PANORAMIC VIEW ON GLASS FIBRE HYBRIDIZATION OF NATURAL FIBRE COMPOSITES

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Abstract
Usage of Natural composite fibres have drastically increased in the past 10 years for several automobile, construction, sporting and aerospace industries as filler materials along various structures. Due to the enormous growth of rapid prototyping and other advanced manufacturing technologies Natural fibres has played its part. In this review some of the natural fibres hybridized with glass fibres have been studied and have been descripted accordingly. These various findings allow us to understand about the various combinations of hybrid natural fibres. Materials such as graphene and carbon Nano tubes have now been used as filler material in these composite laminates which shows promising results. Hence, this has also been considered in this review paper.

1.Introduction

Composites have been used in the fabrication of sheets, tubes and pipes since 1908.Since then, research and engineering interest has been shifting from traditional monolithic materials to fibre reinforced polymer-based materials due to their unique advantages of high strength to weight ratio, non-corrosive property and high fracture toughness. These compositesconsist of high strength fibres such as carbon, glass and aramid.Now a days the aerospace, leisure, automotive, construction and sporting industries have employed such materials.The Nano hybrid composites can be used in marine, automobile, aerospace and lightweight application due to their high strength and stiffness [1]. It has been noticed that the mixing of Nano filler to glass fiber/epoxy composites increases the interfacial shear strength tremendously [2]. when the percentage of Nano filler material is increased it is observed that thermal properties of the composite gets reduced [3].

Due to the strong emphasis on environmental awareness worldwide, thecomposites have brought much attention in the development of recyclable and environmental materials. Environmental legislation as well as consumer demand in many countries is forcing the manufacturers to use materials and develop product with consideration ofenvironmental concernsand their life cycle and disposal [4].

Natural fibres have attracted the attention of scientists and technologists because of the advantages that these fibers provide over conventional reinforcement materials, and the development of natural fiber composites has been a subject of interest for the past few years. These natural fibers are low-cost fibers with low density and high specific properties. These are biodegradable and nonabrasive, unlike other reinforcing fibers.

It is almost 50 years that the significance of eco-friendly materials has been realized once again andthese ancient materials have rapidly taken over primarily. Due to the issue of the environment and the shortage of oil.

Frequently used modern technologies provide powerful tools to develop materials for new applications. Various attempts have been made to use natural fibre composites in place of glass mostly in non-structural applications. Although these materials have been deemed renewable by researchers however, in development of these composites, the incompatibility of the fibers and poor resistance to moisture often reduce the potential of natural fibers and these draw backs become critical issue.

Fiber glass is a lightweight, strong, and robust material but somewhat lower than carbon fiber and itis less stiff, the material is typically far less brittle and the rawmaterials are much less expensive [5].

Sisal–jute–GFRP hybridcomposites are environment friendly and user-friendly materials [6] and have very good elastic properties [7]. The method ofdisposal of GFRP and theirrecycling have been the serious issue [8, 9] and the natural fiber composites plays very important rolein the environmental situation and variety of applications [10].

However, various types of natural fibres including flax, hemp, jute straw, wood, rice husk, wheat, barley, oats, rye, cane (sugar and bamboo), grass, reeds, kenaf, ramie, oil palm, sisal, coir, paper mulberry, banana fibre, pineapple leaf fibre and papyrus. Classification of Natural fibres are given in Fig.1.1.

Natural fibres are largely divided into three categories accordingly:

- Mineral based,
- Plant based, and
- Animal based.

MINERAL FIBER:

Mineral fibres are naturally occurring fibre or slightly modified fibre processed from minerals can be defined into the following forms. Asbestos is the group of minerals that occur naturally in the environment as bundles of fibres. These fibres are resistant to heat, fire and bad conductor of electricity.

PLANT BASED:

Although the strength of such fibres (more than one type) are general lower than that of the traditional advanced composites, in certain extent, the strength of plant-based fibre-reinforced composites is sufficient enough for domestic or household plastic products. Attempts have been done in the past few years on using jute, bamboo, sisal, coir, hemp, flax, pineapple leaves, etc.

