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A review on green hybrid composites – (Glass-Sisal-Bamboo) for aircraft structural applications

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ABSTRACT

Green Hybrid Composite Materials are an emerging trend for future applications mainly in the Automotives and in the Aviation sector, so lots of researches are on the way mainly for Natural Hybrid Composites. This is a review journal which deals with the Green hybrid composites to be used in the Aviation industry, as we have more probability for these kinds of Hybrid Composites. In this review, a good touch is given to reinforcements such as glass, sisal, bamboo, and its hybrid properties. Also, the use of green hybrid composite, their special focus on aerospace structural development in terms of its performance and requirement are explained in this review work.

Keywords— *Hybrid, Bamboo Sisal Glass, Aircraft structures*

1. INTRODUCTION

We all are aware that there is a continuous decline in conventional energy resources. Thus, the researchers are continuously striving hard to limit the use of the conventional sources of energy, thus to find a material to be replaced for the existing conventional materials. The result is what they have replaced the use of conventional materials to composite materials.

The term 'Composite' refers to any combination of two or more materials combined together macroscopically especially when the basic constituent materials used are a Matrix and a Fibre material. Even after the development and the use of the composite material, the researchers were looking for a more effective solution which has led to the development of the hybrid composite. The term 'Hybrid Composite' refers to the composite material which has either one fibre material along with one or more matrix material or one matrix material along with one or more fibre material. The Evolution of the Hybrid Composite has changed the way; we look at the composite material because it has the capability to forecast the properties similar to that of the other conventional materials and sometimes more than that. Also, it is more interesting to see that some of the natural fibres have been very efficient to be used as a fibre or as a filler material in the composite. These natural fibres can be obtained either from Minerals, Animals, and Plants. 'Fibre' means any hair like or thread like structure with very high aspect ratio. As these natural fibres are more eco-friendly, very cheap, easily available, have low pollutants, low greenhouse emissions, enhanced energy recovery, bio-degradability, reduced wear, etc., these are preferred more as compared to other synthetic fibres. The combination of Hybrid Composite and Natural Fibre makes the Green Hybrid Composite, which we can discuss in detail in this journal.

As the major need for the Aviation industry is a material with high strength to weight ratio. This combination of Green Hybrid Composites can have good strength, light weight, low cost, high modulus, high mass specific properties, high tensile strength, high strength to weight ratio, etc. Although, many research scholars have been already worked and reported the mechanical properties of many green hybrid composites, there has less work that has been focused on the hybridization of the Glass fibre with the Natural fibre. Thus, this journal deals with the importance of the Glass, Sisal and Bamboo fibre with polyester as a resin matrix. Now-a-days most of the parts of the aircraft are being manufactured by the use of the glass fibre composites. The purpose of this journal is to ensure that the green hybrid composites can also be used for the aircrafts.

2. SYNTHETIC FIBRE

The most important fibres used as reinforcements in the composite material are the synthetic fibres. The combination of small molecules of synthesized polymer is known as the synthetic fibres. Petroleum based chemicals or petro chemicals are the raw materials for these synthetic fibres. Glass fibre is one of the synthetic fibre. The Glass fibre is explained below.

2.1 Glass fibre

Glass fibres were first developed in Egypt around 1600 BC. These Glass fibres were manufactured initially by drawing filaments from the heated rods. Then they came to be used in many forms such as chopped strands, woven clothes and long continuous fibre and also as yarns.

From [3]; the glass fibres were used as reinforcement just because they showed many more unique properties such as high stiffness, good flexibility, high strength, good chemical resistivity and a robust material too. In comparison with the metals, the glass fibre can be manufactured very easily by a molding process. Glass Fibre are available in many different forms, such as A-Glass, C-Glass, D-Glass, E-Glass, ECR-Glass, AR-Glass, R-Glass, S-Glass, S_2-Glass, and Quartz. Out of these, glass fibres which can be used as reinforcements in the composite structure are E-Glass, AR-Glass, R-Glass, and S-Glass. The Properties of the four above mentioned glass fibres are shown in table 1, their Chemical compositions are shown in table 2 and their Physical and Mechanical properties are shown in table 3.

