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Abstract. Utilization of composite material in military application can provide better performance compared to metal material especially in increasing the mobility capacity of defense personnel. The objective of this research is to develop ballistic material from composite hybrid with coir and synthetic fibers as its reinforcement. Composite hybrid is formed using epoxy matrix with (Coir + Alumina)-E-glass-Fabric-Rubber. The coir used is in short fibers form after fibrillation process. Alumina is used for 5% of resin weight. The specimen is formed with hand lay-up method. The test of mechanical and physical properties is conducted to observe the reinforcement mechanically and physically. The firing test is aimed to find out the ballistic durability. The result of mechanical characteristic test shows that composite hybrid has tensile strength 76 Mpa, 58,02 kJ/m^2 for impact strength and 0,00122 g/mm^3 for density. The result of ballistic test shows that composite hybrid material is able to detent the bullet in level IIA.

1. Introduction

In defense industry, the necessity of defense tool in facing the globalization era has been raising and the type of the tool is getting more complicated. Ballistic material for bullet-proof vest, helmet and the body of combat vehicles are continuesly developed. The ballistic material in general is made of steel which has the ability to hold the bullet properly, however steel has big density which make the material has heavy weight and this will limit the mobilisation of the wearers.

Along with the development of technology, the research to obtain new materials, specially eco-friendly and renewable ballistic materials (called also as green materials) is conducted continuously. Green materials for ballistic is expected to have lighter weight yet have good bulletproof. This is done to obtain the alternative steel which has heavier weight.

The utilization of composite as the bullet-proof material has been done in many researches. The technology development of composite lately has shifted from composite with synthetic fibers to composite with natural fibers. The natural fibers such as hemp, jute, sisal, pineapple, palm fiber, oil palm empty fruit bunch fiber and coir fiber have been utilized as the reinforcement of composite material.

The advantages of natural fibers compared to synthetic fibers are; it is more environmental friendly as it is biodegradable and most of all, it is renewable. In addition, natural fibers also has light

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characteristic, easy to find, renewable, easy to be processed, non-abrasive, it has rated power and enough modulus, relatively cheap and easy to be recycled. [1,2,3,4]. These advantages cause some type of natural fibers start to take the position in many applications in substituting the synthetic material like insulator component which substitutes glass fibers and furniture component and floor tile substituting plastic and ceramic and among many applications of natural fibers, ballistic material become one of most interesting application

Tjokorda G. et al [6] observed economic bullet-proof armour made of polymer composite strengthened with silicon carbide particle in carbon fiber. The power of bullet proof was tested with rifle gun of revolver magnum 38 special with shooting range in 10 meter. Result of the research showed that panel of carbon fiber can reach level II in *National Institute of Justice* NIJ Standard-0101.06. Zubaidi et al [7] in their research made bullet-proof vest from polyester fiber. The sample was made by weaving fabric with plain woven construction in 0.2 mm thickness. The result showed that panel from polyester fiber could reach IT level of international standard NU-0101.04. Dachyar [8] from Centre of Material Technology (BPPT) had reversed and applied the technology of composite hybrid ballistic material to body hull protection for tactical vehicles. This research developed ballistic material of composite hybrid using hempen for tactical vehicle of Indonesian National Army (TNI). Daud [9] had published the interaction between projectile and polymer composite with strengthened with silicone carbide (SiCp) particle and carbon fiber in ballistic test. The result showed that polymer composite added with two layers of carbon fiber in the top and the bottom provided better detention of projectile lunge which is 13 mm.

Merging technology between synthetic fiber and natural fiber or also known with composite hybrid enable to design the material characteristic with has several advantages such as easy to find, low density, strong, flexible, renewable and biodegradable. Study of impact resistance for natural fiber composite mixed with synthetic fiber to be applied in ballistic material has been done until now. Generally, the fabrication of composite material is intended to reduce the usage of synthetic fiber like Kevlar or fiberglass, and to depress the production cost. Several studies which have been done included, composite of coco fiber-Kevlar fiberglass with matrix resin ABS which able to detent the 9 mm FMJ (NLJ IIA) bullet, composite of S-glass cloth-coco fiber with matrix resin epoxy which able to detent 45 ACP FMJ (NIJ IIA) bullet, and composite of hemp fiber-kevlar with matrix polyesther resin which able to detent FMJ bullet massed 5-7 gram with 250-656,8 m/s of speed (NIJ II) [10,11,12].

