel is applied on to the mould surface to facilitate the easy removal of component from the mould. Thin plastic sheets are used at mould surface to get good surface finish. A spray gun is used to spray pressurized resin, catalyst and reinforcement in the form of chopped fibres. A roller is rolled over the sprayed material to remove air trapped into the lay-ups. Curing of the product is done either at room temperature. After curing, mould is opened and the developed composite part is taken out and further processed.

2.1.8 Spray lay-up

Spray release gel is applied on to the mould surface to facilitate the easy removal of component from the mould. Thin plastic sheets are used at mould surface to get good surface finish. A spray gun is used to spray pressurized resin, catalyst and reinforcement in the form of chopped fibres. A roller is rolled over the sprayed material to remove air trapped into the lay-ups. Curing of the product is done either at room temperature. After curing, mould is opened and the developed composite part is taken out and further processed.

2.1.9. Pultrusion

Automated process for manufacturing of composite materials into continuous cross-section profiles Developed around 1950 for making fishing rods of glass fibre reinforced polymer (GFRP). Usually grouped into two categories: solid rod and bar stock, structural profiles.

2.1.10. Autoclaving

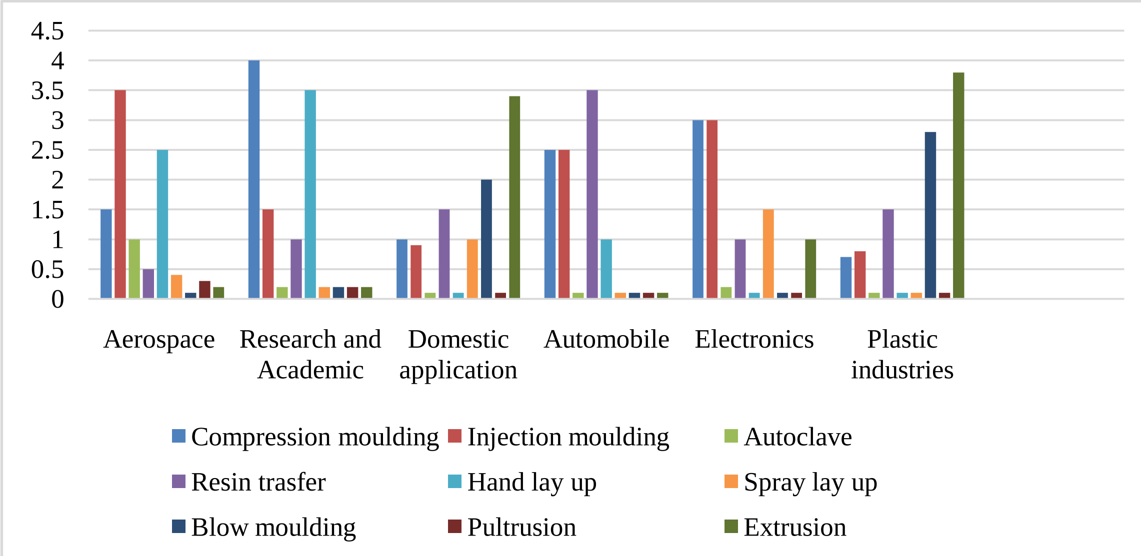
Autoclave moulding technique is similar to vacuum bag and pressure bag moulding method with some modifications. This method employs an autoclave to provide heat and pressure to the composite product during curing. In this method, prepregs are stacked in a mould in a definite sequence and then sealed to avoid any relative movement in between the prepregs sheets. Initially, a release gel is applied onto the mould surface to avoid sticking of polymer to the mould surface. After stacking the prepregs, the whole assembly is vacuum bagged to remove any air entrapped in between the layers after a definite period of time when it is ensured that all air is removed, the entire assembly is transferred to autoclave. Heat and pressure are applied for a definite interval of time. After the processing, the assembly is cooled at a definite rate and then vacuum bag is removed. The composite part is taken out from the mould.

2.2. Secondary processing of Polymer composites

Secondary processing of polymer composites is post processing like material removal process, joining process and all the below methods are generally applicable. Adhesive joining is a permanent type joining technique. Material on which adhesive is applied, is called adhered (Mechanical interlocking, Chemical bonding, Diffusion bonding), Mechanical joining is a non-permanent type of joining technique. It is performed either by mechanical fastening or integral mechanical attachment. Microwave joining process is a non-conventional joining process which is applicable for joining of thermoplastic matrix composites. Subsector materials are used to accelerate the heating process . Drilling of polymer Metrix composites (PMCs) is a secondary processing technique that is done prior to mechanical fastening.

