ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 5, May 2017

Natural Fiber Metal Laminates an Idea for Better Properties Than Fiber Metal Laminates

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Abstract: **-- Biocomposites (natural fiber composites) from local and renewable resources offer significant sustainability; industrial ecology, eco-efficiency, and green chemistry are guiding the development of the next generation of materials, products, and processes. Considerable growth has been seen in the use of biocomposites in the domestic sector, building materials, aerospace industry, circuit boards, and automotive applications over the past decade, but application in other sectors until now has been limited. Nevertheless, with suitable development, the potential exists for biocomposites to enter new markets and thus stimulate an increase in demand even in the field of Fiber Metal Laminates . Many types of natural fibers have been investigated with polymer matrices to produce composite materials that are competitive with synthetic fiber composites which require special attention. Fibre Metal Laminate (FML) is largely used in the manufacture of aircrafts. The commercially available FMLs, GLARE, CARALL (CArbon Reinforced ALuminium Laminate) and ARALL make use of Aluminium metal. Other FMLs that are under study by researchers make use of metals such as Titanium and Magnesium based alloys. Owing to the high cost of carbon Fibre and the necessity for environment friendly alternatives, in the present work, a portion of carbon is replaced by natural fibre materials in CARALL and CARMAL (CArbon Reinforced MAgnesium Laminate). To the knowledge an attempt has not been made before in the field of FMLs the use of Natural fiber in place of Glass fiber and Carbon fiber In recent an attempt has been made by using a natural fibers as a laminating material by which a number of Natural materials like Fiber or flakes can be used. An attempt is also reported with jute as CArbon-Jute Reinforced ALuminium Laminate and CArbon-Jute Reinforced MAgnesium Laminate are named as CAJRALL and CAJRMAL. Both these laminates are made by hand layup technique and then compressed in a compression moulding machine.**

***Keywords*— Fibre Metal Laminate (FML), CARALL(CArbon Reinforced MAgnesium Laminate), GLARE (Glass Reinforced Aluminium Laminate), ARALL(aramid aluminium laminate), CAJRAL (CArbon-Jute Reinforced ALuminium Laminate) and CAJRMAL.(CArbon-Jute Reinforced MAgnesium Laminate)**

I. INTRODUCTION

The trend developed, and led to the reinforcement of fibres in the form of laminates. These laminated composites showed significant properties in comparison with random oriented composites. Later, in the life cycle of the composite material, appeared a new form of composite, wherein the fibre is reinforced with a metal, so as to inherit special properties in order that it can be used in the aerospace industry. A Fibre Metal Laminate (FML) was originally developed at the Delft University of Technology. It consisted of thin sheets of aluminium, bonded with fibre adhesive layers. This laminated structure behaves much the same as a simple metal structure, but with considerable specific advantages with regard to properties, such as metal fatigue, impact, corrosion resistance, fire resistance, weight savings and specialized strength properties. Some of the commercially available FMLs such as GLARE (GLAss Reinforced Epoxy laminate), ARALL (Aramid Reinforced ALuminium Laminate) and HTCL (Hybrid Titanium Composite Laminate) have significant properties that are useful in the aviation field [5-6]

So far, studies have been made on FMLs such as GLARE, ARALL, HTCL and also on FMLs, manufactured with man-made fibres reinforced with other metals, such as magnesium and titanium [1-3], in aeronautical applications. According to Cortes et al, FMLs are capable of absorbing significant energy through localized fibre fracture and shear failure in the metal plies [2]. Also the interface bonding between the composite and the metal plies, tensile behaviour and low velocity impact studies were performed on these FMLs [3]. To bring down the cost of fibres such as carbon and glass, and for the sake of a pollution-free environment, an attempt is made in this work by bringing in a natural fibre, Jute, a cost effective and eco-friendly fibre, into the FML. Jute is a lingo-cellulosic fibre that falls into the bast fibre category like kenef, hemp, flax, ramie etc. It belongs to the family of Sparrmanniaceae. It requires plain alluvial soil with standing water, moderate warm and wet climate with temperatures ranging from 20 C to 40 C and relative humidity of 70% to 80%, for successful cultivation. This fibre has been an integral part of the culture of Bengal,