Coir fiber is one of the natural fiber materials that can be utilized in composite manufacturing. This type of fiber used because it is easy to find and widely available. Coir fiber as a strengthened element greatly determines the mechanical characteristic of the composites as it forwards the loads distributed by the matrix. Coir fiber combined with polymers as a matrix, will produce the alternative composites that are useful for the industrial world. The initial treatment of coir is expected to produce maximum composite mechanical properties to support the utilization of alternative composites.

From the previous ballistic material study, the composite of coir hybrid still dominantly use the reinforment from Kevlar, carbon and glass fibres. Besides, the usage of coir as the reinforcement is conducted without any chemical and mechanical treatments. The result from the previous research still needs to be improved by giving pre-treatment to the coir both chemically and mechanically. This treatment is intended to increase the material structure of hybrid composite mechanically and ballistically.

The study of fiber fibrillation on impact and flexural strength of coir fiber strengthened with epoxy hybrid composites has been conducted. Coir is soaked in 5% NaOH solution for 5 hours. Then fiber is pprocessed using a blender of 2000 rpm density fibrillation. The length of time the fibrillation varied for 10, 20 and 30 minutes. The volume is consisted of 30% fiber and matrix 70% composited. The composite uses a matrix of epoxy by hand lay-up method. The implemented tests are impact and flexural tests. The test results show fiber fibrillation treatment can improve the composite mechanical properties. The highest impact and flexural strength, 24.45 kJ/m^2 and 87.91 MPa were produced with fiber fibrillation for 10 minutes. The composite hybrid reinforcement with coir fiber and synthetic

fiber should be studied to obtain new ballistic material that has a proper bullet-proof, light, affordable and easily recycable [13]. In addition, another impact device controlled electronically using a solenoid has been developed have the potential to replace the conventional one [14].

The state of the art in the study is material panel ballistic that made of polymer composite reinforced with coir. The engineering of composite hybrid material is aimed in producing light material panel and bulletproof. This innovation of technology is to secure a structure which is strong, light and safe. This innovation cannot be sepated from the effort of technology development in producing the green and affordable ballistic material. It is also intended to reduce the dependences of synthetic fibre that is not eco-friendly.

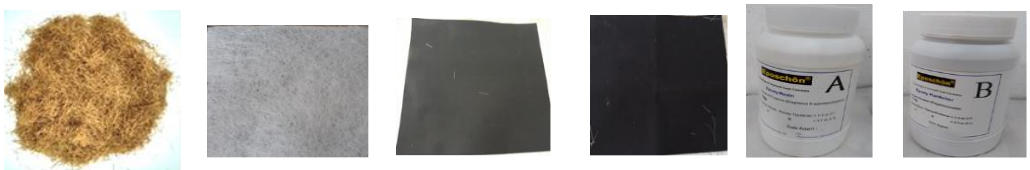
This study need to be done because the main material of ballistic panel or the product of national weapons are still imported with high price and many other requirements of buying terms, this condition makes the material become hard to afford. For that reason, it is necessary to find the alternative materials. One of them is hybrid composite. Coir is one of natural fibers that potentially can be made as reinforcement fibers in composite material. Furthermore, the coir is available in sufficient amount, it also contains high cellulose. Natural cellulose is generally structured by fibril micro which has some advantages in mechanical characteristic.

The objective of this research is to develop the ballistic material from composite hybrid reinforcement with coir and synthetic fibres. In particular, this study is aimed to obtain the physical, mechanical and durability of ballistic material from epoxy hybrid composite which is reinforced by coir and synthetic fibres.

2. Experimental

2.1. Materials

Reinforcement materials consist of coir fibers, which were collected from local resources in Aceh, E-glass fibers, rubber and fabrics (Figure 1). Alumina (Al_2O_3) with 99% purity is applied as a filler. As a matrix, the epoxy resin is used. The Eposchon type A for epoxy resin (bispenola epichlorohydrin) and type B for epoxy hardener (polyaminoamide) with a ratio of 1: 1 were used. The epoxy resin is supplied by PT. Justus Kimia Raya-Indonesia.



