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Assessment of Mechanical Properties of Kenaf - Kevlar Composites made by Hand Lay-up Technique

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Abstract

In recent days, composites are being replaced in various Industries including defense, aerospace and aircraft industries which produce materials of structural support with high specific strength and specific modulus. The new trend is natural fibre composites are replacing composites of synthetic fibre make for numerous applications in divergent engineering products because of low manufacturing cost and environmental friendly behaviour. By considering this, Kevlar based hybrid composite material is chosen as it includes prolonged life and best reliability nature. This research paper pays keen attention on production and performance assessment due to the impact of fibre orientation in particular mechanical behaviour on hybrid natural fibre composites using Kevlar and Kenaf fibres by hand lay-up process. This pilot research work confirms the essence of essentiality about produced Kenaf-Kevlar composites combat nature to its unique strategic applications like tyre plies and automotive parts.

1. Introduction

Meena gupta et al. [1], investigated about MRR, surface roughness (mR_a) correlating turning operation of UD-GFRD by Taguchi and PCA method using L18 orthogonal array experimental design. Principal Component Analysis is a great technique of practical importance in numerous statistical inference applications, from this research analysis; it's clear that the mR_a enhances with high feed rate. ¼ 0.2 of feed rate, ¼ 1.4 mm depth of cut and ¼ 159.66 m/min speed creates R_a as an optimum value. Roughness mR_a ¼ 1.498 mm and the optimum material removal rate MRR ¼ 330.267 mm3/s. From the research findings feed rate is pivotal factor other than cutting speed and depth of cut. R. Yahaya et al. [2], reported hybrid composites made of woven kenaf-Kevlar with the content of woven kenaf varies in volume fraction from 5.40 to 14.99 with two variant arrangements. The hybrid composites were examined by ballistic measurement approach through fragment simulating projectiles by varying residual and impact velocities. They conceived that concurrent research on hybrid composites with Kevlar/Kenaf combination will bring out new frontiers on research by the arrangement of optimum layer amalgamation of these two variant fibres to diminish the utilization of fibres of synthetic composition in composites. R. Yahaya, et al. [3], detailed on sequence of layers and analyzed about the mechanical properties relating to chemical treatment of hybrid laminated composites with kenaf–aramid combination by hand lay-up process by sequencing kenaf (woven) and fabrics of Kevlar in multiple varying layers arrangement with the usage of treated kenaf mat. For examining the hybrid composites relating to chemical treatment impact, the kenaf (woven) mat was allowed to treat with diluted 6% sodium hydroxide (NaOH) then the mechanical properties are measured with the comparison to non-treated Kenaf/Kevlar hybrid composites. The authors concluded that treated kenaf/Kevlar hybrid composites are superior in tensile and flexural properties performance than untreated Kenaf/Kevlar hybrid composites. The Kenaf/Kevlar combination fractured hybrid composites were examined through scanning electron microscopy. This research concluded with the potential application identification of prepared hybrid composites mainly for high velocity impact. Shilpa N. Raja et al. [4] explored about the Kevlar processing upto particular strength using hot-drawing fabrication process; which gain through perceptible empathetic interrelationship betwixt structural and mechanical properties for the time being of pre-drawing process. On hand, they utilized innovative monitoring through continuous dynamic analysis (CDA) in storage modulus and factor of loss for Kevlar 49 type fibres as strain function through quasi-static testing of tensile properties. They concluded the findings that Kevlar's storage modulus should necessarily be equivalent to Young's modulus, the systematic significant accord betwixt storage modulus and strain can cater observations for accommodating the aramid materials mechanical properties for unique applications. Thingujam Jackson Singh et al. [5] analyzed a review report of Kevlar type fibres and its composites. In concurrent time, the importance of utilizing fibre reinforced composites (FRCs) has enhanced because of its capability in restoration of conventional materials for numerous utilizations. The higher specific strength and modulus of Kevlar type fibres are its specific nature and that become most common reinforcement combination in composite materials appreciably. Yet, to have improvised properties in numerous utilizations a significant study is essential. Vishnu Prasad et al. [6] dealt FEA of hybrid polymer matrix composite comprising of banana and jute fibres as reinforcement and evaluated optimization of design parameters using ANOVA. In this research investigation, jute fibre a class of natural fibre was taken and fabricated by hand lay-up process. The behaviour of hybrid matrix composites at varying compositions is also analyzed. The FEA analysis software of commercial value namely, ANSYS is utilized for numerical study. The tensile behaviour of fabricated composites was examined through numerical and experimental investigation approach.

