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RAMIE FIBER REINFORCED EPOXY (RFRE) COMPOSITE FOR BULLETPROOF PANELS

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ABSTRACT

The purpose of this research is to make RFRE composite as a bulletproof panels level IIIA National Institute of Justice (NIJ) standard. Ramie fibers be wattlet into woven roving using loom machines. The woven molded into composite using hand lay up method. The mold 15 x 15 x 5 cm^3 be given epoxy as a based. The woven fiber put into mold so that all of ramie fiber wetted by the matrix epoxy to be 15 x 15 x 2 cm^3. The second layer until fourteenth layers such as first and second layer. Panel clossed the mold and pressed so that produce RFRE 60% volume fraction. The projectile caliber 9 mm, 124 gram FMJ RN used for ballistic test. The result of ballistic test shows that the projectile speed just before tauching the panel 1433 ft/s. The projectile could not penetrate panel and got stuck in the panel. The projectile deformed up to 68%, so the panel able to withstand the projectile penetration in level III-A NIJ standard.

Keywords: RFRE composite; ramie fibers; epoxy; level III-A.

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1. INTRODUCTION

1.1. Background

The most popular basic material of bulletproof panels are kevlar and ceramics. Wambua et al. reveal that the weakness of bulletproof panels based on synthetic polymer composite and ceramic are not environmentally friendly and high cost production [1]. Meanwhile, Low et al reveal that the reinforced composite by natural fibers as an alternative materials is environmentally friendly and low cost production [2]. So, it is very urgent to develop new alternative bulletprof material from natural fibers.

The polymer composite reinforced with synthetic fibers is an alternative material. It is populer as bulletproof panel because it has high mechanical properties and low density compared convensional metal by Nam and Netravali [3], [4]. The most synthetic fibers widely used for bulletproof panel are kevlar and aramid. The synthetic fibers material widely used for primary equipment for defense system. The main disadvantage of composite bulletproof material using synthetic fibers and ceramic is high cost compared using metal [1].

Many researchers investigated the fiber ability as a bulletproof panel, i.e. kevlar reinforced epoxy and carbon steel 6061-T6 by Ramadhan et al. [5], Aramid by Otham and Hasan [6], kevlar reinforced Al_2O_3 composite by Thalib et al. [7], kevlar helmet by Tham et al. [8].

Feasibility of natural fibers research as a reinforcement in bulletproof polymer composite was done by Wambua et al. [1]. He used polypropelene as a matrix reinforced flax, hemp and jute fibers by fragment simulating projectiles. The ballistic properties of flax, hemp and jute fabric reinforced polypropylene composites processed by hot compression moulding. The composites ballistic limit was determined by subjecting the material to ballistic impact loading by fragment simulating projectiles using block manometric cannon interchangable gun. The result showed that composite polypropelene reinforced flax more ability to absorb impact energy of projectile than hemp and jute fibers. The phenomenon of delamination failure, broken fiber, and shear failure were appear in the composite panel reinforced flax, jute and hemp fibers. The composites failed by shear cut-out, delamination and fiber fracture. He found that the ballistic properties of hemp composites increased significantly when a mild steel plate was used as facing and backing.

Ramie fibers is one of natural fibers which having very good mechanics characteristic, i.e.

tensile strength 849MPa and toghness 16MPa by Munawar et al. [9]. The next previous research by Marsyahyo et. al. [10], he developed the prototype of composite epoxy reinforced ramie fibers as a bulletproof level II-A-II NIJ standard. He gave the ramie fiber surface treatment and identified mechanical and physical properties. The compatibility of ramie fibers and epoxy matrix is good. The contact angle formed droplet ramie fibers about 35^o-55^o. The ballistic performance showed that 5 laminas of ramie, vf=40%, thickness 16,73 was able to withstand projectile penetration level II NIJ standard. The type of bullet was full metal jacket, velocity 223-243 m/sec NIJ standard. The panel damage occured in layer number I, II and III, while in layer IV and V just cracked.