Coir E-glass Rubber Fabrics Epoxy resin

Figure 1. Reinforcement materials and matrix

2.2. Microfibrillation of coir fibers

Coir fiber is sorted for uniformity in diameter and cut for 10-20 mm. Pretreatment is done by boiling fiber in a 5% NaOH solution at temperature of 80 ℃ for 10 minutes. The fiber that has been decreted is then carried out by the fibrillation process. The process of fiber fibrillation is carried out by semi-mechanically, using a high-speed blender. Coir fiber is blended at 20000 rpm for 10 minutes. This process aims to reduce fiber diameter. Fibrillated fibers are then washed with distilled water and dried for 3 days before composite molding [13].

2.3. Hybrid composite fabrication

Composite materials were fabricated by hand lay technique at room temperature. Epoxy resin, alumina and hardener were mixed in a bowl to prepare the matrix materials. A well-mixed mixture of matrix

and coir was poured into the mould. The first layer composition (Coir fiber + Alumina), with the percentage of alumina as much as 5% of the weight of epoxy. Based on the volume fraction of coir and matrix are 30:70. Hybrids composites reinforced by coir, alumina, E-glass fiber, synthetic fabrics, and rubber (Figure 2).

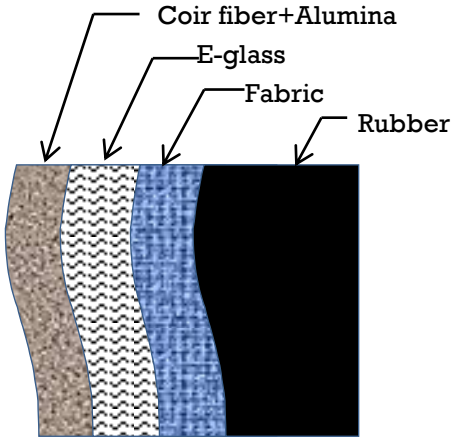


Figure 2. Design of hybrid composites reinforcement

2.4. Testing of the composites

Physical and Mechanical Test

Tensile and impact test are done for the mechanical test, while for physical test the density measurement is conducted. The specimen for tensile test is formed based on ASTM D 3039 standard (figure 3) and impact test is carried out according to ASTM D 6110-02 standard.

Ballistics Test

Ballistic test is conducted by using shotgun, type Glock HS9 and Revolver. The bullet used has 9 mm diameter , and it is jacketed lead type (bullet with tipped copper) and lead bullet (bullet with top of tin) with range of fire 20 m and 25 m. The test of Ballistic is carried out in the firing range of Mobile Brigade Corp of Indonesia National Police in Lhokseumawe.

3. Results and Discussion

The treatment of fiber with NaOH and followed by a fibrillation process using a high-speed blender can change the dimensions or morphology of the coir fiber. After the fibrillation process, the fiber diameter is reduced to 40%. It will improve the matrix-fiber interface. This phenomenon will increase the properties of the composite. Hybrid composite reinforced by coir and other reinforcement (E-glass, rubber and fabric) has been formed into ballistic test specimens. The result for mechanical and physical test of hybrid composites strengthened with coir and synthetic fibers (E-glass + fabric +rubber) is displayed in table1.

Table 1. Mechanical properties of hybrid composites

Hybrid composite reinforcement	Impact energy (joule)	Impact strength (kJ/m^2)	Tensile strength (Mpa)	Density (g/mm^3)
(Coir fiber + Alumina) + E-glass + fabric +rubber	18.8	58.02	76	0,00122

Based on the protection level, the ballistic panel can be categorized to several types as National Institute of Justice standard-0101.04 [15].

Ballistic durability is the main factor to the bullet-proof panel. The ballistic test has been conducted with shotgun type Glock HS9 and Revolver. The bullet has 9 mm diameter, and the type of bullet are jacketed lead and lead bullet with the firing range for 20 m and 25 m. If the composite hybrid panel can detect the bullet, it means that the panel has reached level IIA and II. Result of ballistic test from the both types of bullet is shown in Table 2.

