Characterization of Hybrıd Yarn/Fabrıcs From of Kenaf-Kevlar Fibers

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ABSTRACT

In this work, new hybridization method used to fabricate different hybrid yarn by using untreated and treated kenaf fiber and Kevlar yarn until development of hybrid fabrics. The hybrid yarn consists of various combination of kenaf and kevlar fiber with the composition ratio of 70% kenaf: 30% kevlar, 50% kenaf:50% kevlar and 30% kenaf:70% kevlar were weaved and also 100% kenaf and 100% kevlar yarns were weaved as the control data to compared with hybrid fabric. The woven of Kenaf-Kevlar composition were carried out by the weaving of hybrid yarn in weft and warp direction. Tensile properties of kenaf fiber, kevlar fiber, hybrid yarn and hybrid fabric were measured by using Universal Testing Machine. Morphology of all fibers-treated and untreated kenaf and kevlar were analyzed by using scanning electron microscopy (SEM). The obtained result showed that 30%Kenaf:70%Kevlar hybrid yarn and fabric has the highest strength (48.511 cN/Tex) and modulus (1815.570 cN/Tex) among the hybrid but its value 70% lower than 100% Kevlar fabric. Both treated Kenaf and Kevlar fibers showed fine surface and light weighted as compared with untreated fibers. The preliminary research results have shown that development of hybrid materials from natural fibers has the potential to be utilized for high performance composite applications.

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Introductıon

Material development is very important in order to develop and produce the best performance and reliable products that will contribute to the saving of cost, time and resources. In order to optimize the performance of the products, a lightweight material is the interest of research that will be the best solution to overcome the issues of high maintenance cost but not compromise to the quality of the product. This paper will explore the potential material that will be used for high performance composite material. Recently, there are many interests from the researchers to explore the utilization of natural fibers and bioresin as the alternative material to the manmade fibers such as glass fiber, carbon fiber and kevlar fiber. The explorations of sustainable materials give them new foresight of future development that will contribute to the sustainable development of the composite industry. Various kind of improvement through research have been carried out of the plant based material for composite which is called biocomposite is more toward the hybridization technology such as fiber metal laminate, hybrid woven, hybrid yarn and hybrid lamination. The hybridization has shown very close and comparable data to the high performance composite industry such as for military, aerospace, marine and automotive.

Hybridization is the process of the combination of different materials and processes with different characteristic and properties for the improvement of existing material. Recently, the choices of composites with high strength and light have encouraged the development of hybrid composites using two or more reinforcing materials in a polymer matrix. This hybrid composite offers a range of properties that cannot be achieved when single fiber is used and potentially reduce the cost of materials. A hybrid composite usually consists of high elongation fiber and a low elongation fiber. The high elongation fiber usually contributes more to the composite tensile strength while the low elongation fiber contributes to raising the composite elastic modulus. [1-3]. The impact strength of composites made of high modulus fibers is generally lower than steel alloys or glass reinforced composite. Strong, low density fibers have been favored materials for ballistic protection, but the choice of fibers is limited for making body armor that is both protective and lightweight[4-7]. In addition to developments of improved fibers, alternative approaches are required for creating more protective and lighter body armor[8-11].

The natural fibers present several advantages compared to synthetic fibers. They are biodegradable, lightweight, and renewable, have good mechanical properties and are abundant. Furthermore, they are not abrasive to the processing equipment, have neutral emission of CO_2 and are an important source of income for the population living in rural areas.[12]. Nevertheless, natural fibers have some discrepancy in term of quality and production efficiency. Natural fibers also have the hydrophilic behavior which leads to water absorption in the composite systems [13-16]. Based on previous study, Kenaf is one of the natural fibers that have an ability to be used as a fiber reinforced for polymer composites for advanced applications [17-22]. There are two distinct types of fiber in kenaf stem, namely bast fiber and inner core which constitutes about 30–40% and 60% of the total dry weight of the stalk, respectively. Kenaf bast fiber is a lignocellulosic fiber and has been used for production of fiber board and particle board, textiles, a fuel and as a reinforcement material for composites. Ligno-cellulosic fibers have a complicated structure. Kenaf bast fiber is made up of elementary fibers which are glued together by a pectin interface, to form technical fiber bundles. These bundles are separated from one another through partial decomposition of the cell wall, induced by bacteria or mechanical processes. From morpholocal analysis it was also reported that 3% NaOH was ineffective concentration for removing the impurities from kenaf bast fibers surface, while 6% NaOH was the optimum concentration for the chemical treatment to remove the impurities. High cellulose content can be obtained from kenaf bast fiber using water and NaOH retting processes [23]. It was also reported that the cross-sectional shape of the kenaf fiber varied widely from noncircular shapes such as a kidney bean shape for cotton to the reasonably circular one for wool).

