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Experimental Investigation of Mechanical Properties of Kevlar/Kenaf/Jute Composite Laminates With And Without Alkali Treatment

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Abstract

Composites are selected primarily for maintaining relative stiffness, strength and are light weight for a component. This paper provides an analysis of hybrid composite laminate, which are alkali treated and non-alkali treated to differentiate the mechanical properties between them. The properties of the composite laminates also differ by various types of fabrication process used. This is verified by various mechanical tests performed. In this work, three individual fibers namely Kevlar, Kenaf and Jute are combined to form a hybrid composite laminate. Alkali treatment is done for a set of Kevlar, Kenaf and Jute as a surface treatment. Vacuum Infusion and Hand Layup technique are the process used for the fabrication of composite laminates. Tensile, Flexural and Charpy are the tests done to determine the mechanical properties of composite laminates. The final outcome of the work describes that the Kevlar/Jute/Kenaf/Kevlar/Jute/Kenaf/Kevlar/Jute/Kenaf/Kevlar/Jute/Kenaf of the composite laminate possess higher Flexural and Impact strength when compared to Kevlar/Kenaf/Jute/Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/Kevlar/Kenaf/Jute. The alkali treatment also helps out in advancing the tensile properties..

Keywords: Alkali treatment, Kenaf fiber, Kevlar fiber, Jute fiber, Hybrid Composites

1. Introduction

In the current context of conserving natural resources and energy, composites play an important role in replacing the raw materials for industrial uses. Composites maintain similar mechanical properties, i.e., Compression, Flexural and Impact properties when compared to raw materials, which makes them as a viable replacement in the industries. Fibers such as Bio-degradable can be used in industrial applications such as components of automobiles, insulating panels, doors and windows for aerospace etc. But using individual fibers makes the composite structurally weak when compared to usage of raw material. This problem can be overcome by hybridizing different individual natural composite fibers with synthetic. The lower mechanical properties and disadvantages of using individual composite fibers as materials can be solved through hybridization of the composite fibers. Usage of complete natural fibers in the industry can be environmentally friendly, but this results to decrease in mechanical properties when compared to raw materials. Synthetic fibers help in drastically increase in mechanical properties when fused with natural fibers. This has a least amount of effect in environment.

1.1 Techniques

Alkali treatment is the process in which the fibers are treated with strong based concentrated aqueous solution which causes in swelling of fiber, cellular rearrangement, surface cleaning of composite fiber resulting in better structure, mechanical properties and dimension. There are many chemical agents used to alkali treat composite fibers but NaOH is the most commonly used chemical for the surface treatment of the fibers.

Fabrication is the process of stacking different types of composite fiber into laminates. This unites the mechanical properties of composite fibers into one. There are various types of fabrication process used in the industry. This paper mainly focuses on vacuum infusion and hand layup method. Vacuum infusion is the most used process in the industries. This process provides some advantages compared to other fabrication methods such as light in weight, effective bonding between fiber and resin etc.

Two or more composite fibres are arranged in a sequence to form a composite laminate. The selected composite fibres with different stacking sequence, helps to vary the difference between mechanical properties of composite laminates

2. Materials

Selection of materials is done by referencing the literature survey and the materials were collected in prior to the initial stage of the work. The required materials such as fibers, resins, hardeners and chemicals were bought as per the requirements.

FIBERS	Kevlar (200gsm), Kenaf (400gsm), Jute (400gsm)
RESIN	LY556
HARDENER	HY951
CHEMICAL	NaOH Palettes

Table 2.1 (Required materials)

Along with these major materials mylar sheet, wax, vacuum consumables like sealant tape, vacuum bag, breather, peeler ply were bought to perform the fabrication process.

2.1 Kevlar

Kevlar belongs to the aramid polymer fiber with good properties like light weight, strong, resistance to heat and toughness. there are two different types of Kevlar used low stiffness Kevlar (Kevlar 29) and high stiffness Kevlar (Kevlar 39). These fibers also have a very high impact resistance property. It is advantageous to use this material in ballistic a body Armor application. It is also known for the high elongation to failure property. The disadvantage of Kevlar is it is difficult to cut and drill. So special tools and scissors were used to cut the material. The Kevlar with 200gsm is used in this project.