II. NATURAL FIBERS

The plants that originate fibers can be viewed as primary or secondary, as a function or role of the fiber in the plant. Primary plants, such as jute, hemp, kenaf, or sisal, are grown with the sole objective of providing fibers for industrial usage. Secondary plants (e.g., pineapple, oil palm, or coir) have a

IFERP
ISSN (Online) 2456-1290
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different main purpose, such as that of a human food source. In general, lignocellulosic natural fibers such as flax, hemp, henequen, sisal, coconut, jute straw, palm, bamboo, rice husk, wheat, barley, oats, rye, cane (sugar and bamboo), reeds, kenaf, ramie, oil palm, coir, banana fiber, pineapple leaf, papyrus, wood, or paper have been used as reinforcement in thermosetting and thermoplastic resin composites [4]. Fabricated products in natural composites include door and trunk liners, parcel shelves, seat backs, interior sunroof shields, and headrests [5].

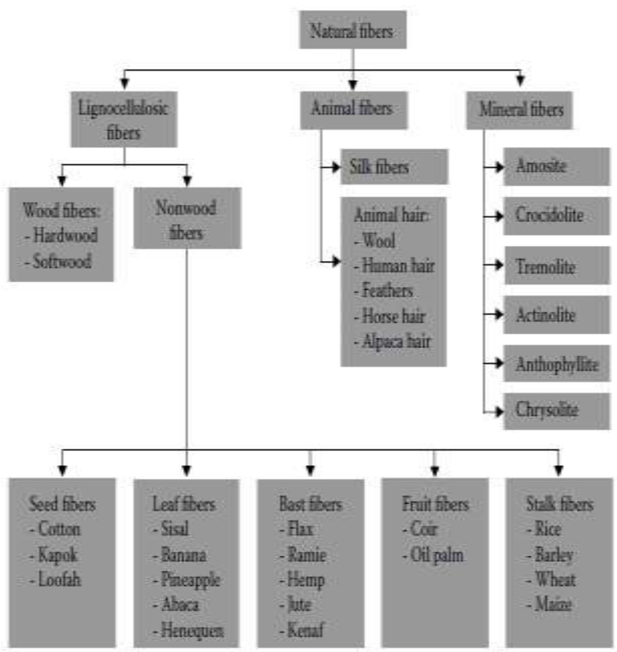

Fig1.Classification of Fibers

Table 1.1 details the most commercially used natural fibers, in terms of annual worldwide production. Natural fibers usually have a diameter on the order of 10 μm and are, by themselves, a composite material, since they are composed by a primary cell wall and three secondary cell walls. The cell walls include microfibrils that are randomly oriented. The angle of the microfibrils with respect to the fiber axis has a major role in the fiber properties, given that smaller angles give high strength and stiffness, whereas larger angles provide ductility [1]. Since fibers are bundled together by lignin and fixed to the stem by pectin (both of which are weaker than cellulose), these constituents must be removed for the fibers to attain the maximum reinforcement effect.

Table 1.1 Worldwide Production of Most Used

Sl No	Fiber Type	World Production (10^3 ton)
1.	Sugarcane bagasse	75,000
2.	Bamboo	30,000
3.	Jute	2,300
4.	Kenaf	970
5.	Flax	830
6.	Grass	700
7.	Sisal	378
8.	Hemp	214
9.	Coir	100
10.	Ramie	100
11.	Abaca	70

III. COMMERCIAL NATURAL FIBERS

The length of the fibers also plays an important role in the composite strength, especially when the interfacial adhesion is weak. Compared with glass or carbon fibers, natural fibers benefit from lower density, less tool wear during machining, no health hazards, biodegradability, availability of natural and renewable sources, and lower cost per unit volume basis [2, 3]. Natural fibers also provide a higher degree of design flexibility, because they will bend rather than break during processing. However, their specific stiffness and strength do not match those of synthetic fibers, and they suffer from high moisture absorption and poor wettability to some resins.