Table 1: Types and Properties of various Glass Fibres

Type	Properties
E-Glass	Higher strength and electrical resistivity
AR-Glass	Alkali resistant
R-Glass	Higher strength and acid corrosion resistant
S-Glass	Highest tensile strength

However, E-Glass and S-Glass are the most widely used glass fibre in the composite material because of its low fiberizing temperature and its raw materials are very cheap too. E-Glass is used where the cost is restricted as in the household products such as glass fibre doors, window frames, and sports products, etc. But, when strength is considered more important than the cost, then S-Glass comes in the way. The components of S-Glass can be used in the components of the vehicle, ship hulls and vessels and most importantly in the tail wings of the aircraft.

Table 2: Chemical composition of various types of Glass Fibres in wt%

Type	E-Glass	R-Glass	S-Glass
SiO_2	55.0	60.0	65.0
Al_2O_3	14.0	24.0	25.0
TiO_2	0.2	-	-
B_2O_3	7.0	-	-
CaO	22.0	9.0	-
MgO	1.0	6.0	10.0
Na_2O	0.5	0.5	-
K_2O	0.3	0.1	-
Fe_2O_3	0.4	-	-

While using glass fibre in the composite material, the plastics matrix to be used can be a thermosetting plastic (mostly epoxy or polyester or vinylester) or a thermoplastic. The common uses of the glass fibres include boats, automobiles, baths, hot tubs, water tanks, external door skins and roofing, pipes.

Table 3: Physical and Mechanical properties of various types of Glass Fibres

Type Of Fiber	E-Glass	AR-Glass	R-Glass	S-Glass
Density (g/cm^3)	2.58	2.70	2.54	2.68
Tensile Strength (GPa)	3.445	3.241	4.135	4.4-4.6
Young's Modulus (GPa)	72.3	73.1	85.5	88-91
Elongation (%)	4.8	4.4	4.8	-
Coefficient of thermal expansion ($10^{-7}/^oC$)	5.4	65	33	-
Poisson's ratio	0.2	-	-	-
Refractive index	1.558	1.562	1.546	-

3. NATURAL FIBRES

Natural Fibre means a thread like or a hair like structure which is obtained from nature. Natural Fibre can be obtained from three main sources like plants, animals, and minerals as mentioned above. The Animal Fibres consist of proteins which are obtained from (hair, silk, and wool). The plant Fibres consist of cellulose, they include bast or stem fibres (e.g Flax, Hemp, Kenaf, Jute, Roselle, Ramie), leaf or stem fibres (e.g Abaca, Date palm, Banana, Curaua, Caroa, Cantala, Henequen, Sisal, Pineapple), seed (e.g Cotton), fruit (e.g coir, oil palm, Kapok, Sponge gourd), wood, cereal straw and other grass fibres (e.g Bagasse, Bamboo).

Out of the three sources of natural fibres, the fibres which are obtained from plants are most widely used in the automotive and aviation industry too. By considering Global sustainability, there has been much significant improvement in the development of renewable materials by studying natural fibres. These natural fibres can be used as reinforcements in the industrial products and their applications and have much more potential to replace the conventional materials. From [2]; Natural fibers have many advantages such as low cost, abundant availability, biodegradability, nontoxic nature, etc. Also, it was reported that 3.07 million tons of CO_2 emissions and 1.19 million m^3 of crude oil can be saved by substituting 50% of synthetic fibers along with natural fiber composites in automotive applications of North America alone. After this report, the natural fibers are being focused worldwide by the composite manufacturers.

