A Comprehensive Review of Mechanical Properties of Hybrid Polymer Composites

Sathiyamoorthy Margabandu[1]
[1]School of Mechanical Engineering,
Vellore Institute of Technology, Vellore,
Tamil Nadu, India

Senthilkumar Subramaniam[2]
[2]Associate Professor,
School of Mechanical Engineering,
Vellore Institute of Technology, Vellore,
Tamil Nadu, India

***Abstract*:- The utilization of fiber reinforced composite materials has become unavoidable in several industrial applications like aerospace, automotive and construction, due to their high specific strength, lightweight and low manufacturing cost. The hybridization of two or more fibers in a single polymer matrix leads to hybrid composites with improved mechanical, thermal, moisture absorption and damping properties compared to individual fiber reinforced composites. In this study, a brief review on the mechanical properties like tensile, flexural and impact properties of hybrid fiber (natural/synthetic) reinforced polymer composites were reported. Besides, this review summarizes the different applications of hybrid fiber composites in various fields.**

Keywords: Hybrid composite, Mechanical properties, Natural fiber, Polymer matrix, Synthetic fiber

1. INTRODUCTION

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibers, particles, or flakes. The matrix phase materials are generally continuous [1]. In the recent years, research and engineering interest has been shifting from metallic materials to fiber reinforced polymer materials (FRP). The FRP composites are considering as an alternative material and have attracted the attention of many researchers and scientists due to their advantages over conventional materials [2]. In FRP composite, reinforcement may either include natural fibers (Banana, jute, sisal, hemp, kenaf, etc.) or synthetic fibers (Glass, carbon, aramid) in polymer matrix. The physical and mechanical properties are shown in Table 1. Natural fibers have become better replacement of synthetic fibers due to their advantages over synthetic fiber. Natural fibers show advantages such as low cost, light weight, abundant availability, environmental friendly, non-toxic, high flexibility, renewability, biodegradability, non-abrasiveness, high specific strength and modulus and easy processing [3-4]. In spite of these advantages natural fibers have some limitations such as low impact strength and high moisture absorption properties. These limitations can be reduced by using hybridization technique. The incorporation of additional fibers with single fiber into polymer matrix has led to the development of hybrid composite.

1.1 Hybridization of fibers

To develop the composite with enhanced properties in an economical method, several steps have been taken from the last decades, and found that hybridization is the most effective way. Hybridization of fibers is carried out using two natural fibers or by a combination of natural and synthetic fibers.

Hybridization can increase the mechanical properties due to following reason (i) in hybridization, two fibers having same length but with different diameters into a polymer matrix provides some advantages over the use of one fiber in the composites. Different diameters of fibers increased the effective area for fibers matrix adhesion so that uniform transfer of stress could take place [8]. (ii)The fiber having low elongation may break first and then the load may be carried by the fiber having high elongation without the failure of matrix, inducing better stress transfer from matrix to fibers and thus resulting in increased mechanical properties [9].

The objective of this paper is to present a review on recent investigations related to mechanical properties of hybrid (natural/synthetic) fiber reinforced polymer composite. Mechanical properties such as tensile, flexural, and impact strength of hybrid composite are studied.

2. MECHANICAL PROPERTIES OF HYBRID FIBER REINFORCED POLYMER COMPOSITES

Many studies reported the effect of incorporation of synthetic fiber on mechanical properties of natural fiber reinforced composites (NFPCs). It is found that mechanical properties of NFPCs are increased due to incorporation of synthetic fiber i.e. positive results of hybridization. Khanam et al. [10] studied the tensile, flexural and chemical resistance properties of sisal/carbon fiber reinforced polyester hybrid composites. Authors reported that tensile and flexural properties are found to increases with increase in carbon fiber content in the hybrid composites. Kumar et al. [11] prepared presented hybrid banana and glass fiber reinforced polypropylene composite using injection molding process to study the mechanical properties (tensile, flexural and impact test) and reported that the mechanical properties are improved due to hybridization. AlMaadeed et al. [12] reported study on Date palm wood flour/glass fiber reinforced hybrid polypropylene composites.

Table: 1 Physical and mechanical properties of natural fibers [5-7]

Fibers	Tensile strength (MPa)	Young's modulus (GPa)	Elongation at break (%)	Density (g/cm^3)
Abaca	400	12	3-10	1.5
Bagasse	350	22	5.8	0.89
Bamboo	290	17	-	1.25
Banana	529-914	27-32	5.9	1.35
Coir	220	6	15-25	1.25
Hemp	550-900	70	1.6	1.48
Jute	410-780	26.5	1.9	1.48
Kenaf	930	53	1.6	-
sisal	610-720	9-24	2-3	1.34
Ramie	500	44	2	1.5