Kevlar mainly use for two reasons, and both are about performance. It's lightweight and easy to integrate. A thin blanket can serve as structural reinforcement or ballistic protection, everywhere from seismic shear walls to bank counters. Sprinkle the fibers into carbon composites to cut weight and boost strength: The grades Kevlar 49 and 149 are the lightest and most robust; Kevlar 29 is comparable in potency to glass fiber, but weighs less. The fact is, Kevlar is still expensive costs need to come down.[24-27]. Kevlar also being apply for various kind of hybridization especially with metal such as Aluminum. [28]

The fabrication of hybrid yarn is not new for industrial textile industry. Hybrid yarns consisting of reinforcing and matrix fibers are one kind of basic material (semi-finished product) with which to construct continuous-fiber-reinforced thermoplastic composites. Composite properties are influenced mainly by the arrangement of the reinforcing fibers and the homogeneity of the fiber distribution in the composite, as well as by impregnation of the glass fibers with the polymer matrix. Hybrid yarns are usually manufactured into thermoplastic composites by hand lay-up, filament winding or by the pultrusion process[29-31].

Based on the literature study, Hybrid Yarn (Kenaf/Kevlar) has shown that Kenaf has the potential to be blended with Kevlar with the right ratio in order to address the requirements of natural fiber to be used as the high performance composite material. Kevlar has been proven that can resist the penetration of bullet with certain level of protection. In this work, the ratio Kenaf/Kevlar has been determined that suit with novelty process of blending, to maximize the usage of kenaf fiber and reducing portion of Aramid but maintaining the properties of high performance composite requirement. In order to measure the mechanical properties, tensile testing will be carried out for each type of fibers. This work is as a preliminary research going to use for development of hybrid composites by choosing right composition of hybrid yarn for advanced composite applications.

Methodology

Fiber Preparation

Kenaf bast retted fiber was supplied by KEFI Sdn Bhd and Kevlar fiber was supplied by Sri Jentayu Sdn Bhd. Both fibers were to be used as the hybrid composition of hybrid yarn and then hybrid woven fabric. Weight percentage of Kenaf and Kevlar was maintained as 30:70, 50:50 and 70:30 respectively. Both fibers were treated before go through the hybridization process. For kenaf fiber, was immersed in the 8% of NaOH for 3 hours at 90°C water bath with ratio of 1:20 water. Then the fiber was softened at 30°C for 5h with 5% softener. In order to make it antistatic agent, 20% of oil concentration was sprayed and sealed for 12 hours. Meanwhile, Kevlar fiber was treated with only sprayed with combing agent of 0.6% Kevlar weight and then was sealed for 12 hours.

Hybrid Yarn and Fabric Processing

In this process, there are three types of hybrid yarn were produced; 100% Kenaf, Kenaf/Kevlar – 70:30, 50:50 and 30:70, respectively, and 100% Kevlar. Each hybrid yarn has gone through the following process. There are seven (7) processes with different machineries. It started with Opening process where the fibers were opened two times and mixed together two times as well. In Carding process, mixed fibers were fed with 16g each time to keep even silver. Then in the Drawing process, for step number 1- silver weight of 25g/5m, posterior region draft ratio is 1.7 times. While for Step 2 & Step 3 - posterior region draft ratio is 1.1 times. Continuously in the Roving, the process were set at thickness-700tex, twist factor-52, spindle speed-450r/min. For Spinning process, the hybrid yarn fineness-60tex, yarn twist-330, delivery speed-10m/min and lastly for Doubling process, doubled yarn with the fineness-120tex, yarn twist-460, delivery speed-15m/min was set for the processing hybrid yarn. Hybrid Woven In this process, hybrid yarn for different kenaf/Kevlar composition was developed by weaving yarn in warp and weft direction. Initially, the hybrid yarn went through the process of warp yarn sizing with single yarn sizing machine. With smooth warp yarn sizing process, Warping process was taken place. Before the weaving process, the yarn has gone through the process of Heald Reeding and tension adjustment. Then finally, the process of weaving started using Semi-automatic sample loom made by Tianjin Jiacheng Electromechanical Equipment Limited Company, China.