From [7]; there are several applications of natural fibers such as dashboards, upholstery, vehicle interiors, and marine sweepers, decking panel applications where sliding wear and coefficient of friction are much important. The chemical compositions and the mechanical properties of the sisal and the bamboo fibre are as shown in Table 4, 5 and 6 and 7 given below; from [8] and [10].

3.1 Sisal fibre

The Scientific name of Sisal is Agave sisalana. The sisal fibers are obtained from the sisal plant. This sisal plant is presently being cultivated in many countries like India, Indonesia, Haiti, Brazil, East Africa, and Mexico. From [8]; this sisal plant on its average is 1m tall, 28mm wide, and has approximately 200-250 leaves. Each leaf has approximately about 1000 fiber, but only about 4% of it is fit for the use. This sisal plant has an average lifespan of about 7-10 years. This fiber can be used for mechanical decortications or manual process after its maturity.
These sisal fibers are usually extracted through hand extraction machine. In this hand extraction technique, the peel of the sisal fiber is clamped between the wood plank and knife and hand-pulled through, thus removing the resinous material. Then these extracted fibers are dried under the sun. After the fiber is dried and get whitened, then they become ready for knotting. Then a bunch of fibers is clamped or mounted on a stick for segregation. Then the fibers are grouped according to the fiber sizes. One fiber is separately knotted to the end of the end of another fiber, thus getting an entire knot of the fiber as a long continuous strand. In this way, the fibers of the sisal plant are being manufactured for industrial purposes.

This manufactured sisal fiber can be used for manufacturing many products. It has many eco-friendly merits such as low density, cheaper availability, good specific strength and modulus, which makes it fit for use in composites as a reinforcement material. Also, sisal fibers have found many applications in the industry. These applications include manufacturing of roofing tiles, carpets and fancy items like purses, wall hangings, automotive parts and in some construction materials too. From [2];

Table 4: Chemical composition of sisal fiber

Type of fibre	Sisal
Cellulose (%)	65.8
Hemicellulose (%)	12.0
Lignin (%)	9.9
Pectin (%)	0.8
Wax (%)	0.3
Ash (%)	4.2
Moisture (%)	10.0

Table 5: Mechanical Property of sisal fiber

Type of fibre	Sisal
Density (g/cm^3)	1.3-1.6
Elongation (%)	1.9-15
Tensile Strength (MPa)	400-700
Young’s Modulus (GPa)	8.5-40
Specific Gravity	1.3
Specific Modulus (GPa)	6.5-30.8

Research article [43] states that sisal fiber has a close value of mechanical specific strength and modulus properties with glass fibers.

Research article [44] states that the Aircraft industry uses sisal fiber as one of the predominant constituents to develop aerospace structure interior panels.

Research article [45] points out that sisal fiber reinforced composites holds greater impact strength with moderate tensile and flexural properties. It is also noted that impact strength here is significantly decreasing due to the improper surface chemical treatment of fibers and the non-discipline adhesion between fiber and matrix.

Author Sreekumar et al [46] carried out research on sisal fiber polyester composites. This is developed by two different techniques and those are RTM (Resin Transfer Molding) and CM (Compression molding). And it is also revealed that RTM fabricated sisal fiber polyester composites are showing higher tensile strength, young’s modulus, flexural strength and flexural modulus whereas CM fabricated composite defects with a high percentage of voids and water absorption. These are all reasonable due to the poor adhesion between fiber and matrix.

It is observed that mostly mechanical properties of sisal fiber reinforced composites are predetermined at the processing stage of immersing fibers into the matrix. Special attention and care must be given during this crucial stage. Here mechanical properties are also influenced by factors like fiber architecture, fiber orientation, critical fiber length and fiber loading which can be altered based on the strength requirement in the determined direction and applications. The non-uniform load transfer in the composites due to the uneven fiber distribution is considered as an ill factor for improvising mechanical properties. It is noted that hybridization of sisal fibers with other synthetic fibers like glass, carbon, aramid gives significant changes in mechanical properties compared to the hybridization of sisal fiber with other natural fibers. [36]

3.2 Bamboo fibre

Bamboo fiber is scientifically called as Phyllostachys pubescens. Bamboo belongs to the family Bambusoidae. From [4]; the bamboo fiber reinforced composite can be easily manufactured by Hand-lay-up technique. It was observed that the mechanical properties of a bamboo fiber were optimum for 9% of bamboo fiber weight percentage.

