An Evaluation of Mechanical Properties on Kenaf Natural Fiber/Polyester Composite Structures as Table Tennis Blade

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Abstract: Nowadays, natural fibers getting attention from researchers and industries to optimize the use it, with combination of polymers as composite structure, due to environmental awareness. Furthermore, it show a few advantage, such as biodegradability, light in weight and non-toxic characteristic. In this study, kenaf natural fibers was used as reinforcement material, with combination of polyester as matrix material, known as polymer matrix composites. The main purpose of this study is to analysis the mechanical properties of kenaf natural fiber/polyester composite structure, in order to know the suitability of kenaf natural fibers as replacement material for table tennis blade structure, instead of using wood. The structural panel of composite laminates has been produced using hand lay-up technique. The experimental works are performed in tension, impact (Charpy) and shear condition. The characteristic of different condition on kenaf composite structure was studied. Based on the result, it found the properties of kenaf composite structure, and it will used as a benchmark, to compare with initial properties of table tennis blade made by wood. In addition, the strength and a weakness of that particular materials and lamination structure will be identified.

1. Introduction

Over the years, people have found various applications by using natural fibers. An example of natural fibers, such as kenaf, hemp, flax, sisal and ramie. The initial characteristic of natural fibers, are emerging as low cost, lightweight and environmental friendly [1]. Therefore, natural fibers become one of the most famous material selected as a reinforcement materials, in order to produce composite structures. Whereby, a composite material is a combination of reinforcement and matrix material, and it can have better properties than the individual materials used alone [2,3]. So, a reinforcement and matrix material need to be chosen according to the application and desired characteristics. As reported by, Davoodi et. al. (2010) natural fiber composites have an advantage, which is better formability, renewable, cost effective and safe toward health [4]. Furthermore, by comparing glass fiber composites, natural fiber composites are likely to be environmentally superior [1].

In this study, kenaf natural fibers or also known as Hibiscus Cannabinus, are consider as a material to be investigated, in term of suitability to become reinforcement materials for table tennis blade structures. Kenaf fibers is obtained from the bast/stems of plants and it requires less water to grow because it growing cycle around 150 to 180 days with avarage yield of 1700 kg/ha [5]. As mentioned by Saba et. al. (2015), kenaf is commercially available and economically cheap amongst other natural fibers. It also hardy, strong and tough plant with a fibrous stalk. Figure 1 shows the kenaf plantation [6]; (a) cross-section of Kenaf stalk [7]. Due to the primary stage on development of natural plant
fibers reinforced composites, researcher need to continuously investigate, especially the basic experimental, such as the mechanical properties [8]. According to previous research, the kenaf bast fibers showed better mechanical properties than other part, that make them as a replacement to glass fibers in polymer composites as reinforcement materials [9]. On mechanical properties, as reported by Wambua et. al. (2003), it was shown kenaf fibers specifically, increased the ultimate tensile strength, tensile modulus, and impact strength with increasing fiber weight fraction. However, the composites tested showed low impact strengths compared to glass material composites [10].

![Figure 1. Kenaf plantation; (a) cross-section of Kenaf stalk [5,6]](image)

An existing of table tennis blade, consist of a wooden blade which incorporates the handle and table tennis rubber which is affixed to each side of the blade using water-based glue, as shown in Figure 2, the side view of a blade showing the wooden blade with table tennis rubber affixed to each side of the blade. The wood structure, will be replaced with other materials. Therefore, the aim of this study is to replace the wood structure with kenaf natural fiber. However, the most important thing to understand is on the characteristic of table tennis blade itself. The characteristics need to investigate and evaluate are the energy absorption, hardness, weight, size and shape of table tennis blade. These characteristics contribute on the performance of table tennis blade [11]. An understanding of the factor affecting the performance of table tennis blade is required to ensure replacement material, contribute a better performance, or at least at the similarity level.

Reviewing on related cases show, a need to investigate the characteristics and behaviours of new designated structures, which is kenaf natural fiber/polyester composite structures, in order to know the strengths and weaknesses of structures. Thus, the objective of this study is to investigate the suitability of kenaf natural fibers used as replacement material for table tennis blade, in term of tension (strength), impact charpy (energy absorption) and shear test (layer strength). The hand lay-up technique is used to fabricate composite materials, with is combination of kenaf natural fibers and polyester resin. An expected results of this study are to evaluate the initial mechanical properties, based on basic experimental that reflected on characteristic need for table tennis blade.
2. Methodology

2.1 Specimen Preparation
Kenaf natural fiber/polyester composite structures were fabricated using hand lay-up techniques. Each specimen consist of kenaf fiber as reinforcement and polyester resin as matrix materials, on five layers lamination structure. On fabrication process, kenaf natural fibers was impregnated with polyester resin until five layers configuration. The resin was applied to the surface of material, after the material was laid down at the mould. Brush rollers was used to remove void in the lamination structure. After lamination process, the specimen was cured at room temperature, and it was cut out according to experimental specimen standard. Figure 3 shows the flowchart of experimental and followed by Table 1 represents the characteristics of laminate specimen.