Tensile Testing and Scanning Electron Microscope (SEM)

Standard test method (ASTM D3822-2007) was used for testing tensile properties of single fibers. The specimens' untreated kenaf 20 samples were prepared and for Kenaf alkali treated 20 samples were prepared as well together with Kevlar fiber 20 samples. Gauge length was set at 10mm and the Crosshead speed was set at 1mm/min. Meanwhile, the Standard Test Method (GB/T 3916-1997) was used for Breaking Strength and Elongation of Single Textile Yarns. The Tensile testing of the yarn was carried out using Instron3369 testing machine with setting of Gauge length-250mm and Crosshead speed-500mm/min. Finally, the Standard Test Method (ASTM D5035-2006) was used for doing tensile testing of woven fabrics. The testing machine was set with width -25mm, gauge length-75mm and speed-300mm/min. In order to study the morphological feature of the natural and synthetic fibers, fiber-matrix interface due to mechanical testing the surfaces of the samples were examined using a scanning electron microscope (SEM; HITACHI TM-1000).

Results and dıscussıon

Tensile properties of treated Kenaf fibers and Kevlar

In the tensile tests, three types of measurement were carried out to determine the strength, the breaking elongation and the modulus of elasticity of single fibers, respectively. The weight of the kenaf fiber was reduced by 26% after the 8% NaOH treatment. The diameter of the fiber became smaller and the surface rougher. Yousif et al. [32] reported that the surface of untreated kenaf fiber was found to be considerably covered with waxy substances and impurities. Farahani et al. [33] reported that as the substances from the surface of the kenaf fiber were removed by the alkali treatment, this may produce an improvement in the wettability property. It seems that the alkali treatment may also extract amorphous portions (lignin and hemicellulose) of the fiber. As for the Kevlar fiber, Cisneros et al. [25] provide micrographs of as-received Kevlar-29 fibers. The fibers appear essentially as smooth cylinders, although some of them present flaws, roughness, striations, and even swarf on the surface. These imperfections seem to come from the fiber manufacturing process. Table 1 displays the tensile properties of kenaf and Kevlar fibers. The tabulated data indicate that Kevlar fiber displays high tensile strength (12855.8 MPa) and elastic modulus (91.1 GPa). As compared to Kevlar, the 8% NaOH treated kenaf fibers had a tensile strength of 504.8 MPa and a modulus of elasticity of 5.2 GPa. Meanwhile, the elongation at break for kenaf is 9.8% and for Kevlar is 15.5%. Cisneros et al. reported that the values obtained for failure stress (α=3.0 GPa), Young's modulus (E= 84.5 GPa), and failure strain (ε=3.2%) were close to those reported by the supplier. If stress is plotted against strain on a graph, the same result will be obtained, as the curve remains practically linear until failure.

Table 1: Treated Kenaf and Kevlar Fiber Tensile Properties

No	Fiber	Force (N)	Strength (MPa) N/mm2	Elongation (%)	Modulus (GPa)
1	Treated Kenaf Fiber	1.070	504.8	9.804	5.2
2	Kevlar Fiber	1.656	12855.8	15.523	91.1

Tensile Testing of Hybrid Yarns

Based on Figure 1, the Hybrid Kenaf/Kevlar Yarn [30/70] showed the highest value of tensile strength and modulus compared to the other hybrid yarns and to Kenaf[100%], but its properties were still far below those of the Kevlar[100%] yarn. The yarns with 100% composition of kenaf or Kevlar were measured for comparison with the hybrid yarns. Based on other reserach, Misri et al. [34] found that the tensile strength of kenaf yarn with a linear density of 764 tex is 139 MPa. Thus, there is a correlation between their results and those obtained in this work, which are also very similar to the value reported by the manufacturer. In addition, the hybrid yarn Kenaf/Kevlar[30/70] exhibited the same pattern for the strength and modulus values as that for the breaking elongation percentage. Furthermore, the pure kenaf yarn was shown the weakest and had the lowest elongation. The higher the kenaf blending ratio, the lower the elongation of the yarn was reported. After blending with kenaf at a 50/50 ratio, the tenacity could drop by more than 70%. On average, the yarns blended with 70% kenaf had the lowest tenacity. It was shown that 70%Kenaf:30%Kevlar was the weakest because of the highest kenaf amount contained in the blend, as compared to the other hybrids. 30%Kenaf:70%Kevlar yarn exhibited the highest values in terms of tenacity and elongation among the three experimental hybrid yarns with Kevlar. The high twist of the rotor yarns also made them more stretching. Kenaf yarn has also been studied by Zhang in blends with cotton in different ratios [35]. It was found that after the chemical treatment, the fiber fineness, softness and elongation at break were improved, but the fiber bundle strength and length were decreased. It was also reported that an increased concentration of sodium hydroxide (NaOH) weakened the fiber strength accordingly. As to the yarns, the more kenaf they contained, the weaker the yarn and the fabric strength were, and the lower was the elongation of the yarn and, respectively, of the fabric. Fabrics became stiffer when the kenaf blending ratio was increased. Another study carried out by Berger et al. [36] on the blending of kenaf and cotton has shown that blending cotton fibers with kenaf fibers, with the proper fabric treatments, can result in a higher value end product, making kenaf a viable textile fashion fiber.