B.Ramesh et al. [7] investigated the standard impacts and geometrical unique arrangement in drill body trait logics and various conduct inflation in drilling laminated thick composites. The standard quality traits of composites are based on the impact of process parameters and unique geometry design of a body performing drill in operation during dry condition of drilling sheet moulding composites (SMC). SMC are commonly utilized for various applications such as automotive, structural and instrumental. The experiments pertaining to drilling operation by drills made of carbide were examined by Response Surface Methodology (RSM). This research proved that twist kind of geometry drill (standard geometry) excelled in performance than ratio kind of drill (special geometry). The process parameters of optimal levels were calculated; spindle speed of 750 RPM, feed as 0.074 mm/rev for standard geometry drill whereas spindle speed of 1250 RPM and 0.091 mm/rev for special geometry. Xin Sui et al. [8], produced safeguard from Kevlar type of fibres to protect atomic oxygen erosion through layer orientation of Nanocomposites. They evaluated vigilant MMT/PPAS combinational layer was hoarded successfully using layer-by-layer process of assembly as proved by scanning electron microscopy and Fourier-transform infrared spectroscopy. The durability of accelerated atomic oxygen (AO) was studied in a ground-based AO-effects reproduction dexterity. The outcome fair that the Kevlar type of fibres with multilayer arrangement contribute exceptional conservation from AO erosion. BAI Jiangbo et al. [9] utilized four different variants of samples to predict notched strength and fracture toughness by examining static tension and tear tests in MTS system relatively. The mechanisms of failure and damage are analyzed and evaluated tear resistance and notched strength results with each other’s comparison. By the experimental results, it’s clear that notch sensitivity pertaining to the film enhances with the whole size increases, yet the sensitivity of notch and concentration of stress in notch are infinitesimal and 4% to 10% of diminished tensile behaviour for notched samples with variant hole sizes in diameter are compared with unnotched sample. At last the fracture tendency and notch sensitivity of Kevlar have been examined.

2. Material and Methods

a. Kevlar

The ultimate development of organic fibres overspread 3 decennium has been the manufacturing by DuPont fibres of aromatic polyamide, on collective basis termed as aramids. In aramids, the favorite and commonly used for so long in composites industry is Kevlar. This type of polymer is depend on aligned diamine and intervenes of dibasic acid tether liquid of yield nature; crystalline solution in acid and amide solvent. Hence, by the process of wet spinning highly oriented fibers are manufactured and strength of Kevlar type poly fibers are in the order of 2.6 Gpa and 130 Gpa, based on the polymer chains alignment degree. These fibres are having properties intermediate betwixt glass and carbon; aramids support excess degree of flexibility in design of composites. One unique behaviour of fibre is that it’s quite tough enough to cut due to its fibrillar structure. The two unique methods namely; Laser and water-jet processes are necessary for frilling bare fabrics and composites. In concurrent situation Kevlar fibre has numerous applications, ranging from bicycle tyres and racing cycles to armor bodies due to its higher specific strength it’s five times stronger than steel on its equivalent weight. The other unique application is to modern drumheads with withstanding capacity of high impact. When this material is used as a woven material; its more opt for anchorage lines and many under water applications. Kevlar/Resin composites are significant due to its exceptional toughness property and impact damage resistance. The matrix of the composite is necessary to cater certain operations; predominant functions are significant for material’s performance. The catalyst for the particulate aggregate mere plays to maintain the mass of the composite in the form of solid, yet composites of fibre variant performs other functional varieties which needs to be applauded if the true nature of composite in understanding phase which predicts the mechanical properties of reinforced material.

