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Investigation on mechanical properties of green fibre (flax, kenaf and sisal)/ carbon fibre – a hybrid composite

Vasanth S[a], Dr. M.S. Nisha[b], Deepak S[c], Vijayasarathi M[d]

[a,c,d] Students, Aeronautical Engineering, Hindustan Institute of technology & Science, Chennai, India
[b] Assistant professor, School of Aeronautical Sciences, Hindustan Institute of technology & Science, Chennai, India.
[a]vipervasanth14@gmail.com

Abstract

The aviation industry plays a dominant role for the mankind in air transportation. Such industry had to deal with major factors like environmental aspects such as pollution and biodegradability. In order to fulfil the above aspects, the green fibre such as flax, sisal and kenaf is used. Though the inherent features of green fibre are considered the synthetic fibre's role cannot be neglected. Carbon fibre is one of the synthetic fibres which has durability, high tensile strength, toughness and it can be easily manufactured. In this paperwork, the carbon fibre is combined and fabricated with the natural fibres to investigate which combination possess high tensile strength. The fabrication process involves cutting fibres with respective dimensions and place three natural fibre in between two carbon fibre by mixing spreading resin hardener on the layers. The process is done for all the three natural fibres. After the fabrication process the specimen is undergone for the investigation of mechanical properties such as tensile testing. Finally, we obtain the three types of green/ carbon fibre combination a simple hybrid composite material. As per the concern of composite materials the complete replacement of existing carbon fibre with natural fibre is not possible, nevertheless the partial replacement would assist the positive approach of environmental impacts.

Keywords:

1. Introduction

A composite material is a combination of two different materials in which the physical and chemical properties varies when they are combined, they create a material which is specialized to do a certain job for instance to become stronger, lighter or resistant to electricity.They can also improve strength and stiffness. As a class of materials composites tend to have following characteristics such as high modulus, high strength, low density, good resistant towards fatigue, creep, creep rupture, corrosion, and wear and low coefficient of thermal expansion (CTE). Composite materials are one such class of materials that plays dominant & significant role in current and future aerospace components. Composite material has exceptional strength and stiffness to density ratio and superior physical properties therefore attracted toaviation and aerospace application.

Composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. The two constituents are reinforcement and a matrix. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. Composites are made from renewable resourcehas become important alternative materials for manufacturing in engineering industry. Natural fibre composites have become superior materials compared to conventional fibre composites due to the ease of manufacturing process. The composite engineers are focusing on the development of new tougher stronger, lightweight structural materials which supports latest technologies and design concepts for the complex shaped structures like aircraft and automotive structures and large wind turbine blade structures. The development of composite materials improves their performance based on the reinforcement of two or more fibres in a single polymeric matrix, which leads to the advanced material system known as hybrid composites with a great diversity of material properties.

Composite consists of three components

1. The matrix as the continuous phase,

2. The reinforcements as the discontinuous or dispersed phase,including fibre and particles

3. Then fine interphase region also known as the interface.[1][2][3]

1.2 Green fibre:

Green composites are completely bio-based composites in whichfibreand matrix arefully biodegradable and renewable. Natural, vegetable fibres can be applied toreinforce the natural polymers such as starch, lignin, hemicellulose and India – rubber whichresulted as 100% biodegradable material. The necessary aspects that the green/natural fibres must have to satisfy the composite requirements are high strengthnatural fibres, resins with good biodegradability and optimum fibreresin interfacialbonding.

Composite's process depends on the properties of the constituents,i.e., the fibres andresin ratiosapplied. The stiffness and strength of the composites are directly a function of the reinforcingfibre properties which carries most of the load and volume content. The relative the position of the fibres are maintained with the help of resin within the composite and, more importantly,transfers the load from broken fibres to the intact fibres. So therefore, the fibre/resin interfacialproperties are necessary and have a significant effect on composites properties, includingtoughness and transverse fracture stress.