ANIMAL BASED:

The content of these fibres is mainly made by proteins, like wool, spider and silkworm silk. The environmental stability of silk fibres in comparison to globular proteins is due to the extensive hydrogen bonding. Silk proteins known as silk fibroins are secreted in the glands ofinsects and spiders as an aqueous solution. Chicken feather fibre has attracted much attention to different product design and engineering industries recently

Because of this there is an increase in population, natural resources are being exploited. The utilization of natural fibres for thereinforcement of the composites has received attention. Natural fibres have many advantages over synthetic fibres.

Research on natural fibers composites has created enthusiastic attention due to its marvellous properties and ecological considerations. A brief discussion on some of the natural hybrid fibers and its extraction is given along with a review.

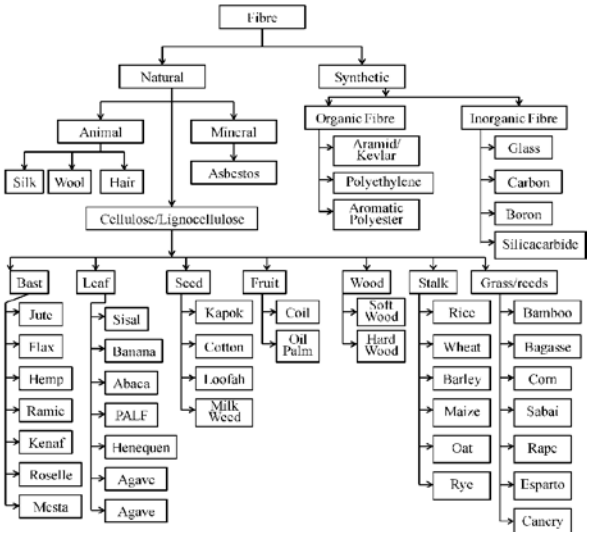

Fig.1.1 Classification of natural fibre.

The process condition plays, important role for the industrial use of these materials. The results presented in this paper show, that natural fibres can be processed with the already commonly applied methods: glass mat thermoplastic matrix (GMT), sheet moulding compound (SMC) or bulk moulding compound (BMC).

Composite materials, in this regard represent a constant endeavour of optimization in materials. Hybrid composites which are found to be predominantly affected by factors which include variation in fiber volume/weight fraction, variation in stacking sequence of fiber layers, fiber treatment, and environmental conditions.

Governmentregulations and growing environmental awarenessthroughout the world have triggered a paradigm shift towards designing materials compatible with the environment [11]. The biofibres derived from annually renewable resources, as reinforcing fibres in both thermoplastic and thermoset matrix composites provide positive environmental benefits with respect to ultimate disposability and raw material utilization.

The thermo physical properties ofnatural fiber reinforced polyester composites is carried out by Idicula et al. [12]. They have indicated that the natural fiber withglass allows a significantly better heat transport ability for the composites. Cicala et al. [13] have studied the properties and performanceof various hybrid glass/natural fiber composites for theapplications in curved pipes. Natural fibres are cheaperandlighter,and they have low mechanical properties than glass fibers. The useof hybrid fibers may solve this issue.

A simple processing technique such as hand layup and spraying, compression, transfer, resin transfer, injection, compression injection, and pressure bag moulding operations. A few other methods such as centrifugal casting, cold press moulding, continuous laminating, encapsulation, filament winding, pultrusion, reinforced reaction injection moulding, rotational moulding, and vacuum forming.

Biofibre reinforced synthetic polymersare being carried out in many R&D work.Thenatural fibres and non-biodegradable synthetic polymers may offer a new class of composites but are not completely biodegradable.The so-called golden fibre from India and Bangladesh [14];coir is produced in the tropical countries of theworld and India accounts 20% of total world production of coir [15].

The main drawback in using these fibres is that they are hydrophilic in nature and this lowers compatibility. Advantages of biofibres over traditional reinforcing materials such as glass fibres are: low cost, low density, high toughness, acceptable specific strength properties, reduced tool wear, reduced dermal and respiratory irritation, good thermal properties, ease of separation, enhanced energy recovery and biodegradability.

2.Literature survey

2.1 Coir-Glass hybrid composites

Jayabal et al. studied themechanical properties of woven coir and woven coir–glass fiber reinforced polyester composite [16]. The evaluation of tensile, flexural, and impact properties of woven coir composites, woven glass and woven coir–glass hybrid composite were carried out and the results were compared within. The effect of hybridization with glass on tensile, flexural, and impact properties of woven coir composites were one of the important key points on their study.