Figure 2.1 (Kevlar)

2.2 Jute

Jute is one of the least expensive natural fibers, and second only to cotton in its production and various uses. Jute fibers are made mainly of plant material from cellulose. It has the ability to withstand torsional vibration after impact. Jute is also widely available and the benefits of natural fiber such as strong and low density. Jute has some unique features such as low heat conduction and healing humility which makes it easy to use.

Figure 2.2 (Jute)

2.3 Kenaf

Kenaf is one of the allied fibers of jute and exhibits similar features. The kenaf fiber is furnished with good mechanical properties such as tensile, lightweight and eco-friendly polymer composites. The Kenaf reinforced polymer composites performance is affected by several factors such as chemical treatment. Kenaf fiber can be used instead of synthetic fiber in many industrial applications.

Figure 2.3 (Kenaf)

3. Alkali Treatment

The fibers were washed with tap water to remove impurities and unwanted particles and allowed to dry under direct sunlight for two days. After drying, all of these fibers were treated with a NaOH solution. Initially, 10L water is heated to 40°C and 500gm NaOH pallets are added to the water. The complete solution was mechanically reinforced so that the NaOH pallets melted completely. Fibers were then added to the solution and treated by heating the solution to 40°C. It was noted that with the addition of natural fibers, the temperature increased by 8-10°C due to the exothermic reaction that occurred. The fibers were stored in an alkaline treatment for 1 hour and then neutralized tap water. The fibers were allowed to dry in direct sunlight for two days until completely dry. Alkaline treatment disrupts the crystalline region in cellulose allowing the fiber to swell. After alkaline treatment, natural bending cellulose would convert to a straight and higher thermodynamic stability.

Figure 3.1 (NaOH Solution)

4. Fabrication

The process of molding the resin and reinforcement material to form a composite laminate is called fabrication. At present, there are numerous fabrication techniques used by the industry for production of composite components. This project uses Vacuum Infusion and Hand Layup techniques for fabrication of composite fibers.

4.1 Vacuum Infusion

Most of the fabricators use Vacuum Infusion technique which involves in adding a plastic sheet sealing the layers using sealant tape and adding one or more ports for suction of air and excess resin. The vacuum infusion Process is a process that uses pressure to exit to drive the resin into a laminate. Dry materials are applied to the mold and vacuum is used before resin is introduced. Packing the bag greatly improves the fiber-to-resin ratio, and leads to a stronger and lighter product. This technique helps in creating a good bond between the fiber and resin. Even though the thickness is low the compared to hand layup it produces a final product with higher strength and lighter in weight.

Figure 3.2 (Vacuum Infusion Method)

4.2 Hand Layup

The very basic method and old for fabricating the composites is Hand-Layup which is done by placing the composite fibers one on another by adding resin in between them. Then the layers are debulked using a roller by hand. This process requires professional to get a good finished product. For a cleaner surface, pigmented gel coat is used to remove stickiness between composites and surface. Remaining consumable are also used such as Mylar sheet and brush.

Figure 3.3 (Hand Layup)

5. Experimental Procedure

5.1 Alkali Treatment

The fibres required for laminate undergoes alkali treatment and are fabricated in to laminate using Vacuum Infusion technique. The fibres are fabricated into laminates in the order mentioned above. Then, the resin and hardener were taken in the ratio of 10:1 for fabrication i.e., 10gm of hardener is used for 100gm of resin.

Before applying the first layer make sure that the mould is cleaned. Then the layer of peeler ply is placed on the mould in order to ensure that the laminate doesn’t comes in contact with the mould. Then the fiber layer placed according to the order by adding resin and hardener mixture between them. Then the layer of breather and layer of peeler ply is added on the top most layer. Then sealant tape is applied around the laminate and layer of plastic bag is attached to the tape ensuring that every edge sealed properly and port for suction of air and resin is allotted. Now the Vacuum pump is connected to laminate from the suction port and the motor is switched ON. Then the air present inside the laminate is sucked out by creating the vacuum, excess resin present inside the laminate is sucked out making sure that every layer is bonded to each other equally.