b. Kenaf

Kenaf-Hibiscus cannabinus a scientific name of Malvaceae plant family. Hibiscus cannabinus plant native is southern Asia; although its original origin is unknown. The name of the fibre signifies the fibre extracted from this variant plant. Kenaf is one type of modified fibres from jute and exhibits similar nature. This is an annual or biennial plant of herbaceous species with short-lived perennial eco-family nature, grows upto 1.5m minimum and 3.5m maximum tall with the base of wood. There are no branched stems yet trunk tends to grow from 1-2 cm diameter. The leaves are in the length of 10-15cm, shape variant with leaves near stem base lobed deeply (3-7 lobes) while leaves the stem top near are lobed shallow or lanceolate unlobed. The flowers are white, purple and yellow colours with size of 8-15 cm diameter whereas in white or yellow have dark purple centre. The size of the fruit is 2 cm diameter with seeds. The fibres are identified in kenaf from bast (bark) and the core (wood). The bast region aggregates 40% of the entire plant. The multicellular fibre segregated from bast is “Crude Fibre” which constitutes a few of singular cells cemented together. The singular fibre cells are long and slender with 2-6mm size. The thick cell wall is of 6.3 µm. The core is plant’s 60% area has approx. 38 µm thick wall yet short 0.5 mm and 3 µm thin walled fibre cells. The pulp of paper is manufactured from whole stem and hence two variants of fibres; bast and the core. The quality of the pulp is similar to hardwood.

c. Composites – Manufacturing

The Kevlar and kenaf fiber reinforced hybrid composite laminates are produced through the hand moulding process and then applying pressure, using the compression molding machine. A typical representation of hand layup technique is shown in Fig.1. At first the fibers are hot sun dried for more than 48 hours before processing, to remove the moisture. For the entire specimen, the natural fibers and synthetic fibers are stacked alternatively.

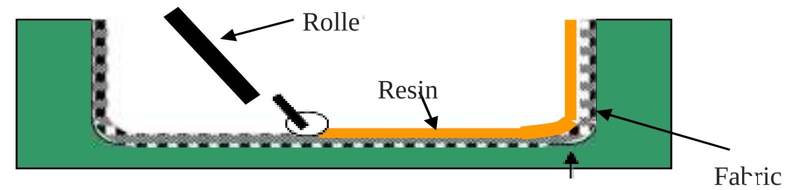

Figure 1 - Hand lay-up technique

Here five layers of fibers are stacked as follows; the first layer kept at the bottom is a woven roving mat of Kevlar fiber followed by a layer of perfectly processed natural fiber of kenaf. While stacking up fibres in layers, a mixture of resin epoxy and the hardener is exercised completely upon fibers. Then resin is exercised, after which roller is rolled over the fibers to bundle and increase the affinity betwixt the Kevlar fiber, natural fiber and the resin. With the roller rolling up-on the manufacturing process aids in eradicating the pockets of air or bubbles created between fibers which provide good outputs in surface finish of the fabricated composites. This process of laying up the fibers and exercising resin are alternatively done upto maximum five layers of stacking fibers into the mould. The first, third and fifth layers contains Kevlar fibers and then the second and fourth layers contains kenaf fibers. Completely fabricated composite laminate process is represented in Fig. 1. The entire assembly is pressed at 60 °C temperature and kept under dead weight compression for 8 hours, and then the composite gets cooled at room temperature and normal pressure. Then the composite laminates are removed from the mould and the thickness of the prepared composite sample was 5mm. Likewise 4 composite samples with different compositions and they are represented in short form as S1, S2, S3, S4 listed below.

