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Mechanical Characterization of Biodegradable Linen Fiber Composites

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Abstract: *The conventional materials like iron, mild steel, cast iron etc are having good mechanical properties. Hence they are widely used in structural engineering applications. These conventional materials have some defects like formation of rust, low weight to strength ratio, high production cost. To overcome these defects, engineers started fabricating composite materials. Composites exhibit peculiar properties like different strengths in different directions, rust resistant, high strength to weight ratio, but they pollute the environment. Now the natural fibre composites are widely used in automobile industry. The natural fibres and resins are used to fabricate an eco friendly composite material. Lack of resources and increasing environmental pollution has evoked great interest in the research of materials that are friendly to our health and environment. Bio polymer composites fabricated from natural fibres is currently the most promising area in polymer sciences. This is designed to assess the possibility of fibre as reinforcing material in composites. Epoxy resin was made a stiffened panel to conduct tensile test. In this paper it is aimed to explain all possible ways to use natural composites in automobile components. The main advantages of using natural fibers are their degradability and light weight. They are environment friendly and also increase the fuel economy.*
Keywords: *Natural fibers, Natural composites, automobile parts, biodegradable.*

I. Introduction

With the development of new high performance fibres, composites began to compete with metals, and replace them, in myriad application. Fibre reinforced composites ventured into areas which were unthinkable few decades ago, making the products light weight, improving the performance of the product and in some cases improving the life time too. Better mechanical properties of these composites are due to excellent interfacial adhesion between fibre and matrix, in addition to good mechanical properties of fibres. However the good interfacial adhesion between fibre and matrix, which is beneficial in the product, is a significant disadvantage in the products "afterlife" since the fibres and matrix cannot be separated easily. This impairs the recycling of either or both. Also these fibres are not easily compostable; hence the composite cannot be used to recover energy. Within today's climate of growing environmental awareness and with depleting natural resources, people have resorted back to using natural fibres in lieu of polymeric fibres wherever possible.

Based on the objectives of the present work a close review has been carried out of the following topics to understand and assess the current status. With the strong emphasis on environmental awareness, much attention has been brought into the development of recyclable and environmentally sustainable literature composite materials since the last decade. Environmental legislation as well as consumer demand in many countries is imposing higher pressure on manufacturers of materials and end products. They have to consider the environmental impact of their products at all stages of their life cycle, including recycling and ultimate disposal. These environmental issues have recently generated considerable interest in the development of recyclable and biodegradable composite materials. Therefore, research in the field of using natural fibres has attracted much attention in the material science and engineering discipline. Natural fibre is certainly a renewable resource that can be grown and made within a short period of time, in which the supply can be unlimited when compared with traditional glass and carbon fibre for making advanced composites. This natural fibre mixing with polymers can produce new class of materials in bio-medical application and lightweight structural application.

The variation in mechanical properties of natural fibres is due to the conditions during growth. Depending on the extraction process, the chemical composition, fibre shape, fibre strength, flexibility, and ability to adhere to other fibres or matrix differ widely between different types of woods. This makes it difficult to predict the mechanical properties of the natural fibre reinforced composites, studied comparative life cycle assessment of natural fibre and glass fibre composites. Natural fibre is emerging as low cost, lightweight and apparently environmentally superior alternatives to glass fibres in composites. Natural fibre composites are likely to be environmentally superior to glass fibre composites in most cases for instance, the natural fibre production has lower environmental impacts compared to glass fibre production and end of life incineration of natural fibres results in recovered energy and carbon credits. Plant based composites may in future, become materials to replace polymer based composites and wood in terms of their attractive specific properties, lower cost, simple processing technologies, eco friendliness, and ability to be recycled after use [2]. The quality and performance of plant-based composites can further be improved by adopting appropriate engineering techniques.

Research on natural fibre composite is still relatively new. It is clear that improvements must be made if natural fibres are to compete with synthetic fibres on the composite market. The adhesion between the fibre and the matrix, the processing of the fibres and the structure of the fibres are examples of areas that need to be studied in more detail. The adhesion between the fibres and the matrix is crucial to all fibre composite materials. If the adhesion is good, stress is transferred between the load carrying fibres over the matrix, which makes the material strong and stiff. A directly proportional relationship was discovered between interphase thickness and adhesion. This, we believe, is a consequence of entanglements formed in an inter diffusion process at the fiber/matrix interface [1].