Figure 5.1 (Alkali Treated Panel)

5.2 Non-Alkali Treatment

The fibers required for laminate does not undergo alkali treatment and are fabricated in to laminate using Vacuum Infusion technique. The fibres are fabricated into laminates in the order mentioned above. Then, the resin and hardener were taken in the ratio of 10:1 for fabrication i.e., 10gm of hardener is used for 100gm of resin.

Before applying the first layer make sure that the mould is cleaned. Then the layer of peeler ply is placed on the mould in order to ensure that the laminate doesn't comes in contact with the mould. Then the fibre layer placed according to the order by adding resin and hardener mixture between them. Then the layer of breather and layer of peeler ply is added on the top most layer. Then sealant tape is applied around the laminate and layer of plastic bag is attached to the tape ensuring that every edge sealed properly and port for suction of air and resin is allotted. Now the Vacuum pump is connected to laminate from the suction port and the motor is switched ON. Then the air present inside the laminate is sucked out by creating the vacuum, excess resin present inside the laminate is sucked out making sure that every layer is bonded to each other equally.

Figure 5.2 (Non-Alkali Treated Panel)

6. Testing

6.1 Flexural Test

This test is performed on the composite in order to determine the flexural strength or modulus. This test helps to find out the bending resistance of any beam made with any material. This can be measured by flex modulus which measures the level of bend before deformation. The material to be tested is placed horizontally with a two-point contact, a force is applied on top centre of the material until the material breaks. The maximum value will be recorded.

Specimen Dimensions: 150mm*25mm (ASTM D 790)

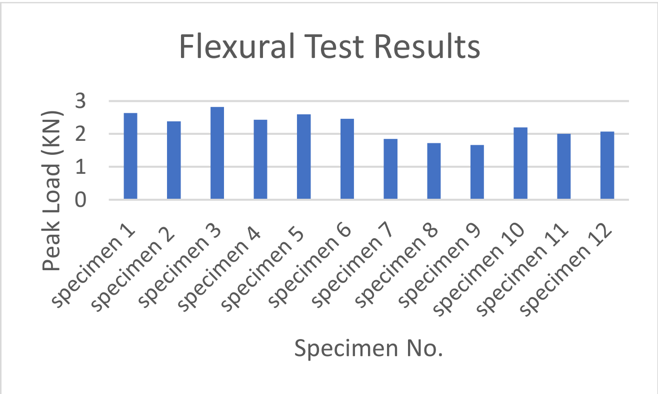
Figure 6.1 (Flexural Test)

Figure 6.2 (Specimen after Flexural Test)

SPECIMEN NO.	ALKALI TREATMENT	STACKING ORDER	PEAK LOAD VALUE
1	Alkali Treated	Kevlar/Jute/Kenaf / Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf	2.632 KN
2	Alkali Treated	Kevlar/Jute/Kenaf / Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf	2.385 KN
3	Alkali Treated	Kevlar/Jute/Kenaf / Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf	2.822 KN
4	Alkali Treated	Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute	2.436 KN
5	Alkali Treated	Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute	2.600 KN
6	Alkali Treated	Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute	2.466 KN

7	Non-Alkali Treated	Kevlar/Jute/Kenaf / Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf	1.852 KN
8	Non-Alkali Treated	Kevlar/Jute/Kenaf / Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf	1.725 KN
9	Non-Alkali Treated	Kevlar/Jute/Kenaf / Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf	1.665 KN
10	Non-Alkali Treated	Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute	2.199 KN
11	Non-Alkali Treated	Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute	2.003 KN
12	Non-Alkali Treated	Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute	2.072 KN

Table 6.1 (Flexural Test Results)



6.2 Tensile Test

Tensile test is also known as tension test. This test applies tensile force to a material and measures the specimen’s response to stress. It also determines how strong the specimen and also how much it can elongate. This test is conducted on **Universal Testing Machine.** The main use of this test is we can obtain a complete profile of its tensile properties. When we plot a graph, we can obtain a graph between stress vs strain which shows how the material reacted to the forces being applied. The test specimen will be placed in the testing machine and slowly extending until it fractures.