Green composites are generally an environmentally friendly materials in various stages of production,processing and waste disposal. Commonly known processing methods of production can beutilized effectively to produce green composites. The better elasticity of polymer compositesreinforced with natural fibres, especially when modified with crushed fibres, embroideredand 3-D woven fibres. They display high acoustic insulation and absorb vibration. Lowenergy consumption when processed, due to its low – temperature requirements andflexibility. when burnt, the polymer composites containing natural fibre produce less CO2

The price of polymer composites reinforced with natural fibre is 2-3 times lower thanpolymers reinforced with glass fibre.

Sustainable package to help reduce the effects of recent environmental issue

- Leaf: Sisal, pineapple leaf fibre (PALF) and henequen.
- Bast, Flax, ramie, kenaf/Mesta, hemp and jute.
- Seed: Cotton.
- Fruit: Coconut husk, i.e., coir.

The natural fibres are lignocellulosic in nature and are the most wantedabundant renewable biomaterial of photosynthesis on earth. In terms of mass units, thenet primary production per year is estimated to be Tons as compared to syntheticpolymers.[4][5]

1.3Carbon fibre:

The most common reinforcement composite materials ever used is the carbon fibre especially for theclass of materials called as carbon fibre or graphite reinforced polymers. Non –polymer materials-whichis also use as the matrix for carbon fibres. Carbonfibres has seen limited of success in metalmatrix composite applications as there is the formation of corrosion and metal carbides.The Reinforced carbon- carbon (RCC) consists of carbonfibre-reinforced graphite which is been used as structurally in high- temperature applications.The merits of using carbon fibres are filtration of high-temperature gases,as an electrode with highsurface area and as an antistatic component moreover impeccable corrosion resistance.

The fire resistance of polymers/thermoset composites is consistently improved by a moulding a very fine thin layers of carbon fibre as the compact and dense layers of the carbon fibres reflects the heat effectively. As there were exponentially increased mode of using carbon fibre for the aviation/aerospace industry, the use of aluminium has been replaced by the entry of carbon fibre.

The asphalt concrete use carbon fibres as an additive. The winter maintenance issues such as fog which lead to flight of snow and ice has been decreased totally by imparting the composites in the transportation infrastructures particularly for airport pavements. The surface temperature of the asphalt is increased by passing current through 3D network of carbon fibres.[6]

2. . Experimental Procedure

2.1 Material Selection:

The selection criteria for the composite manufacturing are deals with fibre and resin combination. We are making the hybrid composite for which the natural and synthetic fibres are required to proceed. The natural fibres chosen **are flax, sisal and kenaf**, whereas the synthetic fibre is **carbon**.

Flax fibre:

Flax fibre is extracted from the stem surface of the flax plant. The benefits of using flax fibre are because of properties like flexible, soft and lustrous, moreover it is stronger than cotton fibre.

Sisal fibre:

Sisal fibre is extracted from the flowering plant, yields a stiff fibre for making fibre mat.

Kenaf fibre:

It is extracted from the hibiscus cannabinus and the primary uses of this fibre is making twine, rope and cloth (similar of jute).

Resin and Hardener:

Epoxy resin **LY556** is widely used as reinforcing material due to its excellent chemical resistivity and medium viscosity. By adding the fillers and hardeners, the resin's property can be modified easily. Hardener **HY951** has a good mechanical strength and shows better resistance to atmospheric and chemical degradation.[7]

Specimen preparation:

All the natural (flax, kenaf and sisal) fibre and carbon fibre were cut into 33*33mm dimension. Seven layers of natural fibre is to be combined with 4 layers of carbon fibre. The resin is mixed with the hardener of ratio 10:1 i.e., 1000ml resin is mixed with 100ml hardener to make one laminated panel.

Figure 2.1 cutting the fibre

Figure 2.2 Applying resin hardener

2.3 Fabrication technique:

Vacuum bagging

It is the technique employed to create mechanical pressure on laminate during its cure cycle. The consolidated material is placed on the mould. The material is covered with peel ply and breather fabric(provides an escape path for the evacuating air. Then the entire lay-up is then covered with vacuum bag and sealed around the edges apart from the connection to the vacuum pump. The pump is activated to suck all the air out of the spaces between the vacuum bag and the mould, causing the laminated composite to be consolidated under 1 bar pressure.[8]