The figure 1 shown below is the adaptation of different manufacturing process in different fields like aerospace, research and academic, domestic application, automobile, electronics and plastic industries. Thisfigure shows the use of different manufacturing process in different fields. For example if total products produced in aerospace industries is 10. Then out of 10 product 3.5 products are by injection moulding, 2.5 are by hand layup, 1.5 are with compression moulding, 1 are by autoclave and so on.

Figure 1. Adaption of different manufacturing process.



3. Application review.

Natural fibres reinforced composites are developing very rapidly as the genuine substitute to the metal or ceramic Based materials in applications that also include automotive, aerospace, marine, sporting goods and electronic industries. Natural fibre composites exhibit good specific properties, but there is high variability in their properties. So their weakness can and will be overcome with the development of more advanced processing of natural fibre and their composites. Both academicians as well as industries to manufacture a sustainable module for future application of natural fibre composites.The natural fibre-based thermoset and thermoplastic skins were developed by researchers for use as aircraft interior panels. The panels were found to possess the required flame and heat resistance, allowing easy recycling and disposal, and were cheaper and offered significant weight savings over conventional sandwich panels. In some countries, composite building materials are being made from straw. Straw bales are being used inthe construction of buildings. Many automotive components are already produced with natural composites, mainly based on polyester or Polypropylene and fibres like flax, hemp, or sisal. The adoption of natural fibre composites in this industry is led by motives of price, weight reduction, and marketing rather than technical demands. Germany is a leader in the use of natural fibre composites. The German auto-manufacturers, Mercedes, BMW, Audi and Volkswagen have taken the initiative to introduce natural fibre composites for interiorand exterior applications. The first commercial example is the inner door panel of the 1999 S-Class Mercedes Benz, made in Germany, of 35% Barer F semi-rigid (PUR) elastomer from Bayer and

65% of a blend of flax,hemp and sisal. It should be emphasized that luxury automotive manufacturers are on board which could be seenas evidence that natural fibre composites are being used for environmental needs and not to lower costs [9].Mercedes-Benz used an epoxy matrix with the addition of jute in the door panels in its E-class vehicles back in1996. Another paradigm of natural fibre composites' application appeared commercially in 2000, when Audi launched the A2 midrange car: the door trim panels were made of polyurethane reinforced with a mixedflax and sisal material. Toyota developed an eco-plastic made from sugar cane and will use it to line the interiors ofthe cars [10]. Biodegradable bark cloth reinforced green epoxy composites are developed with view of application to automotive instrument panels [11].The coir/polyester composites have been used to produce mirror casing, paperweights, projector cover, voltage stabilizer cover, mail-box, helmet and roof. In structural applications and infrastructure applications, natural fibre composites have been used to develop load-bearing elements such asbeam, roof, multipurpose panel, water tanks and pedestrian bridge [12]. Jute-based green composites would besuitable for even primary structural applications, such as indoor elements in housing, temporary outdoor applications like low-cost housing for defence and rehabilitation and transportation. Due to its insulating characteristics, jute may find areas of applications in automotive door/ceiling panels and panels separating the engine andpassenger compartments [13]Natural fibre reinforced polymer composites have been proven alternative to Synthetic fibre reinforced polymer composites in many applications [14 &15]. Many 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 include for parcel shelves, door panels, instrument panels, armrests, headrests and seat Shells [16]. Plastic/wood fibre composites are being used in a large number of applications in decks, docks, Window frames and moulded panel components [17]. The passenger car bumper beam is manufactured by kenaf/glass epoxy composite material [18]. Recently, banana fibre reinforced composites are coming into in interest due to the innovative application of banana fibre in under-floor protection for passenger cars [19]. Automobile parts such as rear view mirror, visor in two wheeler, billion seat cover, indicator cover, cover L-side, nameplate were fabricated using sisal and Rosellefibres hybrid composites [20].

4. Conclusion.

The variety manufacturing process for the processing of polymer and fibre composite was discussed in this paper. Due to better properties with the situations natural fibre composite is considered as the best fit solution. This article includes a deep review on applications of natural fibre and its composites in aerospace, construction, automobile and many more industries due to its beneficial properties like low weight, low density, low cost, biodegradability, flame retardancy, tribological properties, mechanical and thermal properties. This review concludes that the natural fibre composites form one of the emergent areas in material science that makes awareness for use in various applications. Also it motivate new researchers for their study in this developing field.

Acknowledgements

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Reference

[1] H. Cheung, M. Ho, K. Lau, F. Cardona, and D. Hui (2009), “Composites : Part B Natural fibre-reinforced composites for bioengineering and environmental engineering applications,” *Compos. Part B*, vol. 40, no. 7, pp. 655–663.