Specimen Dimension: 250mm*25mm (ASTM D 3039)

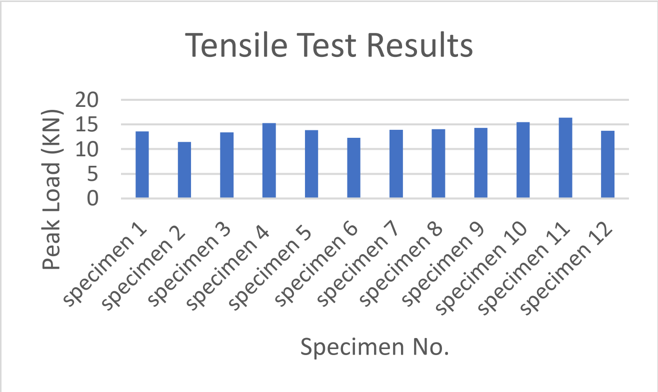
Figure 6.3 (Tensile Test)

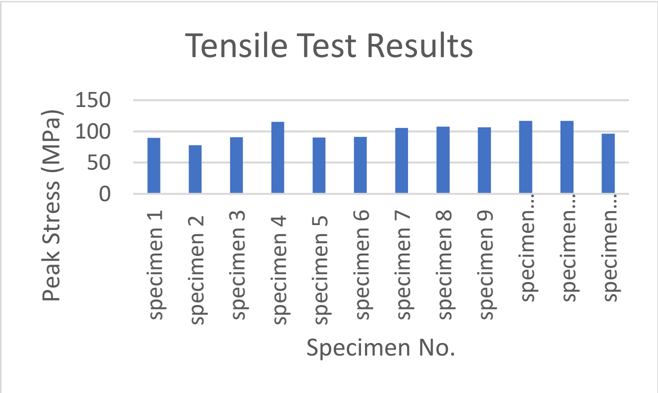
Figure 6.4 (Specimen after Tensile Test)

SPECIMEN NO.	ALKALI TREATMENT	STACKING ORDER	PEAK LOAD (KN)	PEAK STRESS (Mpa)
1	Alkali Treated	Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf	13.597	89.61
2	Alkali Treated	Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf	11.469	77.7
3	Alkali Treated	Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf	13.372	90.76
4	Alkali Treated	Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute	15.292	115.5
5	Alkali Treated	Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute	13.844	90.37
6	Alkali Treated	Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute	12.308	91.37
7	Non-Alkali	Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/	13.923	105.72

	Treated	Kevlar/Jute/Kenaf		
8	Non-Alkali Treated	Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf	14.044	107.82
9	Non-Alkali Treated	Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf/ Kevlar/Jute/Kenaf	14.281	106.66
10	Non-Alkali Treated	Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute	15.501	116.75
11	Non-Alkali Treated	Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute	16.377	116.63
12	Non-Alkali Treated	Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute/ Kevlar/Kenaf/Jute	13.720	96.55

Table 6.2 (Tensile Test Results)





6.3 Charpy Test

The Charpy impact test, also known as the Charpy V-notch test, is a high-performance test made to find out the impact resistance of the material. A simple pendulum is swung horizontally toward the vertically placed V-notched specimen. Impact assessment helps to measure the amount of energy absorbed by the sample during the failure.

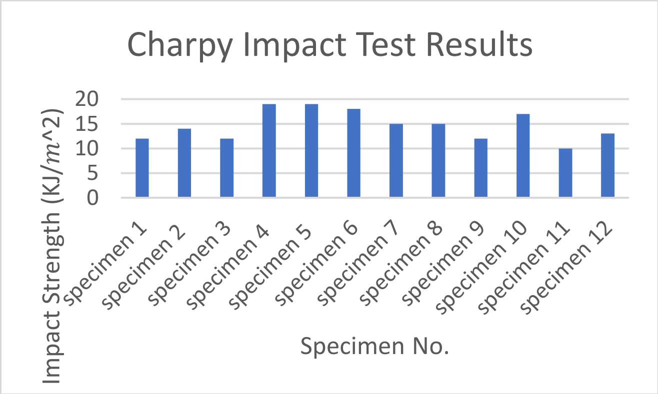
Specimen Dimension: 55*10*3 mm (ASTM D 6110)