1. 90% Kenaf + 10% Kevlar – Sample 1, (S1)
2. 80% Kenaf + 20% Kevlar – Sample 2, (S2)
3. 70% Kenaf + 30% Kevlar – Sample 3, (S3)
4. 60% Kenaf + 40% Kevlar – Sample 4, (S4)

3. Results and Discussion

Tensile Properties bar chart (Fig.2**)** predicts the amount of force required to break a composite sample and the limit of the sample; whether it stretches to the breakeven point. These methods of tests are application of stress over particular zone of the material and observe its response curve to this impact of load. The scientific symbolic representation of stress (S) is the load (P) on particular weight (P) on the entire body disseminates all around the area of that particular body, $S = \frac{P}{A}$. The tensile properties of fabricated composite samples are in the below Fig.2. The results shows that F_{max} (KN) slightly increases with the reinforcement increase from S1 (10% = 1.74 KN) to S4 (40%=2.78 KN). The maximum Ultimate tensile strength (UTS) value of fabricated composites samples is correspondingly higher in sample, S4 = 24.35 Mpa. S4 Tensile sample SEM image evidences ductile fracture nature.

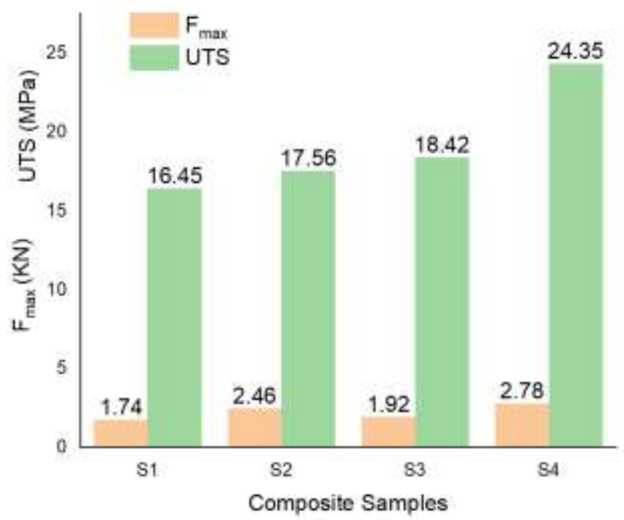

Figure.2 – Tensile Properties of Composite Samples – F_{max} (KN) & UTS (Mpa)

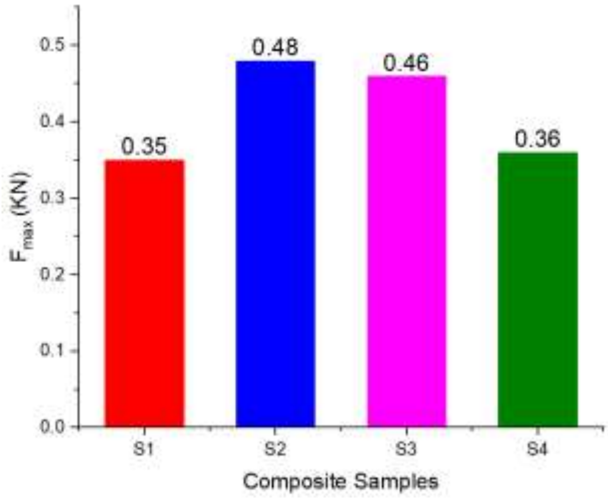

Figure.3 – Flexural Properties of Composite Samples – F_{max} (KN)

Flexural properties graph (Fig.3**)** predicts the necessary force mandate for beam bending at 3 point load conditions. This research study often proves the selection of materials for specific parts that needs to withstand at load conditions without flexing nature. Flexural modulus is notification factor about stiffness of the material during flexing condition. Based on the ambient temperature; varying physical nature of numerous materials in particular thermoplastics, in some occasion opt for materials testing at simulating temperatures with intended environmental usage. From the above Fig.3 the maximum F_{max} observed at sample S2 = 0.48 Mpa. Flexural sample SEM image also evidences ductile fracture nature of the material.