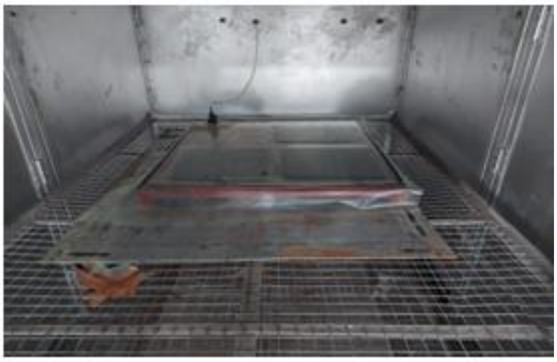


Figure 2.3 vacuum bagging technique

2.4 Stacking sequence of the materials:

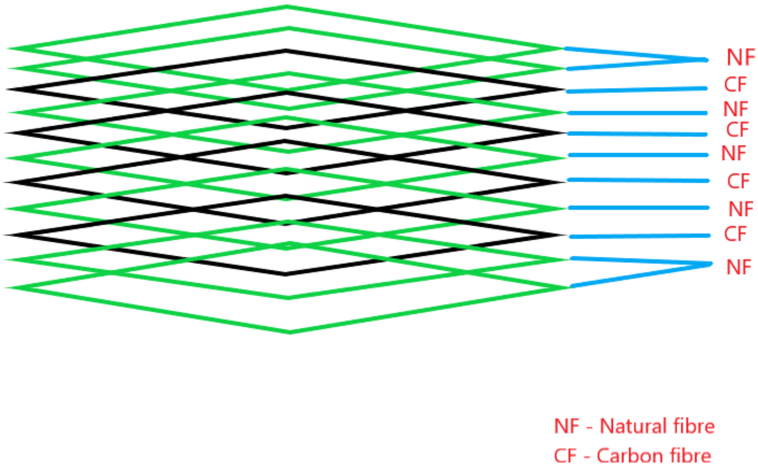


Figure 2.4 sequence of the materials

3. Experimental procedure:

3.1 Water absorption test:

The water absorption test is carried out to determine the amount of water absorbed during the test period. Three types of water have been used for the testing namely distilled, sea and normal water. Natural fibre has the nature of absorbing large amount of water due to its nano scaled cellulosic fibres, so that water absorption test is carried out to analyse the amount of water absorbed. The specimen dimension for the water absorption test is 1*1cm for flax, sisal and 2*2 for kenaf of totally 27 specimens (flax-9, sisal-9 and kenaf-9) are made to cut. The prepared composite specimen is immersed in distilled water, sea and normal water at room temperature for ten days. Then the specimen taken out from the water and wiped with the cotton. Then the specimens are dried in normal room temperature for 1 hour and again weighed.

Percentage of water absorption = (Weight of the wet specimen – Weight of the dry specimen)/Weight of the dry specimen) * 100

Therefore, the moisture absorption capacity is determined by the weight difference.[9]

3.2 Tensile test:

Tensile testing properties of ASTM D3039 is used to determine the force needed to break the composite specimen at some extent to which it extends, elongates or stretches to that breaking point. Tensile tests produce the stress-strain diagram to find the tensile modulus. The data is used to specify the materials, to withstand the application force and quality control check of the materials. Specimens are placed in the grips of a Universal testing machine at a specified grip specimenand then its pulled unit failure. The typical speed of testing the specimen for ASTM D3039is 2mm/min.The tensile test is used to determine ultimate tensile strength, yield strength, young's modulus, ductility and poisson's ratio.[10]

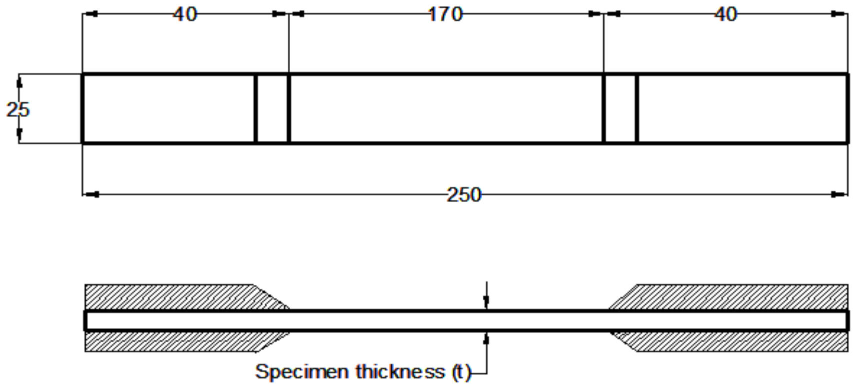


Figure 3.1 Tensile test properties

3.3Flexural test:

The purpose of flexural test is to determine the flexural strength and flexural modulus. The composite specimen is laid horizontally over two point of contacts then the force is applied on top of the material till the material breaks. Flexural strength is defined as the maximum stress at the outermost fibre on either the compression or tension side of the specimen. By flexural testing we can be able to measure the force required to bend a beam of plastic material and determines the resistance to flexing or stiffness of a material.[11]

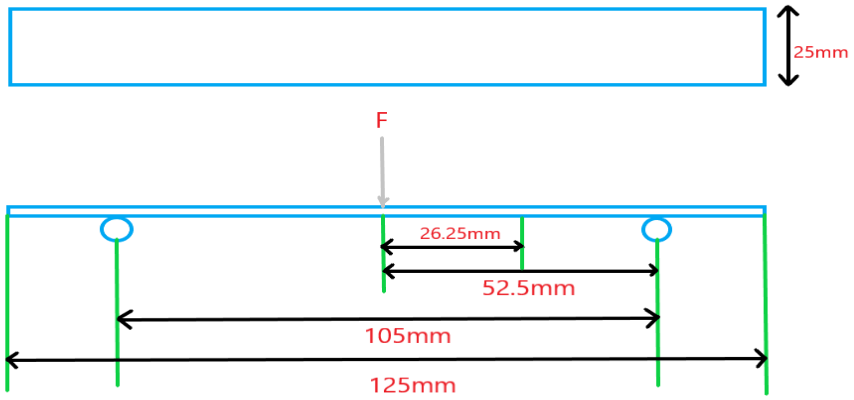
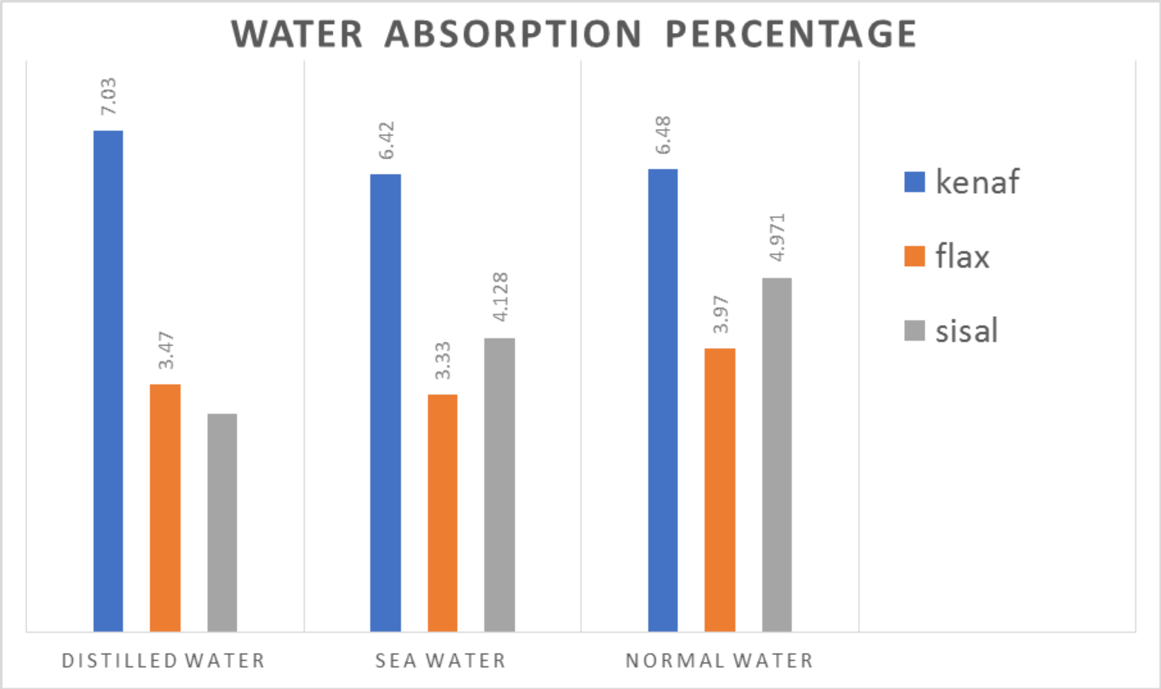


