Abstract: Kenaf is known for many years as a typical crop that can be used in various applications such as in automotive, and building structure. Along with the depletion and environmental issues raised nowadays by excessively used of man-made synthetic fibres make the natural fibre to become popular and favourable to be implemented. This paper discusses on the development of long kenaf fibre reinforced polyester matrix composite. Total weight of about 40% fibre fraction was selected. In this study, the addition of about 10% weight fraction of fibreglass in the composite system is needed in order to strengthen the composite material and also to retain its reliability and robustness in their applications. Thus, preparation of two different layer arrangement of kenaf and fibreglass were conducted viz (i) kenaf at inner layer and fibreglass at outer layer (0°)/[0°][0°]/0°/90°) (ii) kenaf at outer layer and fibreglass at inner layer (FG/0°90°90°0°/FG). All configuration samples were fabricated by hand lay-up and cold press technique. Fracture toughness testing was carried out using a single edge notched bend specimen at a loading rate of 10mm/min. All samples were prepared according to ASTM D5045 (Standard Test Methods for Plane-Strain Fracture Toughness and Strain Energy Release Rate of Plastic Materials). Results obtained from SENB test were then evaluated and discussed. It can be used as a guideline or reference for further research on this type of polymer composite.

Keywords: Kenaf reinforced polyester composite, Kenaf and fibreglass hybrid composite, Single edge notch bend (SENB).

I. INTRODUCTION

Recently, research on new materials which are stronger, stiffer and light weight are gaining major interest in the composite world. Fibre reinforced polymer (FRP) are used in various applications where fibreglass, kevlar, and carbon are among the popular bridging materials used. These materials offer superior performance and strength as compared to the traditional materials used for example wood, plastic and metals. However, nowadays the increase in cost for petroleum resources that are used as feed stocks for these reinforcement materials are the reason why many people are trying to find new materials in order to replace the synthetic fibres. Scientists, researchers and academicians are now facing the challenge on improving the quality of life by reducing the usage of synthetic materials which give bad impact to the environment and human life.

Thus, using natural renewable resource based materials have led to an increase in the study and development of novel bio composite materials. The prices of natural fibres are also much lower when compared to synthetic fibres. Many attempts have been made in using natural fibres as reinforcement materials in polymer matrix as it has resulted in similar or comparable mechanical properties of synthetic fibres [1]–[3]. Natural fibres are also used due to its biodegradability, abundantly, light weight, eco-friendly and nontoxic. The processing of natural fibres is not harmful as compared to synthetic fibres and not abrasive to the processing equipment. However, the usage of natural fibres have some limitations such as low thermal stability, highly flammable, high moisture absorption, strength degradation, variation in mechanical properties and many more [4], [5]. Thus researchers have to find ways to overcome this situation. One of the method is to hybrid it with other reinforcement materials.

The most commonly and favourable synthetic fibre used in composite material is fibreglass. Hybridizing fibreglass together with natural fibres has shown to be promising in many applications. Unidirectional, multidirectional, and woven fibre composite laminates showed excellent properties such as high specific strength, better impact properties and also easy to handle [6]–[8]. More importantly it is much cheaper as compared to other synthetic fibres without sacrificing its mechanical properties.

This study is about the hybridization between kenaf and fibreglass. Layer arrangement becoming is an important thing that needs to be considered when it comes to hybridization materials. The right decision for material position might be helpful to increase the mechanical properties of the whole composite system. Thus, data reported in this study is limited to only the effect of its layer arrangement. There are two types of layer arrangement selected and SENB test was conducted and evaluated to get the fracture toughness values. Few literatures showed the effects of layer arrangement on fracture toughness of these hybrid materials. These types of hybrid materials have great potential to be implemented in high load bearing engineering applications. Thus, the result of fracture toughness from this project can be used as a guideline or reference for further research on hybrid reinforced polymer composites.
II. MATERIALS AND METHOD

A. Materials

In this study, the sample composites were made up from long kenaf fibre and woven fibreglass with reinforcement of polyester as the matrix resin to produce hybrid composite material. About 50% weight fraction of fibre is used in this research. Another 40% weight fraction applied was from kenaf fibre.

Two layer arrangements were prepared for the long kenaf – fibreglass hybrid composites viz. (i) long kenaf fibre at the outer layer, fibreglass at the inner layer designated as [0°/90°]k/FG2p/[90°/0°]k and (ii) fibreglass at the outer layer – kenaf at the inner layer designated as FG/[0°/90°/90°/0°]k/FG.