The bamboo fiber is used as reinforcement in the composite materials where strength is considered. The bamboo fiber composites are used for many structural applications. Bamboo fiber has a very fast growing rate, it yields within 4-5 years of planting. Within 3 months, the height of the bamboo plant reaches up to 6m. Bamboo is mainly produced in countries like South America, Central America, and Asia.

There are two different ways to extract these bamboo fibers. The first method is to extract the fiber by a mechanical process without the use of any chemical method. The second method is by a chemical method using an alkali hydrolysis process. The bamboo fiber becomes suitable to be used as a reinforcement material in the composite material because of its eco-friendly characteristics such as higher growth rate, light weight, high strength, and biodegradability. Because of these characteristics of the bamboo fiber, it has many industrial applications. These industrial applications of bamboo fiber composites include the manufacture of furniture, decorative items, sports goods, floorings to ceilings, etc.

Table 6: Chemical composition of bamboo fibre

Type of fibre	Bamboo
Cellulose (%)	48.2-73.8
Hemicellulose (%)	12.5-73.3
Lignin (%)	10.2-21.4
Pectin (%)	0.37
Wax (%)	ND
Ash (%)	2.3
Moisture (%)	11.7

Table 7: Mechanical Property of bamboo fiber

Type of fibre	Bamboo
Density (g/cm^3)	1.2-1.5
Elongation (%)	1.9-3.2
Tensile Strength (MPa)	500-575
Young’s Modulus (GPa)	27.0-40.0
Specific Gravity	0.4-0.8
Specific Modulus (GPa)	67.9-50

Author Juan – Kai Huang [38] noted out in his research that usually the bamboo fiber reinforced epoxy composites are manufactured through RTM(Resin Transfer Molding) process and the strength of the bamboo fiber is decelerated by alkaline treatment during preparation. But it is found that an increase in tensile strength would be an interesting factor when bamboo fibers are being gone through alkaline surface treatment. And a weak interface shear stress and bonding tendency between fibers and resin is a worrying factor but it can attain positive values for untreated bamboo fibers through the alkaline process.

It is found that often tensile strength and young’s modulus of the composites having a negative proportionality with bamboo fiber dimensions especially diameter and during hygro thermal aging test, Bamboo fiber reinforced epoxy composites show negative results due to the moisture content and high rate of its absorption. This particular phenomenon leads to the deceleration on mechanical properties of bamboo fiber/epoxy composites. The various results observed from references [39,40,41,42] shows that lignin and hemicelluloses content of bamboo fibers are washed away efficiently by a disciplined surface treatment which provides good interface ability to bamboo fibers than that of without undergoing series of alkaline treatment.

4. INTRODUCTION TO BIO POLYMERS

In polymer composites, compressive strength, in planar stress and inter laminar strength are improvised by the types of polymers used. When it comes to tensile strength, the contribution of matrix or resin is not appreciable. [37]

Polymers in reinforced composites are generally grouped into three divisions. They are natural polymers, synthetic polymers, and polymers from microbial fermentation such as Poly-Hydroxy-Butyrate (PHB). Natural polymers are extracted as starch and cellulose. Synthetic polymers are derived from natural monomers such as Poly-Lactic-Acid (PLA).

4.1 Poly-lactic-acid (PLA)

PLA is a revolutionary finding from green research and it is nature friendly and biodegradable which can be collected from natural feedstock such as corn starch, rice, potatoes, sugar beet, and other agricultural wastes.

