Comparison analysis of abaca fiber/polyester and abaca-e-glass/polyester hybrid composites to impact strength and its application to ballistic

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Abstract. The aim of this study concentrates of mechanical properties of abaca fiber and compares with the hybrid fiber composite on using abaca-e-glass fiber as reinforcement for composites. The fibers were arranged to make a bidirectional ±45º fiber arrangements by using polyester as a matrix with hand lay-up method is used to manufacture the composite. Based on the impact test results showed that the abaca-E-glass/polyester has a higher strength than the abaca/polyester specimen. Therefore, the abaca-E-glass/polyester hybrid composite has a better ability to ballistic test.

Keywords: abaca fibre, polyester, hybrid composite, ballistic, e-glass/polyester

1. Introduction

Natural fibres have attracting the interest to engineers, researchers, professionals and scientists all over the world as an alternative reinforcement for fibre reinforced polymer composites, because of its superior properties such as high specific strength, low weight, low cost, fairly good mechanical properties, non-abrasive, eco-friendly and bio-degradable characteristics [1].

Hybridization of natural/glass fiber reinforced polymer composites have been developing to build their applications in the field of engineering and technology [2]. Glass Fibre Reinforced Polymers are mixing with natural fibres to increase Engineering and Technology applications [1]. Abaca, common name for Musa textilis, is a species of banana native to the Philippines, grown widely as well in Borneo and Sumatra [3]. Abaca fiber is known as one of the strongest natural fibers native to the Philippines and widely distributed in the humid tropic’s countries including Indonesia. In the last years, natural fibers reinforced composites have received high attention due to their low density, excellent thermal properties, low cost, biodegradability, availability, non-toxicity and absorbing CO2 during their growth [4-5]. It has been reported that Abaca fiber is resistant to rotting and has a high tensile strength, and a specific flexural strength comparable to that of glass fiber [6]. Therefore, abaca fibers can be used as reinforcement in thermoset polymer composites. Thermoset polymer was used extensively in natural composites, whether in the form of ramie/epoxy composite [7], flax/epoxy composites [8-9] and natural
fiber/vinyl-ester composites [10]. Therefore, in this paper, we used the polyester thermosetting polymer which was then mixed with alkali treatment abaca and e-glass fibers. The fibers were arranged to make a bidirectional ±45° fiber arrangements. The processing method was using a hand lay-up. The produced specimens were prepared for the impact tests according to ASTM D 6110-04 standards.

Therefore, the abaca/polyester and abaca-E-glass/polyester hybrid composites applied to ballistic respectively. Ballistics aims to see the phenomenon of bullets fired at the target plate so that they can know the characteristics of bullets. Then can be developed bulletproof material that can reduce energy from the shooting process as much as possible [11]. Furthermore, in 1965 Stephanie Kwolek synthesized Kevlar synthesis fibers which could be used as ballistic materials, but Kevlar was expensive.

Research on ballistic testing has been carried out by many researchers in the world, and at this time ballistic testing is still being developed, but very little has been published because the capability of making ballistics is very closely related to a country’s defense forces. The following are some studies on ballistics that have been carried out. Economical bullet resistant shirts made from polymer composites reinforced with silicon carbide granules and carbon fiber capable of holding level II bullets by using special magnum 38 revolver guns at a range of 10 meters [12].

Engineering raw materials and cocoon waste have been made bullet proof vests and are able to withstand the rate of bullets from the M16 rifle at a distance of 100 mm [13]. Study of the characteristics of composite leather and hemp skin with an epoxy resin matrix as an impact resistant material and ballistic test results of all bullet translucent samples [14]. Analysis of the effect of the angle of attack on the ballistic impact on composite matrix resin materials with a reinforcement of water hyacinth (eichhornia crassipes) woven from the test results at a firing angle of 0°, 15°, 30°, 45° at a distance of 5 meters impermeable bullet [15].

Polymer composites as ballistic resistant materials are able to provide better performance compared to metal materials, especially in enhancing the mobility capabilities of military defense personnel [16]. In the present study, based on impact test results, this composite was applied to the manufacture of ballistic test plates. The next step is to perform a ballistic test to determine the penetration of SS2-V4 weapons and tanfoglio guns with a caliber of 5.6 and 9 mm respectively. It is expected to produce bullet resistant composite materials that are easy to make, inexpensive, and have the strength to withstand bullets.

2. Research Methodology

Figure 1. shows the alkali treatment of abaca fibers which is soaked using 5% NaOH solution for 2 hours, then Figure 2. washed the fiber with clean water and dried at room temperature.

![Figure 1. Alkali treatment of abaca fibers](image1)

![Figure 2. Drying the abaca fibers](image2)

The fiber was carefully arranged that eventually will produce with ±45° fiber orientation for both abaca and E-glass fiber respectively and placed into the molding, were then mixed with polyester resins as a matrix using hand lay-up method.