Pavithran et al. studied the enhancement in properties of coir– polyester composites by incorporating glass as intimate mix with coir [17].

2.2 Sisal-Jute-Glass hybrid composites

Ramesh et al. studied the mechanical properties of sisal–jute–glass fiber reinforced composite.The properties such as tensile, flexural and impact strengths of sisal/GFRP, jute/GFRP, sisal/jute/GFRP composite were studied and compared within and the surface characteristics of the composite material were studied through Scanning Electron Microscope (SEM) and images were observed for interfacial properties, internal cracks and internal structure of the fractured surfaces of the composite material [18].

2.3 Oil Palm-Glass hybrid composites

Sreekala et al.studied the mechanical performance of glass/ phenol-formaldehyde composite and glass/OPEFB fibre hybrid phenol-formaldehydecomposite [19]. Tensile properties such as tensile stress– strain behaviour, tensile strength, tensile modulus and elongation at break of the composites as a function of fibre composition were analysed. The tensile fracture mechanism of the composites was studied by scanning electron microscopy. Impact fracture mechanisms were evaluated using scanning electron microscopy. Variations in hardness and density of the composites with various fibre volume fractions were also checked. Finally, the hybrid effects of the glass and OPEFB fibres were calculated. Tensile strength, tensile modulus and elongation at break of the hybrid composites were theoretically calculated and compared with the experimental results.

2.4 PALF-Sisal-Glass hybrid composites

Mishra et al. studied the changes in the tensile, flexural and impact properties of PALF/glass and sisal/ glass fibre hybrid polyester composites as a function of relative weight fractions of the two fibres [20]. In addition to this, sisal/glass hybrid polyester composites of alkali treated, cyanoethylated and acetylated sisal fibre have been fabricated and their mechanical properties have been assessed.

2.5 Kenaf-Glass hybrid composites

Ramesh Kumar et al. have studied Kenaf/Glass fiber hybrid composite filled with graphene as Nano filler and to investigate the mechanical properties of hybrid composites [21]. The different types of hybrid composites laminates are fabricated without filler, 0.5, 1 & 1.5Wt % of graphene by using kenaf and glass fiber as reinforcing material with epoxy resin. The specimen was prepared using Hand layup method and tensile, compression and flexural strengths were studied for different graphene loading conditions.

2.6 Banana-Sisal-Glass hybrid composite

Arthanarieswaran et al. studied the effect of glass fiber hybridization with the randomly oriented banana (B) and sisal (S) fibers reinforced with epoxy matrix [22]. Nine different kinds of laminates were prepared in the following stacking sequence of B, S, BS, G/B/G, G/S/G, G/BS/G, G/B/G/B/G, G/S/G/S/G and G/BS/G/BS/G. Mechanical properties like tensile strength, flexural strength and impact strength were evaluated and compared. Interfacial analysis was also carried out with the help of Scanning Electron Microscope (SEM) to study the micro structural behaviour of the tested specimen.

2.7 Banana-PALF-Glass hybrid composite

Hanafee et al. studied the effect of fibre volume fraction on mechanical properties of banana-pineapple leaf (PaLF)-glass reinforced epoxy resin under tensile loading [23]. Uniaxial tensile tests were carried out on specimens with different fibre contents (30%, 40%, 50% in weight). 13 different composite specimens were fabricated using hot compression method. The effect of hybridisation between synthetic and natural fibre onto tensile properties was determined.

3.Findings

3.1 Preparation and testing

Hybrid materials	Authors	Findings	
		Composite preparation	Testing
Coir-Glass	Jayabal et al.	Woven coir and glass were prepared using simple hand lay-up in a mould(36x36cm^2) at ambient temperature. Polyvinyl acetate release agent was applied to the surfaces of the mould. Resin used is unsaturated polyester.	**Tensile:** As perASTM D638 standard at a cross-head speed of 5mm/min. **Flexural:** As per ASTM D 790 standards at 2.8mm/min rate of loading. **Impact:** As perASTM D256-05 standards.
Sisal-Jute-Glass	Ramesh et al.	Chopped sisal and jute fibers of 30mm length were fabricated by hand layup process. The specimen consists of total five layers in which glass fiber layers are fixed in top middle and bottom of the specimen. Secondand fourth layers arefilled by natural fibers such as sisal and jute. The layers of fibers are fabricated by adding the required amount of polyester resin.	**Tensile:** The specimen was cut using saw cutter and prepared as per ASTM D638 standards **Flexural:** 3 point flexural test in specimens prepared as per ASTM D790 standards **Impact:**Specimenswere prepared usingASTM