1.1 Two main reasons for the interest in biodegradable materials are:

1. The growing problem of waste thereby resulting general shortage of landfill availability, and 2. The need for environmentally responsible use of resources, together with the carbon dioxide neutrality aspect. Bio-composites or more specifically the "green composites," consists of bio-fibre and bio-plastic from renewable resources and thus are expected to be biodegradable. Biodegradable polymers may be defined as those that undergo microbially induced chain scission, leading to mineralization, photo degradation, oxidation, and hydrolysis, which can alter a polymer during the degradation process.

II. Materials And Procedure To Prepare Laminate

2.1. Lenin Fibre

Linen is made from the fibres of the flax plant, *Linum usitatissimum*. Linen is labour-intensive to manufacture but when it is made into garments, it is valued for its exceptional coolness and freshness in hot weather.

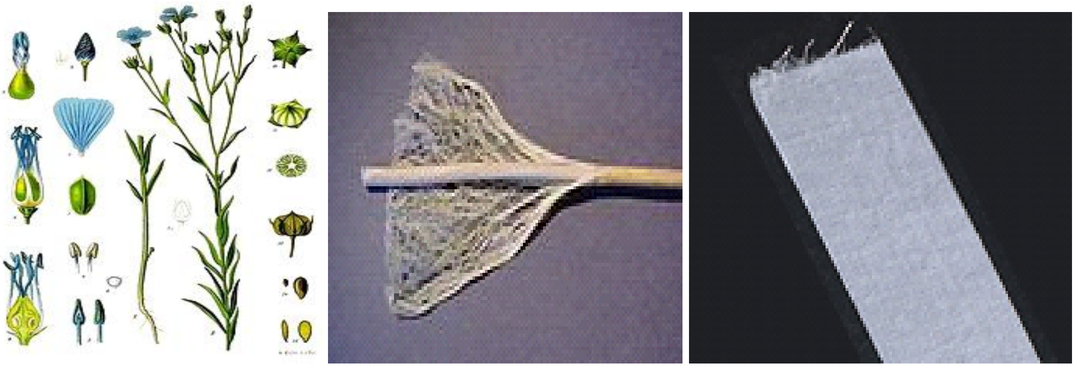


Figure 1: Preparation of Linen fibre from flax plant

2.2 Properties of Linen

- Linen is renowned for its spectacular durability and long life. The tensile strength of linen thread is twice as high as that of cotton and three times that of wool.
- Flax cell is highly compatible with the human cell thereby producing a benevolent effect on the human organism.
- Used as bed linen as it reduces fatigue and lifts spirits.
- Flax fabric is an excellent filter protecting against a chemically aggressive medium, noise and dust.
- Linen reduces gamma radiation nearly by half and protects the human organism against solar radiation. Flax fibre from contaminated soils appears not to exhibit even traces of radiation.
- Linen underwear possesses rare bacteriological properties. Resistant to fungus and bacteria, it is found to be an effective barrier to some diseases. According to medical studies conducted by Japanese researchers, bed-ridden patients do not develop bedsores where linen bed sheets are used. Wearing linen clothes helps to get rid of some skin diseases - from common rash to chronic eczemas.
- Linen does not cause allergic reactions and is helpful in treating a number of allergic disorders.