PLA processing is a typical one which starts at the transformation of feedstock into textrose, which then transformed into lactic acid or lactide through a fermentation process by in taking pure catalyst. The lactide then permitted into polymerization process by the intake of a suitable catalyst.

Further polymerization process leads the development of widely available and biodegradable polymer known as poly-L-lactic acid (PLLA) which has a melting point relatively to 160^0 and similar to the thermoplastic polypropylene in handling and application. [33]

Author Sarath shekar H S [33] mentioned in his research article about PLLA with 70% kenaf fiber shows good results in strength during failure.

4.2 Starch

Starch is also stated as a complex polymer because of its richness in amylose and amylo-pectin polysaccharides. Starch form and property is entirely depending on this mixture and the source of the plant. Starch is extracted in a greater percentage from corn but it is also presented in potato, wheat, and rice.

Cashew nut shell [35], Butylene succinate, Furan based resins [34], Cellulose acetate, polyhydroxybutyrate-co-hydroxyvalerate (PHBV), Cellulose are some of the biopolymers identified in the recent development of biodegradable composites.

5. GREEN HYBRID COMPOSITE

The fibre reinforced composite can be obtained by combining one or more fibres in a single matrix or a single fibre in one or more matrix. The material which is composed of different mixtures of matrices combined with two or more reinforcing and filler material is termed as Hybrid in 'Greek-Latin' origin. As I have previously mentioned that Green Hybrid composite is a combination of synthetic fiber as well as natural fiber. The very important merit that can be obtained from the hybrid composite is that, if one of the fiber lacks a particular property, then that particular property can be obtained from another fiber which is being hybridized. A very efficient material can be obtained by considering proper material design considerations.

By varying structure of the fibre, the orientation of the fiber, fiber content, length of the fiber, fabric-matrix bonding and arrangement of the fiber, the failure strain of each fiber in the composites, the properties of the hybrid composite can be varied too much. There are two different ways of hybridizing composite. The first one is called as interlaminate which means a simple laminate that is obtained by depositing layers of lamina one above another. The second one is called as intralaminate which means that different fibers are reinforced in a single matrix or layer. There are several ways to manufacture hybrid composite. Some of the manufacturing methods are Hydraulic Process, Cold Press Method, Compression Molding Method, Hand-layup Method, etc.

The hybridization of natural fiber along with synthetic fiber gives superior mechanical properties than that obtained from the hybridization of natural with natural fiber or synthetic with synthetic fiber. The concept of hybridization gives much more comfort to the design engineer for designing a material suitable for a particular purpose. Also, there is an increasing trend for the usage of the polymers. From [1]; The physical properties of the green hybrid natural composites are too a great extent dependent on the cellulose content, angle of fibrils, structure of fibbers and cross section of the fiber, etc.

Author Santulli et al [32] followed out experimentation on bamboo/glass fiber reinforced unsaturated polyester composites carrying in weight percentage of 25 in total fiber weight content, with a bamboo fiber amount of 6.2% and glass fiber having 18.8% remaining weight. For this sample, the results from the impact test are being found out which shows the sample gives maximum withstanding strength of 32 KJ/m^2. Also, it is found out that significant high value of flexural and modulus by rising up the fiber volume fraction in the composition which is a required criterion for any kind of composite structures and materials to prove itself worthy for commercial application in design cases.

Author Thwe et al [30] followed out experimentation on short bamboo fiber reinforced polypropylene composites (BFRP), and it is found out that the durability of BFRP can be improved by hybridization with a low percentage of glass fibers.

Author Ramesh et al [31] has done experimentation on the different level orientation of orientation of 'Jute-glass' fiber, 'Sisal-glass' fiber and 'sisal-jute-glass' fiber reinforced polyester composites. The observation of the maximum tensile strength of 229.54 MPa was found compared to 'sisal-glass-jute-glass' fiber reinforced hybrid composites.