Double Shear curve (Fig.4**)** states when two parallel opposite forces acts in either direction opposing, which influence to deliver one part sliding with the respect to other part of the body. Latch's & screws such as rivets, bolts and pins are some of the functional exact to shear concentration in stress; in excess shearing operations such as punches create shear stress. As like tensile and compression testing the results are not so precise in shear test; it slightly varies because of additional introduction of bending forces and friction in the process of testing. On shear tests often flat stock are used in single or double shear process whereas round stock is mostly preferred in testing double shear. In testing using double shear the utilizable area is twice that the area of cross-section. As in the graph, the observed bread even load value is 7.180 KN, the corresponding displacement y = 15.500 mm at F_{max} which is also an observed maximum displacement for the area of 42,750 mm^2 for the sample S4.

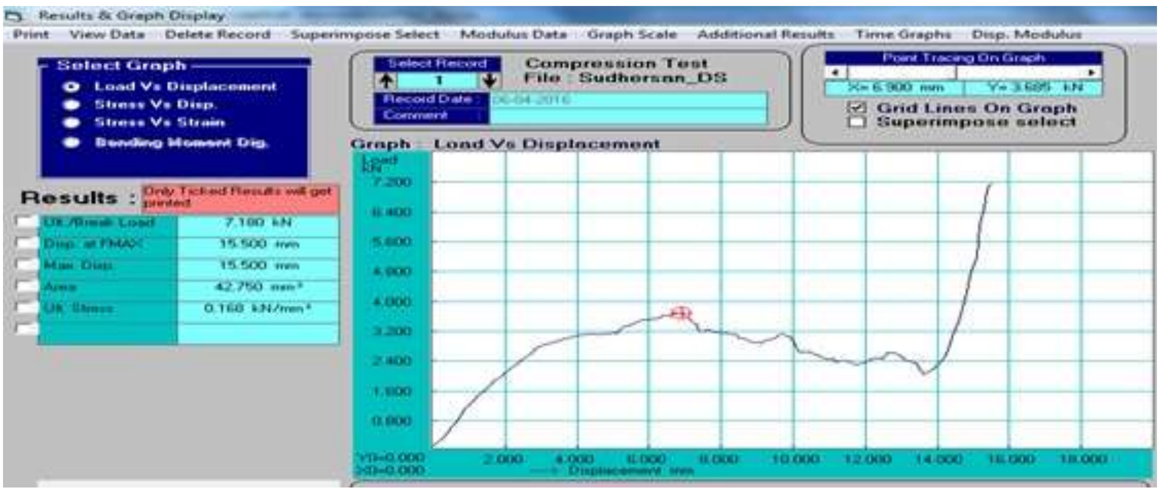

Figure. 4 – Double Shear test – graph – load vs. displacement

Impact Graph (Fig.5) depicts to predict toughness, load-deflection plots and total energy absorption of impact events because speed can be varied to simulate actual impact values at high speed. This lavish test machine gives full force and curves of energy while the impact millisecond using "TUP" which has impact head and load cell. The data is often used to specify appropriate materials for applications involving impact. The test is also used to evaluate the effect of secondary finishing operations or other environmental factors on plastic impact properties. Obtained maximum Impact value = 10 Joules at S3 sample

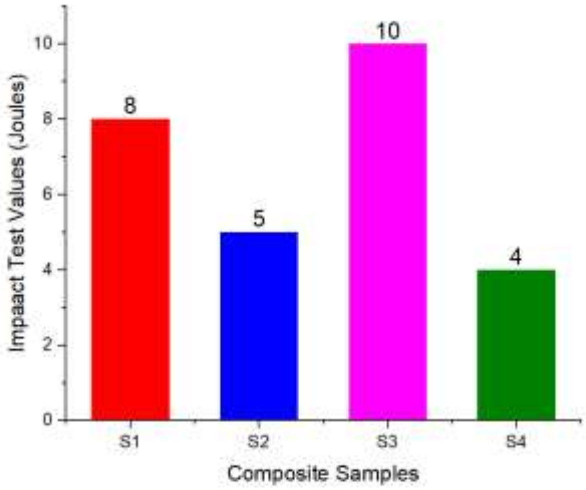

Figure.5 – Impact Test Properties of Composite Samples – F_{max} (KN)