- Linen is effective in dealing with inflammatory conditions, reducing fever and regulating air ventilation, and is also helpful in the treatment of some neurological ailments;
- Linen cloth does not accumulate static electricity - even a small addition of flax fibres (up to 10%) to a cloth is enough to eliminate the static electricity effect.
- Linen is highly hygroscopic as it is capable to rapidly absorb and yield moisture. [3]It evaporates water as quickly as the pond surface. It has been established that before giving a feeling of being wet, linen cloth can absorb as much as 20% of its dry weight. That explains why linen cloth always feels fresh and cool.
- Linen possesses high air permeability and heat conductivity properties. Heat conductivity of linen is five times as high as that of wool and 19 times as that of silk. In hot weather those dressed in linen clothes are found to show the skin temperature 3°-4°C below that of their silk or cotton-wearing friends. According to some
- Studies, a person wearing linen clothes perspires 1.5 times less than when dressed in cotton clothes and twice less than when dressed in viscose clothes. Meanwhile in cold weather linen is an ideal warmth-keeper.
- Silica present in the flax fibre protects linen against rotting - the mummies of Egyptian Pharaohs preserved to the present day are wrapped in the finest linen cloth.
- Linen rejects dirt and does not get teaselled.
- Linen and Linen-containing articles are easily laundered in hot water, may be boiled and dried in the sun, besides they may be hot-ironed thereby ensuring maximum sterilization.
- The more Linen is washed the softer and smoother it becomes.
- Linen underscores naturalness, softness and relief increasing is yet another precious property possessed by Linen.

The main drawback of natural fibers is their hydrophilic nature that lowers their compatibility with comparatively hydrophobic polymer matrix. The surface chemical modifications of natural fibers like dewaxing, alkali treatment, vinyl grafting, cyanoethylation, acetylation, bleaching, peroxide treatment, sizing with polymeric Iso cyanides, treatment with saline and other coupling agents have achieved various levels of success in improving fiber-matrix adhesion in natural fiber composites [7]

2.3 Matrix (Resin)

Araldite sets by the interaction of a resin with a hardener. Heat is not necessary although warming will reduce the curing time and improve the strength of the bond. After curing, the joint is claimed to be impervious to boiling water and all common organic solvents. It is available in many different types of packs, the most common containing two different tubes, one each for the resin and the hardener. Other variations include double syringe-type packages which automatically measure equal parts.

Interior parts from natural fiber and polypropylene (PP),exterior parts from natural fiber - polyester resins are already in use[5].Ford has a long history of R&D on new materials[6]. He performed a durability test with a fire axe on prototype car made of plastics derived from soybeans

Araldite (Resin/ Hardener) is an epoxy adhesive used for multi-purpose, viscous material that is suitable for bonding a variety of materials including metal, Ceramic and wood. The various applications, advantages and properties of Resin are shown in Table 1. The electrically insulating adhesive is easy to apply either manually by spatula and stiff brush or mechanically with meter/mix and coating Equipment. Araldite resin/Hardener an epoxy adhesive cures at temperatures from 68ºF (20ºC) to 356ºF (180ºC) with no release of volatile constituents. Unlike other biopolymers, cellulosic plastic shows better compatibility with lingo-cellulosic bio-fibers [4]

Table 1: Applications, Advantages and Properties of Resin

Applications of Resin in other materials	*Advantages*	*Key Properties*
• Metal • Ceramics • Wood • Vulcanized Rubber • Foams • Plastics	• Long open time • High shear and peel strength • Easy to apply • Good resistance to static and dynamic loads • Electrically insulating	• Easy to mix and apply • Gap filling • Excellent resistance to chemicals • Solvent free • Heat resistance up to 120°C • Cures @5^0-100°C

2.4 Preparation of Laminate

Step-1: Remove every alternate string from the Lenin cloth horizontally and vertically in such a manner that it Looks like a band aid cloth, leaving gaps such that resin can be uniformly filled.

Step-2: Take a single layer of PVC sheet and apply grease on it.

Step-3: Take equal proportions of Hardener and Resin forms of Araldite in a bowl and mix properly to get a uniform mixture.

Step-4: Apply this mixture uniformly on the PVC sheet.

Step-5: Place a woven linen fibre of two folds on the PVC sheet and coat on the fibre uniformly with brush . Place it in open air for curing, formed a laminate as **sample-I**.

Step-6: Again repeat steps 4 and 5 to obtain Three layered laminate by keeping three layers on PVC sheet and Considered as **sample-II**.