Next previous study was Mukhammad and Jamasri [11] investigated the optimal thickness of composite epoxy-ramie fibers as a bulletproof panels level II NIJ standard. They applied ramie fiber as a composite reinforcement for bulletproof panel. There are three kinds of bulletproof panel composite epoxy-lamina ramie (vf=60%) which lamina number i.e. 12, 14 and 16 laminas. The composite panels 12 laminas ramie [0/90/0/90/0/90/0/90/0/90/0/90] (thickness 20 mm) able to withstand the bullets penetration but still rupture and delamination in back side of panel. The panel ramie [0/90/0/90/0/90/0/90/0/90/0/90/0/90] (thickness 23,3 mm) 14 laminas ramie vf=60% did not rupture and delamination. The composite panels 16 laminas [0/90/0/90/0/90/0/90/0/90/0/90/0/90/0/90] and has thickness 28,2 mm did not rupture and delamination. The test result of mechanical composite vf=60% epoxy-14 laminas ramie was good, i.e. the tensile strenght 125,67 MPa, impact test 58 kJ/m^2. The optimum thickness of ramie lamina reinforced epoxy composite was 23,2 mm, i.e. 14 laminas of ramie, vf = 60%. The panel laminas 12 was not the optimum thickness because rupture and delamination occured, which potential harm to the user. The panel was not be able to withstand projectile penetration level III and IV. One of the causes of the failure is projectile sharpness which is lacerating the fiber woven. Therefore, it need hard layer i.e. above 60 HRC for projectile blunting material of projectile from the AA6082-T4 aluminum, Borvik et al. [12]. The layer addition of hard metal in the ramie fiber composite could blunt the projectile.

National Institute of Justice 0101.04 standard is one of standard governing the ability of bulletproof product. This standard clasifies product bulletproof capabilities based on the level from level I, II-A, III-A, III, and IV. Each level showed type and speed of projectile.

Ramie fibers drawn from the stem of ramie plant is one of natural fibers which has potential to develop to be composite. Currently, the ramie plant widely cultivated by farmers in Indonesia. For examples, Koperasi Pondok Pesantren Darussalam (Kopontren Darussalam), Garut, West Java have ramie garden 300 ha and Ramindo Berkah Persada Sejati, Wonosobo, Central Java.

Marsyahyo [10] tried to increase the strengh of composite epoxy based on ramie fibers added steel plate. There are two kinds of specimen, i.e. steel plate flanked 8 composite laminas epoxy-ramie vf=50%, i.e. 0/90/0/90/St/90/0/90/0/St and 10 composite lamina epoxy-ramie-steel plate placed rearmost vf= 47%, i.e. 0/90/0/90/0/0/90/0/90/0/St. Both kind of panels tested using ballistic level IIA and IV. The ballistic performance showed that the hybrid epoxy-lamina ramie-steel plate composite was able to withstand projectile penetration level II NIJ standard which has phenomenon delamination in center of panel occured. The panel was not able to withstand projectile penetration level IV NIJ standard which has phenomenon translucent failure.

Mukhammad and Jamasri [11] tried to know the eligibility of hybrid composite epoxy-10 laminas ramie-number variation SS 304L screen mesh as a bulletproof panels level II NIJ standard. Ballistic result showed that all panel hybrid composite epoxy 10 laminas ramie which has variation 4, 8 and 12 SS304L screen mesh and the average thickness 17.7 mm, 18.5 mm and 19.3 mm respectively were not abble to withstand projectile penetration level II NIJ standard. The phenomenon of failure were translucent failure, rupture, and delamination in both side of panel. The addition of steel plate 1.5 mm in the hybrid composite polypropelene-natural fibers (flax, jute and hemp)-steel plate low carbon in front side increased speed V50 50%. The addition of steel plate 0.8 mm in front and back side of composite hybrid increased speed V50 109% compared bulletproof composite-natural fibers, i.e. flax, jute and hemp by Wambua et al. [1].

All previous research of ramie fiber as a reinforcement, the ramie fiber used to warp and weft of woven roving. It was expensive and difficult in process because we should make the ramie yarn. In this research we used cotton fiber as a warp and ramie fiber as a weft to increasing the power of webbing.

The first subtitle opens with an introduction that presents the specific problem under study and describes the research strategy. The first subtitle opens with an introduction that presents the specific problem under study and describes the research strategy. The first subtitle opens with an introduction that presents the specific problem under study and describes the research strategy. The first subtitle opens with an introduction that presents the specific problem under study and describes the research strategy [1].

1.2. METHOD

Material

The material of composite is epoxy resins EPR 174 as a matrix and woven roving of rami fiber as a reinforcement. Ramie fibers is one of natural fibers which having very good mechanics characteristic, i.e. tensile strengh 849MPa and toughness 16MPa. The woven roving consists of ramie fiber as weft and cotton fiber as warp. The cotton yarn used in this research is 12s/3.