Figure 6.5 (Charpy Test)

Figure 6.6 (Charpy Test)

SAMPLE ID	TESTED PARAMETER	OBSERVED VALUES
I1	Charpy Impact Test	12
I2	Charpy Impact Test	14
I3	Charpy Impact Test	12
I4	Charpy Impact Test	19
I5	Charpy Impact Test	19
I6	Charpy Impact Test	18
I7	Charpy Impact Test	15

I8	Charpy Impact Test	15
I9	Charpy Impact Test	12
I10	Charpy Impact Test	17
I11	Charpy Impact Test	10
I12	Charpy Impact Test	13



7. Results

7.1 Flexural Test

Graphical value is noted for KEVLAR/KENAF/JUTE composites individually after completing Flexural test. These obtained results are used to compare the difference between alkali treated and non-alkali treated composite laminates.

With the help of the maximum load by the specimens during Flexural test, Flexural strength of each specimen is calculated.

The average Flexural Strength for each panel is:

- Panel 1: 2.613 KN
- Panel 2: 2.500 KN
- Panel 3: 1.747 KN
- Panel 4: 2.090 KN

7.2 Tensile Test

Graphical value is noted for KEVLAR/KENAF/JUTE composites individually after completing Tensile test. These obtained results are used to compare the difference between alkali treated and non-alkali treated composite laminates.

With the help of the maximum load by the specimens during Tensile test, Tensile strength of each specimen is calculated.

The average Tensile Strength for each panel is:

- PANEL 1
  - PEAK LOAD: 12.812 KN
  - PEAK STRESS: 86.02 Mpa

- PANEL 2
  - PEAK LOAD: 13.814 KN
  - PEAK STRESS: 99.08 Mpa
- PANEL 3
  - PEAK LOAD: 14.071 KN
  - PEAK STRESS: 106.73 Mpa
- PANEL 4
  - PEAK LOAD: 15.199 KN
  - PEAK STRESS: 109.97 Mpa

7.3 Charpy Test

Graphical value is noted for KEVLAR/KENAF/JUTE composites individually after completing Charpy Impact test. These obtained results are used to compare the difference between alkali treated and non-alkali treated composite laminates.

With the help of the maximum load by the specimens during Charpy Impact test, Impact strength of each specimen is calculated.

The average Impact Strength for each panel is:

- Panel 1: 12.66 KJ/m^2
- Panel 2: 18.66 KJ/m^2
- Panel 3: 14.00 KJ/m^2
- Panel 4: 13.33 KJ/m^2

8. Conclusion

To conclude from overall test results, 2nd Panel stacking order, Alkali treated and Vacuum Infusion as the fabrication process provides the best outcome. This is due to certain parameters such as, Alkali treatment, Stacking order. Alkali treatment is to improve the mechanical properties of composite laminates by cellular rearrangement. This process results with the addition of strong aqueous solution to the composite fibers to increase swelling which helps in change of mechanical properties, dimensions and morphology. this process involves in removing wax, lignin and oils covering the surface of the fibers. This treatment is also improved with the %wt ratio with different fibers. In this project alkali treatment is processed for and the result for mechanical properties are compared to the non-alkali processed panels.

Fabrication is the most important part in preparing the composite laminates with the help of resin and hardener. There are various techniques present for fabrication but in this project, Vacuum Infusion and Hand-Layup are the preferred fabrication techniques followed. This method of fabrication depicts the overall thickness and strength of the composite panel when fabricated.

The stacking sequence is defined as arrangement of fibers one above another with different orientation. The stacking sequence is interpreted from bottom to top, and the orientation angles are in general specified in degrees. In this project two types of stacking order followed.

ORDER 1:

KEVLAR/JUTE/KENAF/KEVLAR/JUTE/KENAF/KEVLAR/JUTE/KENAF/ KEVLAR/JUTE/KENAF

ORDER 2:

KEVLAR/KENAF/JUTE/KEVLAR/KENAF/JUTE/KEVLAR/KENAF/JUTE/ KEVLAR/KENAF/JUTE

By comparing the test results obtained, laminate with order 2 stacking sequence has better mechanical properties when compared to laminate with order 1.

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