[2] N. Venkateshwaran, A. Elayaperumal, and G. K. Sathiya (2012) , “Prediction of tensile properties of hybrid-natural fiber composites,” *Compos. Part B Eng.*, vol. 43, no. 2, pp. 793–796.

[3] C. Girisha, G. Rangasrinivas, and S. Manu (2012) , “Mechanical Performance Of Natural Fiber-Reinforced Epoxy- Hybrid Composites,” *Int. J. Eng. Res. Appl.*, vol. 2, no. 5, pp. 615–619.

[4] X. Li, Æ. L. G. Tabil, and Æ. S. Panigrah (2007), “Chemical Treatments of Natural Fiber for Use in Natural Fiber-Reinforced Composites : A Review,” pp. 25–33.

[5] P. Ranga, S. Singhal, and I. Singh(2014) , “A Review Paper on Natural Fiber Reinforced

Composite," vol. 3, no. 2, pp. 467–469.

[6] Robert W.MesslerJr(2004)., "Joining of Polymers and Polymer Composites," *Join. Mater. Struct.*, pp. 1–16.

[7] T. A. Osswald and S.-C Tseng, (1994) "Compression Molding," *Flow Rheol. Polym. Compos. Manuf.*, pp. 361–413.

[8] Puglia, D., Biagiotti, J. and Kenny, J.M. (2004) A Review on Natural Fibre-Based Composites—Part II: Application of Natural Reinforcements in Composite Materials for Automotive Industry. *Journal of Natural Fibres*, **1**, No. 3**.**

[9] Koronis, G., Silva, A. and Fontul, M. (2013) Green Composites: A Review of Adequate Materials for Automotive Applications. *Composites*: *Part B*, **44**, 120-127.

[10] Rwawiire, S., Tomkova, B., Militky, J., Jabbar, J. and Kale, B.M. (2015) Development of a Biocomposite Based on Green Epoxy Polymer and Natural Cellulose Fabric (Bark Cloth) for Automotive Instrument Panel Applications. *Composites*: *Part B*, **81**, 149-157.

[11] Ticoalu, A., Aravinthan, T. and Cardona, F. (2010) A Review of Current Development in Natural Fiber Composites for Structural and Infrastructure Applications. *Southern Region Engineering Conference*, Toowoomba, 11-12 November 2010, SREC2010-F1-5.

[12] Khondker, O.A., Ishiaku, U.S., Nakai, A. and Hamada, H. (2005) Fabrication and Mechanical Properties of Unidirectional Jute/PP Composites Using Jute Yarns by Film Stacking Method. *Journal of Polymers and the Environment*, **13**, No. 2.

[13] Sanjay, M.R., Arpitha, G.R. and Yogesha, B. (2015) Study on Mechanical Properties of Natural-Glass Fibre Reinforced Polymer Hybrid Composites: A Review. *Materials Today: Proceedings*, **2**, 2959-2967.

[14] Arpitha, G.R., Sanjay, M.R., and Yogesha, B. (2014) Review on Comparative Evaluation of Fiber Reinforced Polymer posites Reinforced with Natural Fibers in the Green Materials World. *Engineering Science and Technology*, *an International Journal* (in Press).

[15] Omrani, E., Menezes, E. and Rohatgi, P.K. (2015) State of the Art on Tribological Behavior of Polymer Matrix Com

[16] Satyanarayana, K.G., Arizaga, G.G.C. and Wypych, F. (2009) Biodegradable Composites Based on Lignocellulosic Fibers—an Overview. *Progress in Polymer Science*, **34**, 982-1021.

[17] John, M.J. and Thomas, S. (2008) Biofibers and Biocomposites. *Carbohydrate Polymers*, **71**, 343-364.

[18] Davoodi, M.M., Sapuan, M.M., Ahmad, D., Ali, A., Khalina, A. and Jonoobi, M. (2010) Mechanical Properties of Hybrid Kenaf/Glass Reinforced Epoxy Composite for Passenger Car Bumper Beam. *Materials and Design*, **31**, 4927-4932.

[19] Samal, S.K., Mohanty, S. and Nayak, S.K. (2009) Banana/Glass Fiber-Reinforced Polypropylene Hybrid Composites: Fabrication and Performance Evaluation. *Polymer-Plastics Technology and Engineering*, **48**, 397-414.

[20] Chandramohan, D. and Bharanichandar, J. (2013) Natural Fiber Reinforced Polymer Composites for Automobile Accessories. *American Journal of Environmental Science*, **9**, 494-504. Matrix Composites. *Advanced Engineering and Applied Sciences*: *An International Journal*, **4**, 44-47.