B. Production of Composite Materials

The kenaf and fibreglass hybrid composite materials were fabricated by using hand layup and cold press technique for each system configuration as shown in Fig. 1. Long kenaf fibre was initially rolled vertically and horizontally at the inner frame before proceeding with the fabrication process. This is to ensure that the fibre orientation of 0° and 90° was achieved. Polyester resin used in this study are mixed with hardener ratio of 100:1. The manufacturer provides the formula. It takes 30 minutes for the mixture to harden. Thus, it is advised that the pouring process should be done quickly or within the time given. A plastic film is used to cover the soaked kenaf in order to obtain smooth surface finish. The samples are cold pressed in approximately 10kN in room condition. The samples are then leave for 60 minutes for bonding purpose.

Finally the samples are cut out of the mould by using a saw with dimension of 44 mm x 10 mm, that follows standard ASTM D5045 method for Plane – Strain Fracture Toughness and Strain Energy Release Rate of Plastic Materials.

![Fig. 1. Fibre configuration for hybrid composite](image)

C. Single Edge Notch Bend Test

The SENB test specimen from each configuration was machined based on the ASTM D5045 standard dimension. The maximum load condition will be obtained in the specimens containing a pre – crack. The dimension of specimens were 44 mm, 40 mm, 10 mm and 6 mm for length (L), span (S), width (W) and thickness (B) respectively which satisfies the condition of 2B < W < 4B require for SENB test. Illustration of specimen configuration is shown in Fig. 2.

![Fig. 2. Standard size for SENB specimen](image)

Fracture toughness is an indication of the amount of stress required to propagate a pre-existing flaw. It is a very important material property for damage tolerance design. Mode I critical stress intensity factor, \( K_{IC} \) is used to determine the fracture toughness of most materials. Based on ASTM D5045 standard, it is calculated with the following relations:

\[
K_{IC} = \frac{6\sqrt{P}}{BW^{3/2}}
\]

(1)

\[
y = 1.93 \left( \frac{a}{W} \right)^2 - 3.47 \left( \frac{a}{W} \right)^{3/2} + 14.53 \left( \frac{a}{W} \right) - 25.11 \left( \frac{a}{W} \right)^{1/2} + 25.80 \left( \frac{a}{W} \right)^{-1/2}
\]

(2)

where \( Y \), \( P \), \( B \), \( a \), and \( W \) represent geometrical factor, rupture forces, thickness of sample, pre-crack length, and width of sample respectively.

D. Scanning Electron Microscopy (SEM)

The electron microscope was used for surface fracture
observation. The samples are first cut leaving only the surface fracture for observation only. This is done to fit the specimen in the electron microscope. For composite specimen it is important to coat the specimen with gold dust to avoid image blur during observation by using coating machine. The sample was then taped on top of the stage by using carbon tap and this is important to discharge the electron. To observe the surface fracture it is important to zoom in at the right area where fractured area is shown. Another way to improve the image was by adjusting the brightness and contrast of the image.

III. RESULTS AND DISCUSSION

A. Single Edge Notch Bend Properties

Fracture toughness test was conducted for both [0°/90°]k/FG/90°k] and FG/[0°/90°/90°]k/FG hybrid composites. Fig. 4 show typical load – displacement curve under loading rate of 10 mm/min as mentioned in respective standard. As can be seen the curve started with linear deformation before the non – linear deformation. The non – linear deformation is preceding to the attainment of maximum load. After it reaches the maximum load, gradual decrement on the curve was observed. This might be due to the cracking of material that happened together with limited plastic deformation. Similar trend was also reported by previous researchers [9], [10].

Table I: K_0 values for kenaf – fibreglass hybrid composites

<table>
<thead>
<tr>
<th>Configuration</th>
<th>K_0 (MPa√m)</th>
</tr>
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<tbody>
<tr>
<td>[0°/90°]k/FG/90°</td>
<td>20.35 (1.63)</td>
</tr>
<tr>
<td>FG/[0°/90°/90°]k/FG</td>
<td>32.54 (2.82)</td>
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Fracture toughness is strongly related with the maximum forces where a high maximum force will produce higher toughness values. Thus, the comparison between two different layers of these hybrid composites shows that FG/[0°/90°/90°]k/FG exhibit higher values due to the position of fibreglass at outer layer which give advantage as its support by fibre - bridging the crack lead to enhanced the crack propagation resistance before its failure.

Fig. 5 shows SENB specimen for [0°/90°]k/FG/90° hybrid composites. Close – up crack length is in between 0.5 ±0.05. Meanwhile Fig. 6 shows the fracture surface of tested specimen. Similar specimen for FG/[0°/90°/90°]k/FG hybrid composites is shown in Fig. 7 and fracture surface in Fig. 8.
IV. CONCLUSION

In this work, the effect of layer arrangement of long kenaf and fibreglass reinforced polyester hybrid composites was successfully investigated. The primary results suggest that layer arrangement of fibreglass at outer layer give better fracture toughness as compared to position of kenaf at outer layer. Fracture surface analysis showed good bridging fibreglass which hold the material well before its rupture.

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REFERENCES


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