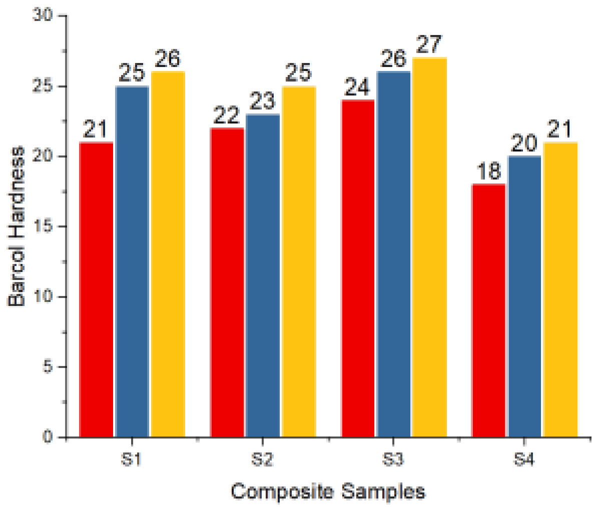

Figure.6 – Hardness Test properties of Composite Values

Barcol Hardness plot (Fig.6) is the prepared composite material's resistance to the permanent dent. It is unique to acknowledge that hardness as factual test and hence it can never be disclosed as material property. So it's a test method based on every test result have a label identifying the use of test method like Brinell, Rockwell, Barcol. Hardness is most commonly used to categorize materials for the suitable intended application. The various hardness tests notified in this section utilize specific indenter of necessary shape. This should be unique harder than the composite samples to be tested on to the sample surface by targeted force. Anyone either depth or indent size is calculated to predict the hardness value. Among all the four composite samples S3 (24,26,27) stands unique in the bar chart than the other three composition at all three averages of different indentations.

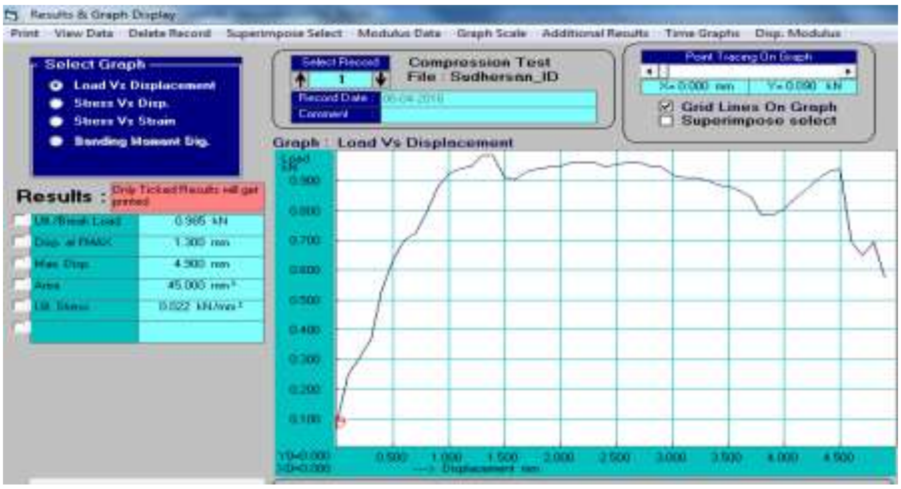

Figure.5 – De-lamination test – graph – load vs. displacement

De-Lamination Test (Fig.5**)** examines the prediction of resistance to peel of bonds in adhesive nature bonds betwixt approximately malleable adherent and proportionately adjusting revetment of hoagie structure and its core. When proportionately a adhesive with brittle behaviour is utilized; the resistance to peel shall notify commonly the cure degree which is higher than normal be understood to notify an inadequate cure. This test implicates a calculation to predict the laminate's bond strength to a material of substrate. This is much equivalent to the applied load of tensile nature divided by width of the sample by measuring sample's thickness. The observed UR stress is 0.022 KN/mm^2 which is in proportion to displacement of 1.300 mm (min.) to 4.900 mm (max.) for 45.000 mm^2.