Step-8: Make four such layers and consider it as **Sample-III.**

Step-9: Now repeat steps 2-4 to get a sample and individual strings removed from the original Linen fibre. Finally apply Araldite mixture uniformly on the sample obtained, which will be considered as **Sample-IV**. Table-2 shows different samples and their individual weights of all the four samples were taken after curing for 24 hours and tabulated as below:

Table-2: Different samples and their individual weights of all the four samples

S. No	*Sample No*	*Total Weight (g) after curing*
1	Sample-I	70.2
2	Sample-II	54.2
3	Sample-III	41.6
4	Sample-IV	36.6

Figure 2: Four layered sample-III

Figure 3: Three Layered sample-II

Figure-4: Two Layered sample-II

Figure-5: Individual fibre sample-I

Table 3: Calculation for weight of resin used in different samples

Sample No	***Total weight of sample (g)***	***Weight of Linen used (g)***	***Weight of Resin (g)***
Sample-I	70.2	3.4×4= 13.6	56.6
Sample-II	54.2	3.4×3= 10.2	43.0
Sample-III	41.6	3.4×2= 6.8	34.6
Sample-IV	36.6	4	32.6

Figure-6: Samples after curing

Figure-7: Sample Measurement

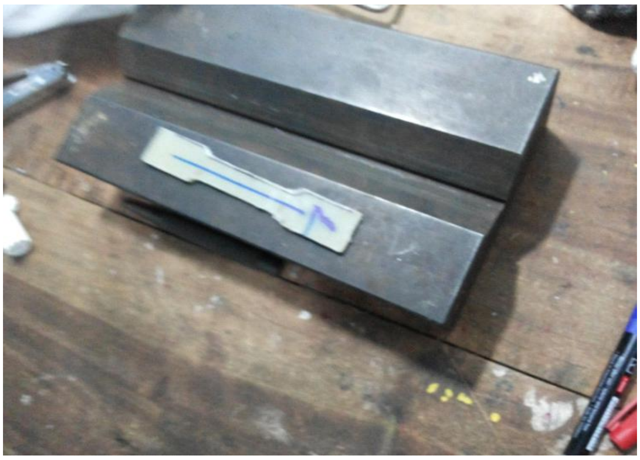


Figure 8: Test sample

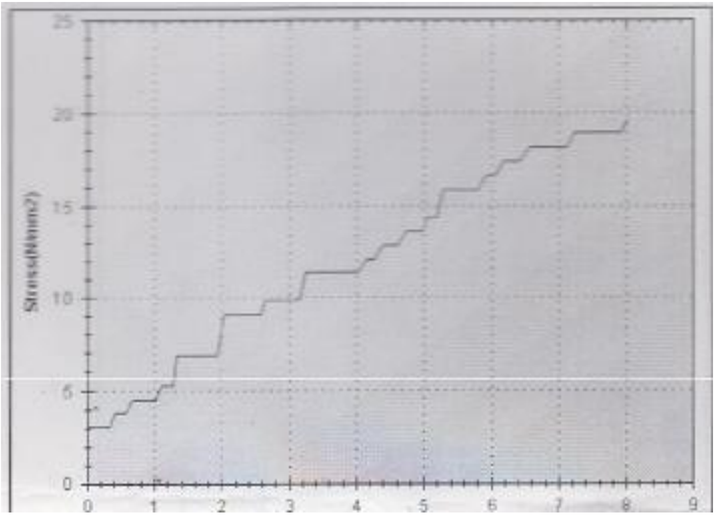
III. Results Of Tensile Test Conducted On Samples

3.1 Sample-I

Table 4: Results of the tensile test conducted on sample containing 4 layers

Input			***Output***		
Specimen shape	=	Flat	Load at yield	=	0.63 KN
Specimen width	=	13.34 mm	Elongation at yield	=	2.790 mm
Specimen thickness	=	2.98 mm	Yield stress	=	15,848 N/mm2
Gauge length	=	50 mm	Load at peak	=	0.78 KN
Pre load value	=	0 KN	Elongation at peak	=	4.07 mm
Max.load	=	600 KN	Ultimate strength	=	19.621 N/mm2
Max.Elongation	=	250 mm	Load at break	=	0.78 KN
Cross section area	=	39.75 mm^2	Elongation at break	=	4.02 mm
Final gauge length	=	50.36 mm	% elongation	=	0.72 %