Table 2. Ballistic test Result

Shotgun Type	Bullet Type	Firing Range (meter)	Explanation
Glock HS9 	Jacketed lead	20	Perforated
		25	Perforated
Revolver 	Lead bullet	20	Unperforated
		25	Unperforated

Figures 3 and 4 show the condition of composite hybrid shooted with pistol Glock, jacketed lead 9 mm bullet, and firing range for 20 m and 25 m. Figure 8 displays the condition of firing using jacketed lead 9 mm bullet in 20 m firing range. The panel of composite hybrid is perforated. The same result also occurs in firing range 25 m (figure 4).

front Back

Figure 3. Form of composite hybrid damage (pistol Glock, *jacketed lead* 9 mm bullet, firing range 20 m)

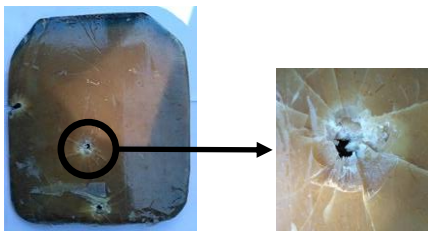


Figure 4. Form of panel composite hybrid damage (pistol Glock, jacketed lead 9 mm bullet, firing range 25 m)

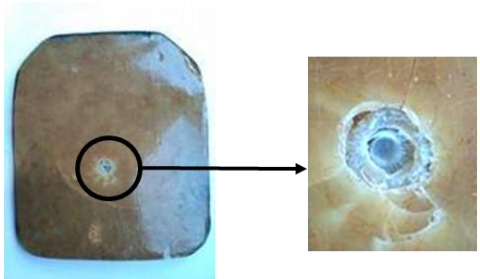


Figure 5. Form of composite hybrid panel damage (pistol Revolver, lead bullet 9 mm, firing range 20 m)

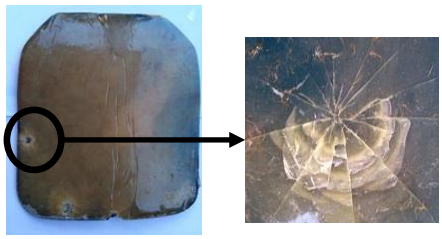


Figure 6. Form of backside composite hybrid panel damage (pistol Revolver, *lead bullet* 9 mm, firing range 25 m

Figures 5 and 6 show the condition of composite hybrid shouted with Revolver, lead bullet 9 mm, firing range 20 m and 25 m. Result of firing from both of the range show that the composite hybrid panel unperforated. The bullet is planted in the panel and the panel is fracturing.

The reinforcement of the panel can be determined by observing the depth of penetration of the bullet or the bullet changing from after fired. When the bullet hit the panel, the bullet is cached by the reinforcement in fiber form structured in the composite hybrid. Those fibers adsorb the impact energy forwarding to each side as "mushroom". Then the energy is absorbed by each layer sequentially until the bullet stops.

On the bullet fire to the panel, the hit occurs in such huge energy absorption process. This absorption of energy will be turned to various material responses such as plastic deformation, hysteresis effect, and inertia. Inertia effect is the ability of a material to remain unchanged when force is given. When load energy given is bigger than the higher strain rate of the material, the material cannot stay in shape and finally it will break and perforate. From the firing test, it is shown that the composite hybrid has better and safer endurance if it is shouted with lead bullet because the bullet remains in the panel (unperforated).

4. Conclusions

Ballistic material from composite hybrid with coir, E-Glass, synthetic fabric, and rubber as the reinforcement has successfully developed. Result of the mechanical and physical test give the tensile strength for 76,00 MPa, impact strength for 58,02 kJ/m^2, and density 0,00122 g/mm^3. The panel of composite hybrid is perforated in firing range 20 m and 25 m using pistol Glock and *jacketed lead* 9 mm bullet. The panel of composite hybrid is unperforated when it is shooted in the same firing range using pistol Revolver, *lead bullet* 9 mm bullet. The result of ballistic test shows that the composite hybrid material can detent the bullet in level IIA.

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