SEM Test (Fig.6) To predict the study of Kevlar composite sample the scanning electron microscopy (SEM) utilized and prepared to the dimension of 1*1 to differentiating micron meter level of SEM machine and this below results depicts cracks, blow holes formed in composite sample. The SEM images represent fiber particles dispersion in composite specimen with different composition of multi tested composite samples to analyze clear distribution of fibres and damages in composite samples by hand lay-up process or hand moulding technique. The tensile fracture image (figures 6.a and 6.b) shown is a pull fracture condition. The figure 6.b was shown, a pull load failure. The image shown is a ductile type of fracture.

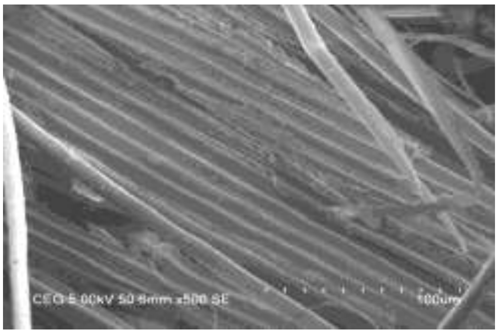

Figure.6.a – 100 µm tensile test

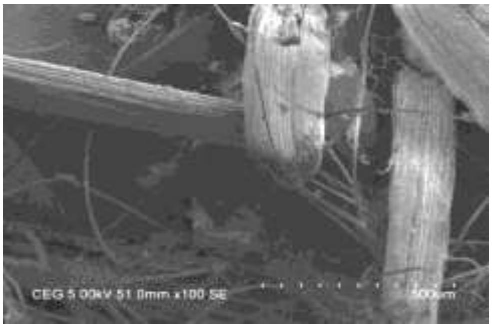

Figure.6.b – 500 µm tensile test

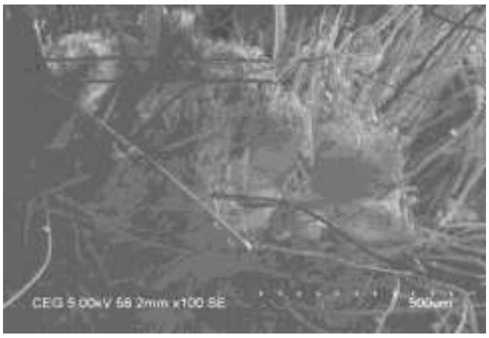

Figure.6.c – 500 µm impact test

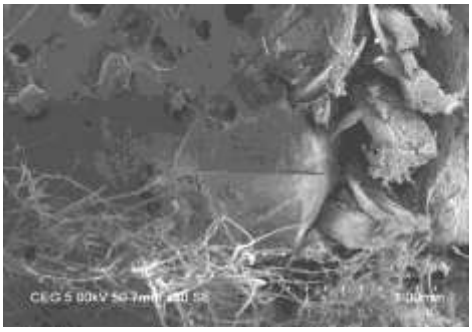

Figure.6.d – 100 µm impact test

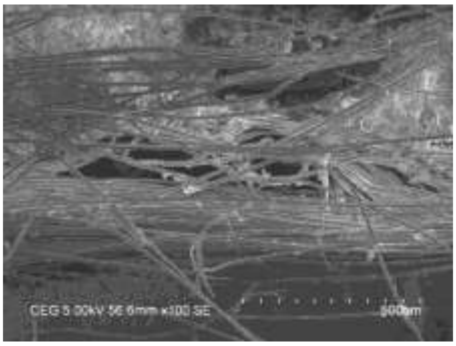

Figure.6 e – 500 µm Flexural test

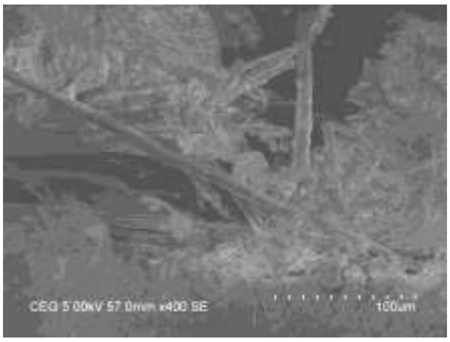

Figure.6.f – 100 µm Flexural test

Figure.6.g – 500 µm de-lamination test

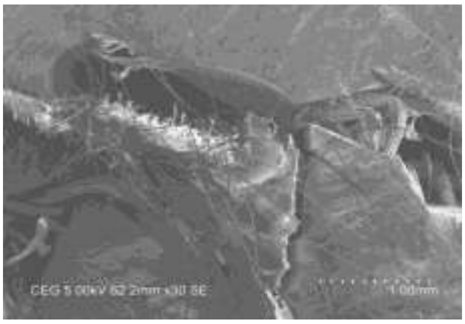

Figure.6 h – 100 µm de-lamination test

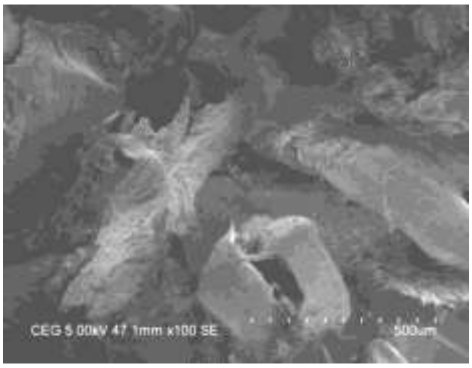

Figure.6.i – 500 µm double shear test

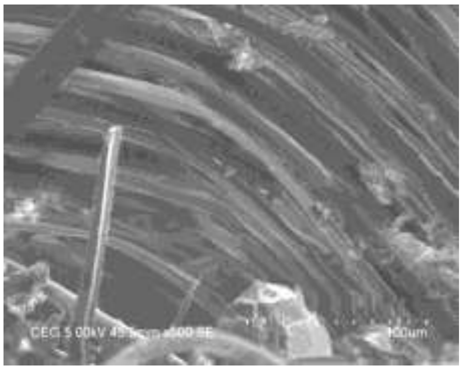

Figure.6.j – 100 µm double shear test

The figure (6.c & 6.d) shown is an impact fracture toughness. The impact image figure 6.d shown is a porosity condition. But porosity was observed due to exothermic heat condition. The figure (6.e & 6.f) shown is a flexural failure. The image shown is an ultimate failure. The maximum failure is under ductile fracture nature. The delaminating images shown are in the figure 6.g & 6.h. The figure 6.g shown is a porosity duet to exothermic heat formation and the figure 6.h shown is a crack formation. The crack formation is due to bending load.