Figure 3.2 Flexural test properties

4. Result & Discussion:

4.1 Water absorption test

Sample	Dry weight sample (average value)	Distilled water tested sample (average value)	Dry weight sample (average value)	Sea water tested sample (average value)	Dry weight sample (average value)	Normal water tested sample (average value)
Kenaf	7.599	8.113	7.796	8.286	6.02	6.41
Flax	1.73	1.79	1.744	1.802	1.736	1.805
Sisal	1.636	1.686	1.623	1.69	1.73	1.816



The amount of water absorbed by the specimen is depicted clearly on the bar graph which holds the information of the three different types of hybrid composite specimen namely flax, sisal and kenaf been immersed in three different types water namely distilled, sea and normal water for ten days. The natural fibre has the tendency of absorbing more amount of water due to is nano cellulosic fibrous molecules in it, so that we are going to find how much water is absorbed by total of nine specimen (flax-9, sisal-9, kenaf-9). From the graph we can find that the specimen tested under distilled water, kenaf has absorbed the 7% of water and which is the highest water absorbed specimen among flax and sisal i.e., the dry weight sample is 7.599 and the wet weight sample is about 8.113, followed by kenaf flax has absorbed 3.5% of water – the dry weight sample is 1.73 and wet weight sample is 1.79. The least water absorbed specimen is sisal of 3% - the dry weight sample is 1.636 and wet weight sample is 1.686. The sea water samples determine the moderate amount of water adsorption namely alike previous distilled water, kenaf has the highest percentage of 6.5- the dry weight sample is 7.796 and wet weight sample is 8.286. Then sisal has absorbed 4% of water – dry weight sample is 1.623 and wet weight sample is 1.691 respectively. Followed by sisal flax has 3% of water absorbed specimen- dry weight sample is 1.744 and wet weight sample is 1.802. Finally, the normal waterabsorption percentage reveals that as usual kenaf has absorbed the more amount of water than the other specimen about 6.5% followed by sisal of 5% and least absorption of water is flax of 4%.

From the above plot, we can identify that flax has the lowest percentage of water absorption in it, therefore **flax** suits for the purpose of utilizing it for aviation industry as it partially fulfils the requirements necessary.