So based on the data picked out from expert's experimentation as mentioned in the previous paragraph, the probability of following out experimentation with the composition of bamboo, sisal, glass as fiber reinforcement and biopolymers as a resin is mostly possible and may be successive.

6. AEROSPACE STRUCTURES-REQUIREMENTS – OVERVIEW

Aerospace industries nowadays come up with featured and attractive improvements in structural parts and components of both commercial and military purpose aircraft vehicles. The revolutionary activity that can be found in modernized design of structures and development is the maximum intake and utilization of composite materials and structures especially hybrid composites of synthetic and non-synthetic bio fibers and matrix because these composites holds the greater potential level of high strength and stiffness to density ratio, parallel with high terms of physical properties. These hybrid composites have already been used in the structures of launch vehicles, satellites, helicopters and in missiles too. [24] For an

outstanding flight performance and efficient structural engineering, the structural elements are designed to equip for the following requirements:
(a) Light Weight
(b) High Reliability
(c) Passenger Safety
(d) Durability
(e) Aerodynamic Performance
(f) Multi role Or Functionality
(g) Stealth Mode
(h) Control system enhancement

6.1 Weather protection

Light Weight Criteria is an all-time expecting one for all category structures in aerospace vehicles. Usually, semi-monocoque fuselage structure is used to obtain high strength to weight ratio and high stiffness to weight ratio in aircraft. High level of reliability is necessary for aircraft structures by maintaining strict quality control and certification. The effective and robust design work must be carried out and submitted as proof for value based certification.

To ensure passenger safety in civil transportation vehicles, the structural elements both interior and exterior must use or come up with fire retardant materials. To obtain cash worthiness, extensive testing should be carried out. The durability of aircraft or spacecraft is measured in the rate of fatigue, corrosion, and degradation. For space vehicles vacuum radiation and thermal effects plays a role in affecting durability. In the case of natural fibers, degradation may be influenced by natural causes like fungus and bio reasons.

Aerodynamic performance of aircraft, reusable spacecraft is influenced by the maximum level of complex loading, thin walled flexible wings and control surfaces – deformed shape/dynamics, complex contoured shapes-efficient machining (Numerical computerized) and molding. Aircraft structures must be designed to have lightening protection and erosion resistance to hang out with all – weather operation. It is also required in stealth operations to get applied all over the structures by stealth coatings to behave like a stealth operative vehicle in order to satisfy specific military aerospace applications. [25-29]. Some typical aerospace application of glass fibers alone as reinforcement: [25-29]

- **S-Glass:** Highly loaded parts in small passenger aircraft
- **E-Glass:** Small passenger aircraft parts, aircraft interiors, secondary parts, radomes, rocket motor casings.

7. BIO COMPOSITES FOR AIRCRAFT APPLICATIONS

7.1 Aircraft Radome applications

The radome is used as a weatherproof to radar and antenna unit. In modernized aircraft it is usually located at on the rear fuselage and come up in the different shape of cylindrical, spherical, planar and it is structured as a closure which covers 360 degrees and protects the inner system such as elements of radio communication from the environmental weather change, bird strike, aerodynamic loading, and unloading. It is predominant for a radome to have positive values in low dielectric constant and high toughness. [14]

Author Harris et al [15] analyzed in his research about the dielectric and mechanical property of five different natural fibers (Banana, Bamboo, Oil palm, Kenaf, Pineapple leaf fiber) for radome development. Usually, natural fibers have their dielectric properties ranges between 2.8 to 3.2 and this one comes to the nearest value of synthetic fibers and resin used as a constituent for radome development (Woven E glass with polyester and epoxy ranges between 4.03 and 4.43).

Harris is also concluded that among those five natural fibers kenaf fiber alone holds good mechanical properties (Tensile strength = 930 MPa, Tensile Module = 53 GPa and Elongation at failure = 1.6 %) and which has stiffness near to glass fiber and low dielectric constants. And Kenaf fiber triggers the mechanical properties and boosts the rain erosion resistance level when it gets to compound with glass fiber.