Table: 2 Mechaical proerties of hybrid fiber reinforced composites

Fibers	Matrix	Tensile strength (MPa)	Tensile modulus (GPa)	Flexural strength (MPa)	Flexural modulus (GPa)	Impact strength	Fabrication method	Ref
Glass/ Sisal/ Banana	Epoxy	104	2.35	163	-	12.8 J	Compression moulding	[16]
Glass/ Sisal	Polyester	65.20	-	89.20	-	-	Hand layup	[17]
Carbon/ Sisal	Polyester	38.3	1.97	131.48	7.97	-	Hand layup	[10]
Glass/ Sisal/ Jute	Polyester	200	-	-	-	12 J	Hand layup	[13]
Glass/ Jute	Polyester	266.22	27.50	343.32	24.60	-	Pultrusion	[18]
Carbon/ Flax	Epoxy	126.30	2.9	318.83	28.83	-	Compression moulding	[19]
Glass/ abaca	Epoxy	44.5	0.270	12.5	1.380	16 J	Hand layup	[14]
Carbon/ Kevlar	Bismaleimie	-	-	665	43	-	Vacuum assisted resin transfer	[20]
Glass/ Flax	Poly-propylene	38-39	2.1-2.5	65-66	4.5-4.6	-	Injection moulding	[21]
Glass/ Banana	Poly-propylene	24.59	0.322	270.86	0.794	29.39 J/m	Injection moulding	[22]

The hybrid composite is developed by injection molding with various wt. % of Date palm wood flour and E-glass fibers. They found increase in tensile strength and modulus of date palm polypropylene composite due to reinforcement of glass fibers. Ramesh et al. [13] presented study on the mechanical properties of glass/sisal/jute hybrid polyester composite. They observed that the hybridization of glass with jute and sisal fiber enhanced the mechanical properties. Glass/jute composite possess the maximum tensile strength; glass/jute/sisal shows the maximum flexural load while glass/sisal shows the maximum impact strength. Ramnath et al. [14] fabricated glass/abaca/jute reinforced epoxy composites to investigate the mechanical properties and reported that the glass/abaca/jute reinforced epoxy composite shows the maximum value of tensile strength, tensile modulus and flexural modulus, whereas, the composite with glass/abaca shows maximum flexural and impact strength. The mechanical behaviors of unidirectional flax and glass fiber reinforced hybrid composites were investigated by Yongli et al. [15]. They found that tensile properties of the flax/glass fiber reinforced hybrid composites were improved with the increasing of glass fiber content. The incorporation of sisal-jute fiber with GFRP can improve the properties and used as an alternate material for glass fiber reinforced polymer composites. A summary on mechanical properties of hybrid synthetic/natural fiber reinforced composite reported in several research are summarized in Table 2. From Table 2, it is found that mechanical properties of natural fiber composites are improved due to the incorporation with synthetic fibers.

3. APPLICATIONS

Fiber reinforced polymer composites have been used for various application because of their ease of fabrication, relatively low prize and higher mechanical properties compared to conventional metallic materials. These composites are considered as replacements for the existing higher weight materials. [23, 24] Ecological attentiveness among all over the world motivated the researchers towards sustainable product design. The uses of natural fiber as reinforcement in polymer matrix are gaining a popularity to replace synthetic based fiber in the formulation of composites. [25] But the composites made of single reinforcing constituents may not provide better results under different loading conditions during their life span. In order to overcome the difficulties, hybrid composites are the best solution for such applications. The hybrid composite with two or more different fibers can balance the deficiency of another fiber. These composites offer high stress to weight ratio, high corrosion, resistance, high impact strength, partial biodegradable with low cost.

In recent days, hybrid composites are used for different applications such as consumer goods, low cost housing, civil structures, automobile components, etc. Cicala et al. [24] developed a pipe bend using jute/glass reinforced hybrid composites with 20% and 23% reduction in cost and weight when compared to commercial pipe construction made of hemp mat. Mahdi et al. [27] fabricated the composite solid cones using the oil palm/coir fiber-reinforced hybrid composites. These composites are used in various sectors.

i) Transportation (automobile and railway coach interior, boat, gears)
ii) Building and construction industry (panels for partition and false ceiling, floor, window and door frames)
iii) Storage devices (post-boxes, grain storage containers)
iv) Furniture (chair, table, bath units), v) Everyday applications (lampshades, suitcases, helmets).

4. CONCLUSIONS

In this study, the mechanical (tensile, flexural, impact) properties of natural/synthetic fiber reinforced hybrid composites have been discussed and the important applications of these composites are highlighted. Following conclusions are drawn from above study:

- Synthetic and natural fiber are reinforced in polymer matrix in different form as randomly oriented, unidirectional, bi directional and woven mat form. These composites were prepared by various fabrication technologies using different weight or volume fraction of fibers.
- Hand lay-up and compression molding technique are very popular among those manufacturing techniques.
- Mechanical properties of NFPCs are found to increase due to hybridization of either synthetic fiber or natural fiber having comparably high elongation. Besides, the hybrid composites can be used as an alternate material for pure synthetic fiber based polymer composites.
- Few research works have been carried out on thermoplastic based hybrid fiber composite compared to thermo-set based hybrid composites. Furthermore, it is found that very less research papers are available on hybridization of natural with carbon fiber reinforced epoxy composite.
- Hence it is necessary to do further research on the incorporation of different natural fibers with synthetic fiber to extend their application range including enhancement of fire resistance and fire retardant.

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