The polyester resins and fiber were measured in order to achieve 50% abaca and abaca-E-glass hybrid fiber volume fractions respectively. Figure 3. shows the final specimens for impact tests according to ASTM D 6110 – 04 standards.
Figure 3. Tests Specimens: (a) Abaca/polyester Composites, (b) Abaca-E-glass/polyester Hybrid Composites

Furthermore, making ballistic testing to determine the two types of composites is able to withstand bullets. Figure 4. shows the ballistic testing sketch.

Figure 4. The Ballistic Testing Sketch

The ballistic specimens placed on the support and then the specimen was subjected to shooting at a distance 100 meters and 10 meters by using SS2-v4 weapons and tanfoglio gun respectively as shown in Figure 5.

Figure 5. (a) SS 2 - V4 Weapons, (b) Tanfoglio Guns

3. Results and Discussion
Impact tests was carried out according to ASTM D 6110 – 04. The analysis was done for all fiber composite configurations for both abaca/polyester and abaca-E-glass/polyester hybrid composites is given in Table 1.

| Composite                  | Impact Strength (J) |
|----------------------------|---------------------|
| Abaca/polyester            | 3.36                |
| Hybrid abaca-E-glass/polyester | 16.5               |
Table 1. shows that the value of impact strength for hybrid abaca-E-glass/polyester specimen is higher than abaca/polyester. It is important also to compare the results of the current study with similar impact strength of natural fiber and hybrid natural-glass fiber composites available in the literature. Table 2. and 3. shows the comparison with other natural fiber composite and other natural-glass fiber hybrid composite systems. It shows that the mechanical properties found in the present study are able to compete with other natural fiber and natural-glass fiber composites.

Table 2. Comparison with Other Natural Fiber Composite Systems

| Composite              | Impact Strength (J) | References |
|------------------------|---------------------|------------|
| Kenaf/epoxy            | 3.9                 | [17]       |
| Kenaf/polyester        | 4.53                | [18]       |

Table 3. Comparison with Other Natural-Glass Fiber Hybrid Composite Systems

| Composite                                      | Impact Strength (J) | References |
|------------------------------------------------|---------------------|------------|
| Nem/kenaf/E-glass/polyester Kenaf/polyester   | 11.26               | [17]       |
| Kenaf–glass fibre reinforced polymer composites| 6                   | [19]       |

Therefore, it can be concluded that the abaca-E-glass/polyester hybrid composites has a good potential to be developed further for wide application, whether in the automotive industries as well as in the ballistic equipment.

The impact strength of this composite is needed to determine which type of composite is suitable for ballistic tests. The greatest impact strength was selected for ballistic testing. The impact toughness value is influenced by the absorbed energy value and the cross-sectional area of the test specimen, and the addition of the number of E-glass fiber layers causes an increase in the resistance of the composite material to shock loads. Based on the impact test results show the abaca-E-glass/polyester fiber will be used as a bullet proof material.

Composite ballistic testing aims to observe the behaviour and the impact of the two composite specimens on the fired bullets. Figure 6. shows the ballistic specimen test result scheme that the abaca-E-Glass/polyester ballistic specimen test can withstand bullets with a depth of 9 mm by using tanfoglio gun, whereas by using SS2-V4 weapon can be penetrated by bullets.

Figure 6. Ballistic Specimen Test Result Scheme

Figure 7. shows the abaca-E-Glass/polyester ballistic test results by using a SS2-V4 weapons.
Figure 7. Abaca-E-glass/polyester Ballistic Test Specimens by Using SS2-V4 Weapons: (a) Upper surface, (b) Lower surface

In the figure above shows that a SS2-V4 weapons using 5.56 x 45 mm caliber with a distance of 100 meters can penetrate the specimen. The bullet damaged the target. Whereas, in Figure 8. shows the abaca-E-Glass/polyester ballistic test results by using a tanfoglio guns.

Figure 8. Abaca-E-Glass/polyester Ballistic Test Specimens by Using a Tanfoglio Gun: (a) Upper surface, (b) Lower surface

In the figure shows that a bullet fired from tanfoglio gun cannot penetrate the specimen. The bullet damaged the target. In Figure 8. shows that the bullet cannot penetrate the specimen and the speed of the 9 mm caliber bullet fired from the tanfoglio gun was lower than the 5.56-caliber bullet fired from the SS2-V4 weapons, because it is held back by fiber. Delamination occurs at the lower surface on the inner layer of the panel due to adhesive failure.

4. Conclusion
The present study concludes that a hybrid abaca-E-glass/polyester composite have a good mechanical property compared with other natural-glass fiber hybrid composite systems. Despite the simple manufacturing processes, the specimens produce good qualities with moderate impact strengths. Therefore, hybrid abaca-E-glass/polyester composite has a good potential to be developed further, for applied in ballistic equipment.

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