Stress



Strain (%)

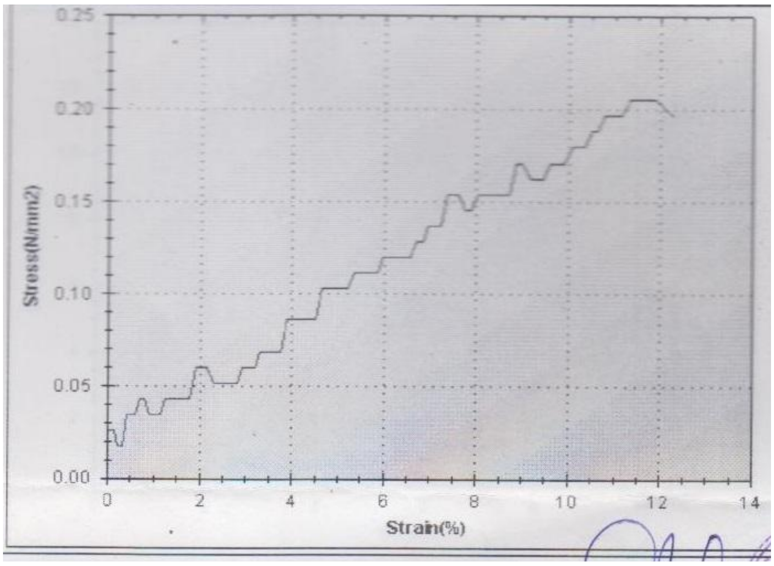
Figure 9: Stress Vs Strain

3.2 Sample-II

Table 5: Results obtained for sample containing 3 layers.

Input			*Output*		
Specimen shape	=	Flat	Load at yield	=	0.57 KN
Specimen width	=	13.77 mm	Elongation at yield	=	4.73 mm
Specimen thickness	=	2.55 mm	Yield stress	=	16.234 N/mm^2
Gauge length	=	50 mm	Load at peak	=	0.72 KN
Pre load value	=	0 KN	Elongation at peak	=	6.04 mm
Max.load	=	600 KN	Ultimate strength	=	20.506 N/mm^2
Max.Elongation	=	250 mm	Load at break	=	0.69 KN
Cross section area	=	35.11 mm^2	Elongation at break	=	6.14 mm
Final gauge length	=	50.44 mm	% elongation	=	0.88

Stress



Strain (%)

Figure 10: Stress Vs Strain

3.3 Sample-III

Table 6: Results obtained for sample containing 2 layers.

Input			***Output***		
Specimen shape	=	Flat	Load at yield	=	0.21 KN
Specimen width	=	14.34 mm	Elongation at yield	=	3.970 mm
Specimen thickness	=	1.74 mm	Yield stress	=	8.434 N/mm2
Gauge length	=	50 mm	Load at peak	=	0.3 KN
Pre load value	=	0 KN	Elongation at peak	=	5.27 mm
Max.load	=	600 KN	Ultimate strength	=	12.048 N/mm2
Max.Elongation	=	250 mm	Load at break	=	0.27 KN
Cross section area	=	24.9 mm2	Elongation at break	=	5.36 mm
Final gauge length	=	50.21 mm	% elongation	=	0.42