4.2 Tensile test plot:

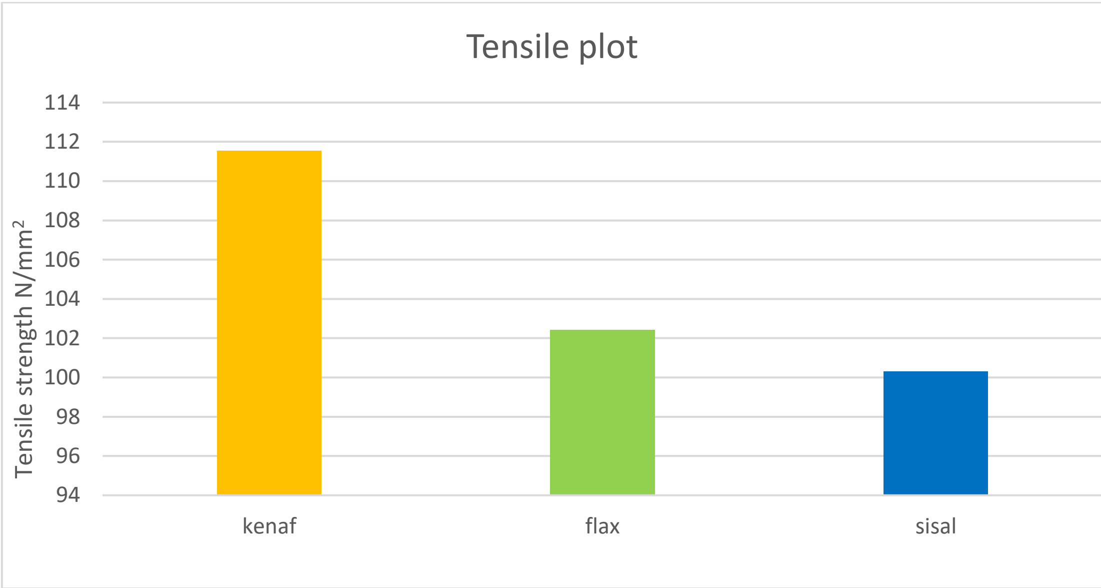


Figure 4.1 Tensile test bar graph

From the above graph kenaf has the higher tensile strength than flax and sisal. The technique undertaken to fabricate the specimen is vacuum bagging which is one of the current reliable process for making composite materials. Therefore, kenaf is the suitable material for aviation industry.

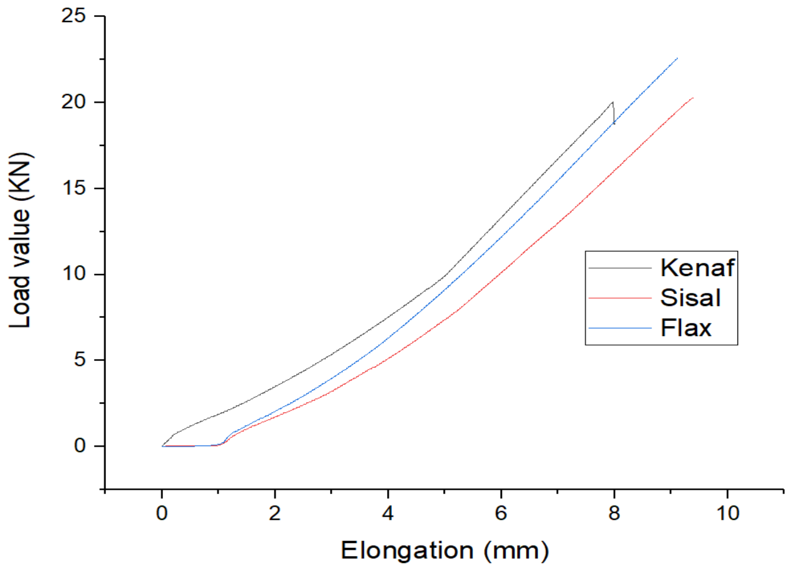


Figure 4.2 Tensile plot

The above tensile graph depicts that the ultimate tensile strength of kenaf, flax and sisal are meted at the point where exactly the breakage of the material occurs after finding the stress and strain values the data is taken for each specimen and make as stress v/s strain tabulations and stress v/s strain graphs are plotted by taking strain in x- axis and stress in y – axis. The Standard deviation of each sample type is taken to find the average of 3 specimens of same sample type namely flax, kenaf and sisal. For the Sample a data calculation the average values were taken and plotted which shows the virgin properties without any fillers.