			A370 standards
Oil palm-Glass	Sreekala et al.	Composite sheets of 150mmx150mmx2.5mm size were prepared using hand lay-up method followed by compression moulding. Composite mats were arranged in such a manner so as to get the OPEFB fiber and glass fiber mat maximally intermingled. It was then soaked in Phenol-Formaldehyde resin and cured under hot pressing	**Tensile:** Specimens were cut and tested according to ASTM D 638-76 standards. **Flexural:** Three-point flexure properties were tested according to ASTM D 790 standards. **Impact:** It was tested according to ASTM D 256 standards.
PALF-Sisal-Glass	Mishra et al.	General purpose polyester resin mixed with 1 wt.% of cobalt naphthenate(accelerator) and 1wt.% methyl ethyl ketone peroxide(catalyst) is thoroughly mixed and poured into the mould cavity containing either PALF (untreated) or sisal mats(treated/untreated) and is compressed with a hydraulic press	**Tensile:** Specimen is prepared as per ASTM D638 standards at a cross head speed of 100mm/min and a gripping length of 150mm. **Flexural:** Specimen is prepared as per ASTM D790 standards at a cross head speed of 2.8mm/min and a gauge length of 25mm. **Impact**: Izod impact test is performed as per ASTM D256 standards
Kenaf-glass	Ramesh Kumar et al.	Kenaf and glass fiber mats were cut in 300x300x4mm dimensions with epoxy as resin and the laminate consists of total 6 layers of glass fiber and 5 layers of kenaf fibres. Two types of laminates with and without graphene ass filler material were prepared using hand lay-up method at room temperature.	**Tensile:** Specimen was prepared as per ASTM D3039 standards. **Compression:** Specimen was prepared as per ASTM D3410 standards. **Flexural:** Specimen was prepared as per ASTM D790-2 standards.
Banana-Sisal-glass	Arthanarieswaran et al.	Different kinds of laminates of different stacking sequence of Banana, Sisal and glass fibbers with epoxy resin in 30x30x3 cm dimensions were prepared using compression moulding machine	**Tensile:** Specimen was prepared as per ASTM D3039 standards. **Flexural:** Specimen was prepared as per ASTM D790 standards. **Impact:** Specimen was prepared as per ASTM D4812 standards.

Banana-PALF-Glass	Hanafee et al.	Banana fiber (6%NaOH treated for 2 hours) and PaLF (6%NaOH treated for 3 hours) later driedfor 24 hours were cut into 30x30cm dimensions along with woven glass fiber. The composite reinforced with 3 different volume percentages of fibres (30, 40, and 50wt%) were prepared using hot compression machine	**Tensile:** Tensile loading test was carried out according to ASTM D3039 standards.

Table 1-Preperation and Testing

3.2 Mechanical testing

3.2.1 Woven Coir-Glass composite

Totally 15 specimens were fabricated in the combination of woven coir, woven coir-glass and glass composites for the mechanical testing.

Hybrid combination	Average Tensile strength (MPa)	Average Flexural strength (MPa)	Average Impact strength (MPa)
Coir	19.9±0.5	31.3±5.6	49.9±4.2
Coir-Glass	47.7±1.5	65.0±4.1	92.5±5.0

Table 2- Woven Coir-Glass composite

From the above tabulation it is found that the hybrid combination of Coir-Glass has a higher strength over a single fibre.

3.2.2Sisal-Jute-Glass composite

Totally 3 specimens for each Glass-sisal, Glass-Jute, Glass-Jute-Sisal composite were prepared for mechanical testing.