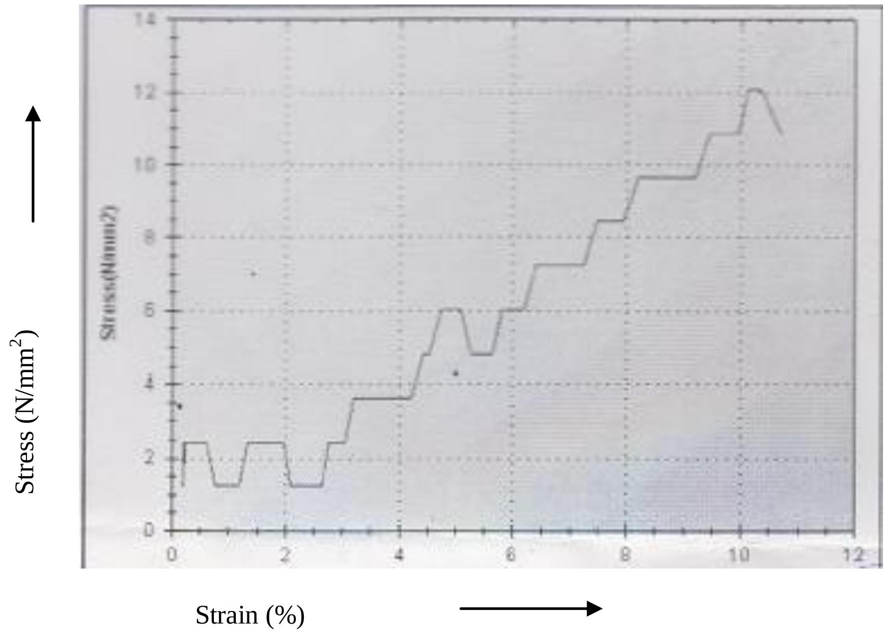


Figure 11: Stress Vs Strain

3.4 Sample-IV

Table 7: Results obtained for sample containing Individual fibres.

INPUT			***OUTPUT***		
Specimen shape	=	Flat	Load at yield	=	0.96 KN
Specimen width	=	13.33 mm	Elongation at yield	=	7.4 mm
Specimen thickness	=	3.13 mm	Yield stress	=	23.009 N/mm^2
Gauge length	=	50 mm	Load at peak	=	1.2 KN
Pre load value	=	0 KN	Elongation at peak	=	8.9 mm
Max.load	=	600 KN	Ultimate strength	=	28.761 N/mm2
Max.Elongation	=	250 mm	Load at break	=	1.2 KN
Cross section area	=	41.72 mm^2	Elongation at break	=	8.81 mm
Final gauge length	=	50.12 mm	% elongation	=	0.24

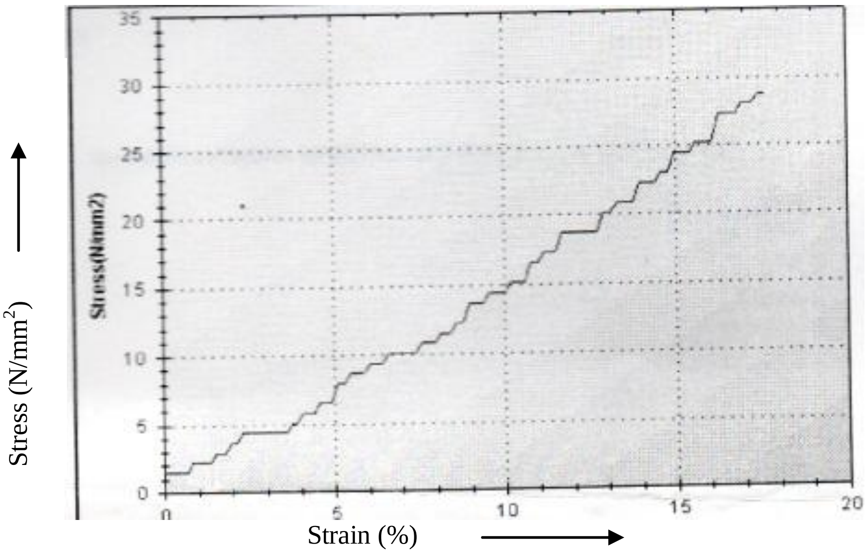


Figure 12: Stress Vs Strain

IV. Conclusion

After decades of high- tech developments of artificial fibers like aramid, carbon and glass it is remarkable that natural fibers have gained a renewed interest, especially as a glass fiber substitute in automotive industries.

Pure woven linen fibre-Araldite resin laminate has more strength than loose fibre –Araldite resin laminate. Both the laminates are very economical and pure plant fibres. Biodegradability of linen fibre is high and absolutely pollution free. Again renewable resource based bio-plastics are currently being developed and need to be researched more to overcome the performance limitations. The main advantage of using renewable materials is that the global CO_2 balance is kept at a stable level.

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