4.3 Flexural test plot:

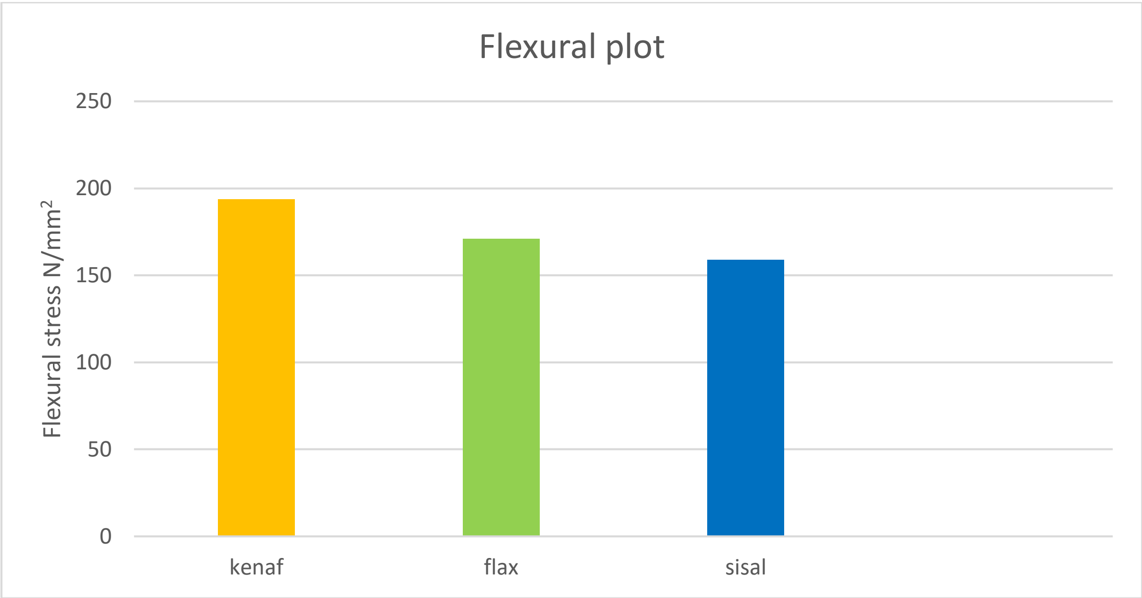


Figure 4.3 Flexural bar plot

From the above graph kenaf has the higher flexural stress than flax and sisal. The technique undertaken to fabricate the specimen is vacuum bagging which is one of the current reliable process for making composite materials. Therefore, kenaf is the suitable material for aviation industry.

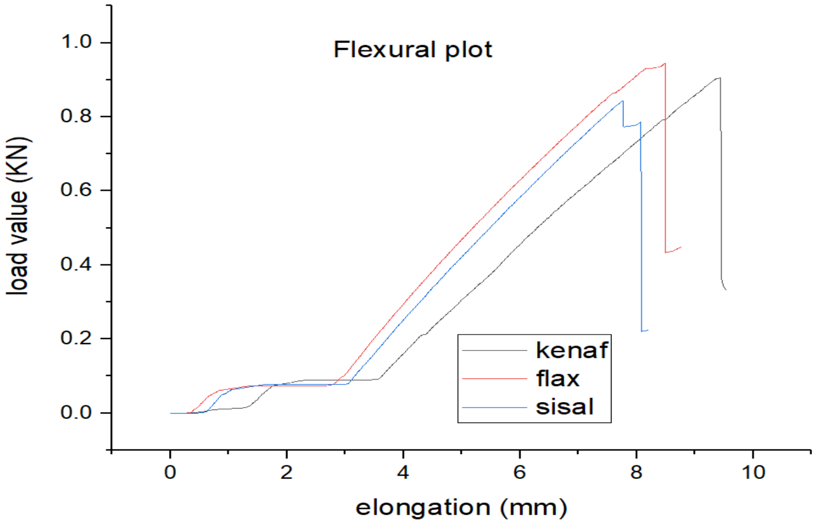


Figure 4.4 Flexural plot

From the above graph the load versus elongation curve of the respective three kind of hybrid composite graph has been plotted to show which hybrid composite has the better values of flexural stress. On the off chance that the bend has no direct locale, a secant line is fitted to the bend to decide slant. The 3-point flexure test is the most widely recognized for polymers. Example redirection is normally estimated by the crosshead position. Test outcomes incorporate flexural strength and flexural modulus. Therefore, there is no variation increase of the length of the curve as it seems to be perfect load value and elongation curve. After some point of the stress is directly proportional to the strain.

5. Concluion:

- The natural and carbon(hybrid) composite will be a futuristic smart material in aerospace industry
- The tensile flexural tested specimen determines the amount of load it can withstand at the peak load one in stretching process and other one is bending type.

- Vacuum bagging process ensures that prevention of thickening of composite specimen
- Because of its wide scope of appropriateness in different businesses, it is significant to comprehend what components influence the properties of natural fibre built up composites

In future, support of composite materials should be possible to increment the load carrying limit. The work might be expanded by breaking down the erosion and warm safe of this material so that, it might discover more applications. By changing the kind of sap, the application might be stretched out to get ready biodegradable and eco agreeable composite materials for various applications.

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