Natural fibers generally work well as reinforcements of inorganic polymers, synthetic polymers, and natural polymers because of their high strength and stiffness as well as low density [6]. Typical strength and stiffness values for flax fibers are actually close to those of *E*-glass fibers [7], which, in turn, gives higher specific properties on account of the smaller density. However, being materials of a natural origin, the scatter in mechanical properties is higher than for synthetic fibers, because of variations in the fiber structure emerging from changing climate conditions during growth (where the fibers are sourced), area of growth, age of the plant, processing methods, and fiber modifications [8]. The lack of standardized procedures for testing natural fibers also helps in the scattering of properties. Table 1.2 shows the main factors related to the stage of production that affect the fiber properties. Other drawbacks include the difficulty to create a strong bond between the fibers and matrix, and the moisture absorption, with consequences on the composite strength.

Many other factors influence the behavior of fibers, such as their length, physical properties (for comparison) [9].

Because of the high degree of variability of natural fibers and testing methods, the mechanical properties have a large scatter. Another feature is their hollow nature, which not only offers the potential for reduced weight but is also a challenge for waterproofing. For comparison purposes, the most typical values for each quantity can be approximated to the average of the presented range. The specific modulus values were obtained by the average stiffness and density, and the most attractive fibers from this point of view are curaua, flax, hemp, jute, pineapple leaf fiber (PALF), and ramie. Values in the same order of magnitude are found between wood and nonwood fibers. The most commonly used synthetic matrix materials used with natural fibers are PP, polyester, polyurethane, and epoxy. Most of the components made of natural fiber composites are fabricated by press-molding, even though a large range of processes are currently feasible. Figure 1 compares the specific modulus of some natural fibers, and also *E*-glass fibers, showing in some of the cases a possibly higher performance of natural fibers, more specifically for ramie, PALF, kenaf, jute, hemp, flax, curaua, and bamboo. On the other hand, a much larger scatter can also be found for natural fibers, because of the bigger variations in stiffness and density. Figure 2 also shows the evaluation of the cost per weight of some natural fibers and *E*-glass. In this scenario, all natural fibers behave better or at least identically to *E*-glass.

TABLE 1.3 Typical Physical and Mechanical Properties of Natural and Synthetic Fibers

	Density	Length	Diameter	Tensile Strength	Tensile Modulus	Specific Modulus	Elongation
Fiber	(g/cm³)	(mm)	(µm)	(MPa)	(GPa)	(approx.)	(%)
E-glass	2.5–2.59	—	<17	2000–3500	70–76	29	1.8–4.8
Abaca	1.5	—	—	400–980	6.2–20	9	1.0–10
Alfa	0.89	—	—	35	22	25	5.8
Bagasse	1.25	10–300	10–34	222–290	17–27.1	18	1.1
Bamboo	0.6–1.1	1.5–4	25–40	140–800	11–32	25	2.5–3.7
Banana	1.35	300–900	12–30	500	12	9	1.5–9
Coir	1.15–1.46	20–150	10–460	95–230	2.8–6	4	15–51.4
Cotton	1.5–1.6	10–60	10–45	287–800	5.5–12.6	6	3–10
Curaua	1.4	35	7–10	87–1150	11.8–96	39	1.3–4.9
Flax	1.4–1.5	5–900	12–600	343–2000	27.6–103	45	1.2–3.3
Hemp	1.4–1.5	5–55	25–500	270–900	23.5–90	40	1–3.5
Henequen	1.2	—	—	430–570	10.1–16.3	11	3.7–5.9
Isora	1.2–1.3	—	—	500–600	—	—	5–6
Jute	1.3–1.49	1.5–120	20–200	320–800	8–78	30	1–1.8
Kenaf	1.4	—	—	223–930	14.5–53	24	1.5–2.7
Nettle	—	—	—	650	38	—	1.7
Oil Palm	0.7–1.55	—	150–500	80–248	0.5–3.2	2	17–25
Piassava	1.4	—	—	134–143	1.07–4.59	2	7.8–21.9
PALF	0.8–1.6	900–1500	20–80	180–1627	1.44–82.5	35	1.6–14.5
Ramie	1.0–1.55	900–1200	20–80	400–1000	24.5–128	60	1.2–4.0
Sisal	1.33–1.5	900	8–200	363–700	9.0–38	17	2.0–7.0

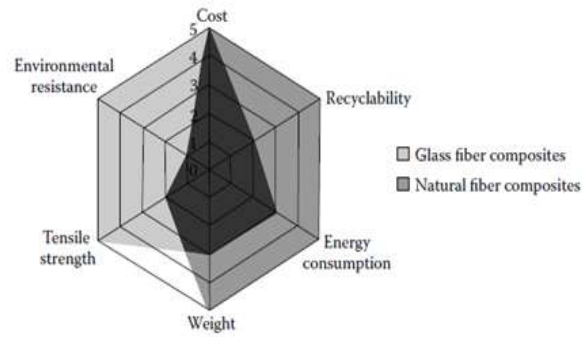

Fig-2 Merit comparison of glass and natural fiber composites (on average).