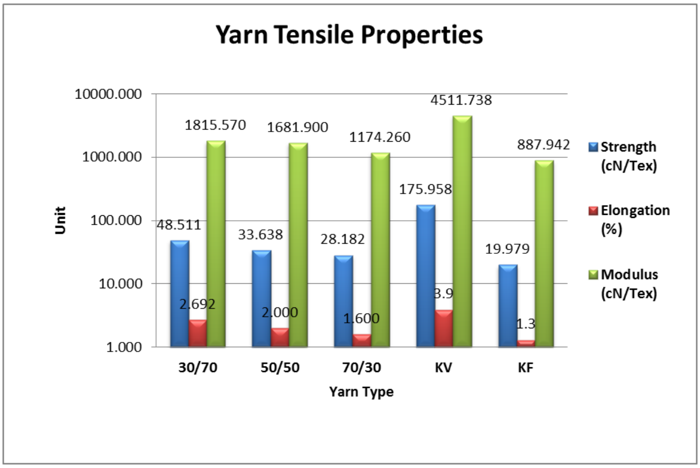

Figure 1: Hybrid Yarn Tensile Properties

Hybrid Woven Fabric Tensile Testing

Apart from yarn type of fiber, the tensile testing of the hybrid woven fabric also was carried out in order to obtain three types of measurements, comprising the strength, the breaking elongation and the modulus of elasticity of the fabrics woven from pure and hybrid yarns. Based on Figure 3, the hybrid kenaf/Kevlar woven fabric with the composition of 30% kenaf and 70% Kevlar showed the highest value in terms of the strength and modulus in both weft and warp directions. The trend was similar for the elongation of the fabric in weft and warp directions. Nevertheless, when a comparison was made between weft and warp, the warp measurements gave higher values compared to the weft measurements of the fabrics. Generally speaking, the tensile strength of the warp of a fabric is higher than that of the weft, due to the fact that warp density is higher than weft density, and the interlacing points increase. However, in our study, in the case of the one layer of Kenaf/Kevlar fabric, weft density was higher than that of the warp, and the warp-wise tensile strength decreased; thus higher warp tension is needed in the weaving process. In the initial stage of tensile testing, as the tension increased, the elongation of the fabric was caused by the change in the yarn tension, which shifted from flexion to extension. Some deformation was caused by the change in the yarn structure and by the extension of the fiber. In the last stage of tensile testing, the yarn basically straightened. Elongation and distortion of the yarn and fiber occurred, reducing the yarn linear density, and causing the fabric structure to become rarefied in the tensile direction. In the tensile test of the fabric, extrusion appeared at the interlacing points because of the increasing tangential sliding resistance between warp and weft, which increases the fabric strength. In the weaving process, the warp suffers more back-and-forth stretching, the friction between the warp and the mechanical parts increases, causing an increase in the fatigue degree of the warp and a reduction in the warp-wise strength. Meanwhile based on other research, Pahmi et al. [37] concluded that in order to produce good quality dry fabric for reinforced material in a natural-based polymer composite, yarn linear density should be considered. Woven kenaf dry fabrics with three different linear densities, of 276tex, 413.4tex and 759tex, were produced. The results indicated that the mechanical properties of the composite increased when the yarn linear densities increased. Meanwhile, the testing methodology is also very important to reveal the right properties of the fabric tested. According to Geoming et al., owing to the existence of 0^{o} and 90^{o} tows, the two types of carbon weft-knitted fabrics that they investigated – stitched with polyester yarns and with preoxidized PAN yarns – exhibited excellent stress–strain and load–displacement curves. On the contrary, because of the deficiency of the tows along the orientation of 45^{o}, the tensile and tearing properties along this bias direction were weak, or even undistinguishable[38].