4. Conclusion

This research work presents hand lay-up process of producing Kenaf-Kevlar composites of Four different compositional matrix and reinforcement amalgamation as follows; 90% Kenaf + 10% Kevlar – Sample 1, (S1), 80% Kenaf + 20% Kevlar – Sample 2, (S2), 70% Kenaf + 30% Kevlar – Sample 3, (S3), 60% Kenaf + 40% Kevlar – Sample 4, (S4) and various types of analysis are observed to obtain the results of produced Kevlar composites properties. The tensile result shows that F_{max} (KN) for S4 sample is 2.78 KN. The maximum Ultimate tensile strength (UTS) value of fabricated composites samples is correspondingly higher in sample, S4 = 24.35 Mpa. opt enough to make reinstatement of automotive parts. Fabricated composite sample S4 with 40% Kevlar is observed to have higher breakeven load of 24.35 Mpa. Therefore to combat high load before breaking it also has exceptional properties of wear which allow them advisable for adequate restoration of tyre plies. The maximum F_{max} observed at sample S2 = 0.48 Mpa relates to Flexural property. In the four composite samples S3 (24,26,27) stands unique in the hardness plot than the other three composition at all three averages of different indentations. From SEM images it is clear that the fibers cutting edges have fiber pullback because of testing process cajoled damage area. At double shear test observed displacement y = 15.500 mm at F_{max}. The variation of composite combinations with different machining techniques using Resin or hardener and fiber stacking layer with stoichiometric approach optimization shall be planned to conduct as future experimentations.

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