| Characteristics Kenaf Composite Structures |
|--------------------------------------------|
| Kenaf Natural Fiber | 5 |
| Stacking Sequence / Orientation | Kenaf [0/90] |
| Ply | 5 |
| Resin | Polyester |
| Average Thickness | ±4 mm |
2.2 Mechanical Testing

In this study, tension test, impact charpy test and shear test were performed, in order to investigate the characteristic and behaviour of composite structures. All experiments follow difference standard, which is; ASTM D638 (Tension Test), ISO 179 (Impact Charpy Test) and ASTM D2344 (Shear Test). Specifically, tension test was conducted to determine the ability of composite structures when subjected to the axial load on the specimen until failure. Then, followed by impact charpy test to examine the potential of the kenaf composite structure to withstand the impact force at high rates. The output from impact charpy test was energy absorption, whereby the test determines the amount of energy absorbed by a material during fracture. At last, shear test was carried out in this study. This experiment examines the shear strength of composite structures. Due to the difference of standard, each experiment have different of specimen geometry, as shown in Figure 4.
3. Result and Discussion
Three sets of experimental results were obtained from the three types of experimental, which is tension test, impact charpy test and shear test. The experimental were demonstrate the characteristics of composite lamination structures, in the field of stress, modulus young, energy absorption and shear strength. As shown in Figure 5, tensile strength and modulus young with different of specimen. It shows, different test specimen exhibit different strength behaviour. This is due to, different of condition on lamination layer, which is on interface condition [12, 13]. The result indicate that the highest value for the tensile strength is for specimen 4, approximately 19 MPa. An average of tensile strength for kenaf composite structures at 15 MPa. As reported in [14], the tensile strength for kenaf/unsaturated polyester is 27 MPa and higher than other natural fibers, which is jute and bamboo. However, due to difference of geometry specimen, it shows difference of behaviour. With respect to the modulus young, average modulus young is 708 MPa. Based on the results, it shows the low modulus of elasticity, will provide high stability when table tennis blade hit the ball. In addition, the structure shows capability for absorption the vibration.

Figure 4. Specimen geometry (mm); (a) Tension test, (b) Impact charpy test, (c) Shear test

Figure 5. Tensile strength (MPa) and Modulus young (MPa) of kenaf composite structures
In this study, an average of impact energy absorption for kenaf composite structures, approaching 0.55 J, as shown in Figure 6. The energy absorption also affected due to orientation angles, as reported by Arifin et. al. (2014). The result shows that the kenaf composite structures has higher capability to absorb energy during impact force imposed on the structures [12]. On manufacturing table tennis blade, this criterion is most important aspect to be investigated. It is essential to note that, this initial study shows the possibility of kenaf natural fibers used as reinforcement material on table tennis blade, due to capability of absorption.

![Figure 6. Energy absorption of kenaf composite structures](image)

As shown in Figure 7, the scanning electron micrographs of kenaf hybrid composites, as reported by Ghani et. al. (2012), shows the surface failure due to matrix fracture, fiber-matrix debonding, fiber pull-out and fiber fracture [5]. This phenomenon represents, the composite materials can exhibit multiple types of damage, if it exceeds the accepted load. In the actual condition of table tennis blade, the load is not high, therefore based on the results, kenaf composite structures can sustain and have capability to absorb the load. Next, the effect of shear condition on the kenaf composite structures are shown in Figure 8. Shear strength represent the capabilities of structures to withstand from structural failure, where the material fails in shear. Additionally, shear load is a force that produce the sliding failure on material along the plane. In this study, shear test was performed on bending condition, in order to investigate the strength of the lamination layer. The result shows that the average shear strength of the kenaf composite structures, in the range 420 N– 450 N. Moreover, it should be noted that the delamination between lamination layers will affect the shear strength of structures. In composite material structures, if delamination of plies occurs between each lamination structure, it means a progressive failure mode has occurred. The failure mode, can be divided into three stages: damage initiation, damage propagation and total perforation (fracture) [12,15,16]. The results obtained in this experimental shows in the range of accepted, but need more investigation related on the actual condition of table tennis blade condition.

![Figure 7. SEM micrograph on fracture surface of kenaf hybird composites](image)
4. Conclusion
In this study, kenaf composite structures were made using hand lay-up technique and tested to evaluate the characteristic of lamination structures, in term of strength and impact condition. The novel ideas from this investigation is to produce new table tennis blade, that have natural fibers in its structures, to replace existing materials used, which is wood. The attraction and motivation using natural fibers as replacement materials in table tennis blade structures, due to the biodegradability, light in weight and relatively stronger [6]. Therefore, this study was conducted, on a basic experimental for mechanical characteristic, in order to know the capability of new structures. Based on the result, it shows the possibility to replace wood, as a main material for the new table tennis blade. However, it should be noted that, this study need to be extended on other scope of study, each aspect need to investigate, to ensure it can be realized, created a same characteristic behaviour with an existing table tennis blade and will be commercialized.

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