Hybrid combination	Average Tensile strength (MPa)	Average Flexural load (kN)	Average Impact strength (joules)
Glass-Sisal	176.20	2.3	18
Glass-Jute	229.54	2.1	10
Glass-Jute-Sisal	200.00	3.0	12

Table 3- Sisal-Jute-Glass composite

From the above tabulation it is found that the hybrid combination of Glass-Jute has a higher tensile strength over other fibre. And the Flexural Load is high for Glass-Jute-Sisal. However, the Impact strength is high for the Glass-Sisal.

3.2.3PALF-Sisal-Glass composite

10 specimens were prepared with different wt% of glass and different chemical treatments of sisal and are taken for Tensile, flexural and impact strength.

Hybrid combination	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (J/m)
Untreated Sisal-5.7 wt% glass	98	138	145
5% Alkali treated Sisal-5.7 wt% glass	127	150	167
10% Alkali treated	108	137	148

Sisal-5.7 wt% glass			
Cyanoethylation treated Sisal-5.7 wt% glass	113	154	152
Acetylation treated Sisal-5.7 wt% glass	116	146	164
25wt% PALF-0% glass	42	68	68
25wt% PALF-4.2% glass	51	84	78
25wt% PALF-6% glass	68	92	108
25wt% PALF-8.6% glass	70	98	122
25wt% PALF-12.9% glass	66	100	126

Table 4- PALF-Sisal-Glass composite

The above tabulation denotes the Tensile strength, Flexural strength and, Impact Strength. Each of the combination varies according to the mixture and so does the strength.

3.2.4Kenaf-glass composite

Kenaf and glass epoxy composite was added with graphene filler material at different composition and mechanical testing was carried out.

Hybrid combination	**Tensile Strength (MPa)**	**Compression strength(MPa)**	**Impact strength (MPa)**
Kenaf-Glass-0% graphene	132.42	22.76	238.64
Kenaf-Glass-0.5% graphene	120.15	12.31	317.21
Kenaf-Glass-1% graphene	128.67	28.95	251.32
Kenaf-Glass-1.5% graphene	114.97	15.54	210.15

Table 5- Kenaf-glass composite

3.2.5Banana-Sisal-glass composite

Six different kinds of laminates of Glass, Banana and Sisal were fabricated and mechanical testing was carried out.

Hybrid combination	**Tensile Strength (MPa)**	**Flexural Strength (MPa)**	**Impact Energy (Joules)**
Glass-Banana-Glass	46	132	10.2
Glass-Banana-Glass-Banana-Glass	88	176	12.5
Glass-Sisal-Glass	52	159	11.7
Glass-Sisal-Glass-Sisal-Glass	93	184	13.3
Glass-Banana-Sisal-Glass	64	192	11.3
Glass-Banana-Sisal-Glass-Banana-Sisal-Glass	104	163	12.8

Table 6- Banana-Sisal-glass composite

For the various hybrid combination applied the Tensile Strength and Impact Energy is High for Glass-Banana-Sisal-Glass-Banana-Sisal-Glass.

3.2.6Banana-PALF-Glass composite

The composite with 3 different volume percentages of fibres (30, 40, and 50wt%) were prepared for tensile testing.

Hybrid combination	Tensile modulus (GPa)
Glass-25% Banana-25% PALF	6.15
Glass-30% Banana	5.45
Glass-40% Banana	6.38
Glass-50% Banana	6.31
Glass-30% PALF	4.79
Glass-40% PALF	6.35
Glass-50% PALF	6.41

Table 7- Banana-PALF-Glass composite

The hybrid combination of Glass-50%PALF has a greater Tensile modulus.

4.Conclusion

In this research review the following conclusions were made,

- Detailed study about glass fibre hybridization of natural composites.
- Glass fibre is hybridized with Coir, Sisal, Jute, Oil palm, PALF, Kenaf, Banana.
- Alkali treated Sisal and glass fibre hybrid gives out better results compared to other chemically treated sisal-glass fibre hybrid.
- Tensile strength is higher for Glass-Jute-Sisal hybrid composite at 200 MPa.
- Flexural strength is higher forGlass-Banana-Sisal-Glass composite at 192 MPa.
- Impact strength is higher for Kenaf-Glass-0.5% graphene composite at 317 MPa.

Therefore, the scope is higher for composite fibres with the addition of Graphene as filler material as impact strength plays a major role in automobile and aerospace applications.

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