7.2 Wing Box applications

Author Boegler et al [18] has done his research on natural fiber composites to replace load bearing structures in aircraft. It is found out through conceptual design and “MATLAB” simulation and analysis that Ramie fiber reinforced polylactic acid and epoxy resin made wing box could be a sustainable one and can be replaced to conventional reference wing box of aluminum alloy material. When ramie fiber composites are used, it could reduce the weight of the wing box by around 12% to 14%.

Table 8: Wing Mass of various wing box structures

Type of Wing Box	Wing Mass
Aluminium alloy	8829 Kg
Ramie/Epoxy	7576 Kg
Ramie/Polylactic acid	7758 Kg

7.3 Aircraft cabin interior panel applications

Author Anandijiwala at el [17] has invoked experimentation on woven flax fabric and phenolic matrics. Here a sandwich honeycomb composite panel is developed by sandwiching honeycomb cores between the layers of phenolic resin impregnated woven flax fiber followed by compression molding at 130 degrees at around 75 minutes. The fire retardant ability of flax fiber is improved by applying special coatings of fire retardant materials like phosphates, phosphoric acids, tetrakin, etc., usually phosphates coating is recommended for cellulosic fiber elements. Finally, a commercial panel for cabin interior with the highest level of fire resistant is made and it is replaceable to conventional monolithic alloys.

7.4 Aircraft indoor structural applications

Author Subash et al [16] has done a recent review on green composites over aircraft structural applications. It is found out from the research that often bast fibers such as hempo, kenaf, flax can be used as a major constituent in composites for aircraft indoor structures. It also can be used for indoor patterns and extensions like seat cushions, cabin linings, parcel shelves, etc, it is also found out that jute fiber reinforced polyester/epoxy with red mud can be used for pilots cabin doors and door shutters.

8. CASE STUDY IN REPUTED COMPANIES

8.1 Airbus

The South African Council for Scientific and Industrial Research (CSIR) and international commercial aircraft manufacturer AIRBUS joins together and started their brief level research program on the replacement of AIRBUS interior design and components by bio composites and maintain sustainability which has the reinforcement of natural fibers such as flax, hemp, kenaf, and sisal. They started to focus on natural fibers which are cultivated at high rates in the South Africa region due to its low cost, high level of biodegrability, low density, non-abrasiveness, and recyclability. They are also focusing on Nano technology for to know more about fine incorporation of resins with natural fibers. They also invoked the revolutionary idea of apply natural fiber such as flax to their recent development of AIRBUS helicopter X3 high speed demonstrator. [14]

8.2 Boeing

Boeing research and technology is already involved in the research of developing bio sandwich panels made with epoxy and utilize it for replacing conventional cabin sidewalls. To improve the fire retardant abilities of natural fibers such as flax, they treat it with halogen free flame retardant agents. Thereby they manufacture full scale side wall panel by using a vacuum bag molding process. It is mandatory that the bio composites developed in this facility are undergo screening for clearance and approval to FAA (Federal Aviation Administration) and EASA (European aviation safety agency). [14]

9. CONCLUSION

This is a review journal that gives us the idea about the properties of the green hybrid composite. Also, this journal expresses the feasibility of hybridizing the bamboo fibre along with sisal and glass fibre by considering biopolymers as an efficient resin matrix. This journal concludes that the green hybrid composite made of bamboo, sisal and glass with biopolymers as a resin matrix can give enhanced properties such as high tensile strength, compressive strength, flexural strength, and impact strength, etc. in comparison to other composites such as natural fiber/natural fiber hybrid and natural fiber/synthetic fiber hybrid composites. This journal also pre-assumes that the hybrid composite has better physical and mechanical properties than that of the individual composite. Even though many of the green hybrid composites researches are ongoing, yet there are lots of researches to be done on the green hybrid composites that might be useful for future applications in aerospace industries.

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