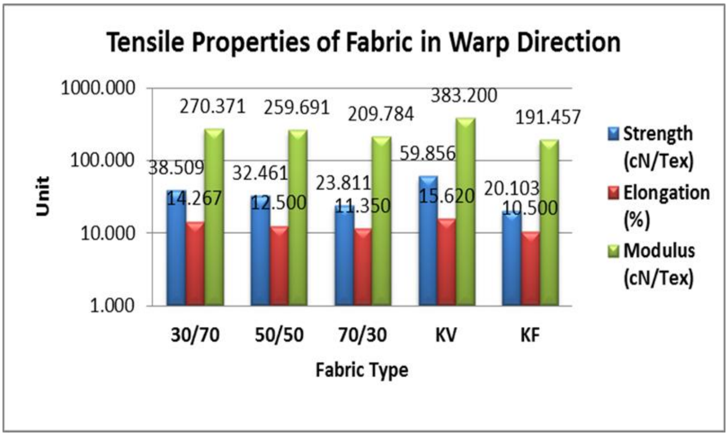

Figure 2: Comparison of Hybrid Woven Fabric Tensile Properties in Warp Direction

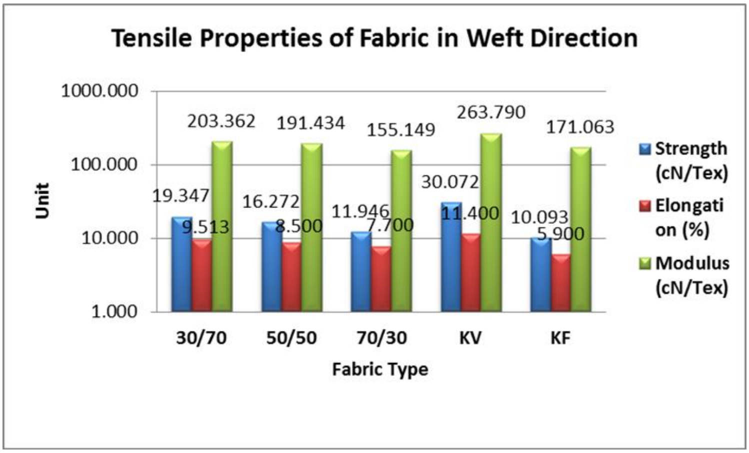

Figure 3: Comparison of Hybrid Woven Fabric Tensile Properties in Weft Direction

Conclusıon

In this work, two types of fabrics have been developed, as follows: fabrics woven using only one type of fiber (kenaf or Kevlar), which were called non-hybrid fabrics, and fabrics combining natural fiber with synthetic fiber, which was called hybrid fabrics. The mechanical properties of both types of fabrics depend on the fabric structure, including the characteristics of the fibers, the twist level of yarns, the density of yarns in the fabric, the weaving method, the characteristics of warp and weft threads, and the factors introduced during weaving, such as yarn crimp. The method of weaving the fabric is the most important parameter of fabric structure, which plays a significant role in deciding the performance of the future composites. The failure of the composite, including the delamination behavior, stress distribution, impact behavior, ductile behavior, and crimp interchange, depends on the characteristic behavior of the yarns. The characteristic properties of the reinforcement and resin fibers, especially the modulus, play an important role in deciding the overall performance of the composites; once the resin reaches a yield point, the entire load has to be shared by the reinforcement yarns. Fabricating fiber reinforced composites using the materials obtained in this study will be our further research objective. Based on the analyses carried out here, it has been concluded that the hybrid kenaf and Kevlar yarn and fabric were affected by alkaline (NaOH) treatment, which improved the strength of both the yarn and the fabric. After the alkali treatment, the weight of Kevlar and kenaf yarn was reduced, while the structural stability of the fiber and the elongation of the yarn became slightly lower. In the 30%Kenaf:70%Kevlar yarn, the warp and weft were used with the maximum thickness. It is because the yarn had a certain twist, which took up more space. As the yarn has linear density, the fabric has minimum gram weight. Overall, the research has anticipated the development of a new fabrication methodology of woven fabrics, which has the potential to be used for high performance composites applications.

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