VI. ADHESIVE BONDING

Adhesive bonding process has been used in the manufacture of aircraft structures and components for 30–40 years [10]. Bonding techniques are used in an ever-growing number of applications: electronics (multilayer boards, bounded components), aerospace and aeronautical industries (F-18 bonded wings), automotive industries and many more organizations. Bonding structural components with adhesives offers many advantages over conventional mechanical fasteners: lower structural weight, lower fabrication cost, and improved damage tolerance [11]. Light weight sandwich construction and structural bonded joints form a major proportion of modern aircraft [12]. Modern metallic bonded structures using longitudinal lap joints in commercial aircrafts were introduced with the advent of the Airbus A300. As stated in Ref. [10], this technique is currently migrating from secondary to primary structural Application s as one of the most interesting ways to fasten structural parts with a high level of confidence. For example, structural adhesive bonding is mainly used for attaching stringers and/or tear straps to the fuselage and wing skins, to stiffen the structures against buckling. It is also applied to skin-to-core bonding in metallic honeycomb structures, such as elevators, ailerons, spoilers, and so on [13]. Bonded structures have been shown to be far more fatigue resistant than equivalent mechanically fastened structures and when designed correctly, can sustain higher load levels than equivalent mechanically fastened joints [12]. As reported in Ref. [12], early experiences in bonding techniques demonstrated that surface treatment prior to bonding is the single most critical step which can not be disregarded, even for tertiary-loaded structures, since it is essential to achieve long-term service capability [12,14]. A particular surface treatment tends to modify the substrate surface by delivering the following features: free from contamination; wettable with either primer or adhesive; highly roughened; and mechanically and hydrolytically stable [14]. Surface treatment technologies need to be explained from the viewpoint of adhesively bonded fibre-metal laminate research.

V. MATERIALS AND FML FABRICATION

The materials utilized for the preparation of the FML samples plays a major role with respect to the type of fiber material used, orientation of fibers, type of adhesive material used, and the metal thickness and stacking of the natural fibers. The laminate to be tested for different behaviors such as tensile, flexure and impact are prepared with varying stacking orders of fibres and metal based on the direction of loading. The stacking of metal sheet and Natural fiber is to be laid by hand lay-up technique. Then they are cured at room temperature and compressed for ten minutes in the compression molding machine at a pressure of 70 kg cm^2 and at temperature of 70° C and thus the final FML is obtained [15,16].

VI. APPLICATIONS

Due to their advantages characteristic FMLs are finding great use in most commonly in Aerospace applications. A number of companies have interest in substitute the traditional aluminium components by FML composites [17]. Both ARALL and GLARE laminates are now being used as structural materials in aircrafts. Fibre Metal Laminates have been successfully introduced into the Airbus A380 [18]. FML composite applications in the Airbus A380 airplane. ARALL has been developed for the lower wing skin panels of the former Fokker 27 aircraft and the cargo door of the Boeing C-17 [19-21]. ARALL 3 material is currently in production and flight test on the C-17 cargo doors and GLARE is selected for the Boeing 777 impact resistant bulk cargo floor.

VII. CONCLUSIONS

The process of extraction of Natural fibre is simple and results is an excellent quality, quantity and lengthy fibre useful for fabrication of large composite components. The lower density of Natural fibre is also an interesting parameter in designing lightweight materials compared to other fibres considered in the present day research. In the review work, is to replace the glass fiber, Carbon fiber by natural fibers, owing to the high cost of carbon and glass fiber and to provide pollution-free environment with a good mechanical performance. Also, owing to the application that essentially require low weight materials with better property of the NFMLs also based on the availability, cheaper and good dielectric strength of Natural fibre composites investigations of the composite can certainly be considered for electrical insulation applications in addition to fabrication of lightweight materials

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