Preparation for Ramie Fibers

Ramie fibers produce in Wonosobo, Central Java, Indonesia. The preparation of ramie fibers start from selected 6 month old ramie plant (*boehmeria nivea*), see Fig. 1. The ramie plant already bloom. Ramie harvest time is 5-6 times per year. Ramie tree will grow back after harvested everi 3 month. But, the ramie tree must be destroyed after five years to be replaced a new ramie plant. The colour of skin stem is brown, see Fig. 1(a). Ramie plant felled and cleared ramie leaves. Ramie plant collected and cut 1-1.5 m from stem.

Decortication the ramie plant for separate skin and the rod. The skin has ramie fibers. The ramie fibers is still bound each other by gum layer so that in bundles shape, called raw jute (china grass). Decortication process ramie in 24-28 hours after logging process.

Fig.1. Processing of ramie plant to ramie fibers (a) ramie bloom (b) brown rod (c) rod and leaves (d) decortation (e) ramie fibers (f) china grass

The Weaving Process of Ramie Fibers

We selected the uniform ramie fibers for one layer. Raw ramie fibers was cutting in 16 cm and bundled as bonds likes in Fig. 2a. For consistancy the number of fiber, each bond of ramie wighed between 4-5 gram. Fibers density is 3,2-4 gr/cm. It requires precision and patience in preparingthe bond of ramie fibers. The bond of fiber become weft in the weaving process using loom machines and the cotton yarn as warp, see Fig. 2b. Weaving product as woven roving sized 15 x 15 cm as a Fig. 2c. We should ensure the uniformity woven ramie fiber product before used it to be weft. The input rovings designed to give controlled excellent lamina properties an wet-out. The contruction was bi-directional (0/90) reinforcement and give the strength of continous filaments.

Fig.2. Processing ramie fibers to be composite reinforcement
(a) ramie fibers cutting process (b) cotton yarn (c) woven ramie fiber (lamina)

Manufacture Process of RFRE Composite

Woven roving of china grass processed deguming in NaOH 5% for 2 hours to remove gum and pectin, after that the sun drying. Composite molding process beguns with water content reduction of woven fiber.

The research material used to make RFRE were epoxy resin and ramie fiber woven. Epoxy resin is thermosetting polymers are already used in various application, i.e. machining component, otomotive, tank, aircraft component and so on.

The composition of fiber must be arrange to get a same strength in all direction. Based on previous study, the arrangement was [90/0/90/0/90/0/90/0/90/0/90/0] for 12 laminas. Next step is molding press method to make RFRE panel. We used hand lay up for molding press method. Completely process of this molding can be read in the result section.

2. RESULTS AND DISCUSSION

Firstly we will discuss about the arrangement of ramie fiber layer composition and molding process to produce panel. The layered arrangement of woven roven was [90/0/90/0/90/0/90/0/90/0/90/0/90/0], see Fig. 3. This arrangement aims to have a same strength in the direction 0 and 90 degree. The woven fiber put in the oven until 110^{o}C for 10-15 minutes until water content 10-14%. Next, the woven fiber molded into composite using hand lay up and molding press method.

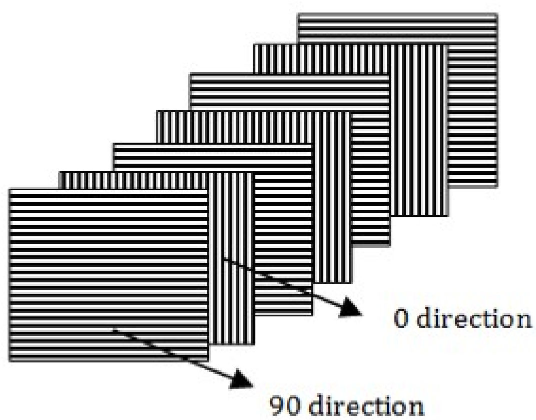

Fig.3. Layered arrangement

The mold 15 x 15 x 5 cm^3 be given epoxy as a based. After that, the woven fiber put into mold so that all of ramie fiber wetted by the matrix epoxy. The second layer of ramie fiber put into mold so that all of ramie fiber wetted by the matrix epoxy. We did the third layers until fourteenth layers such as first and second layer. After the fourteenth layer, clossed the mold and pressed, see Fig. 4(a), so that produse RFRE 60% volume fraction and thickness 20 mm, see Fig. 4(b).

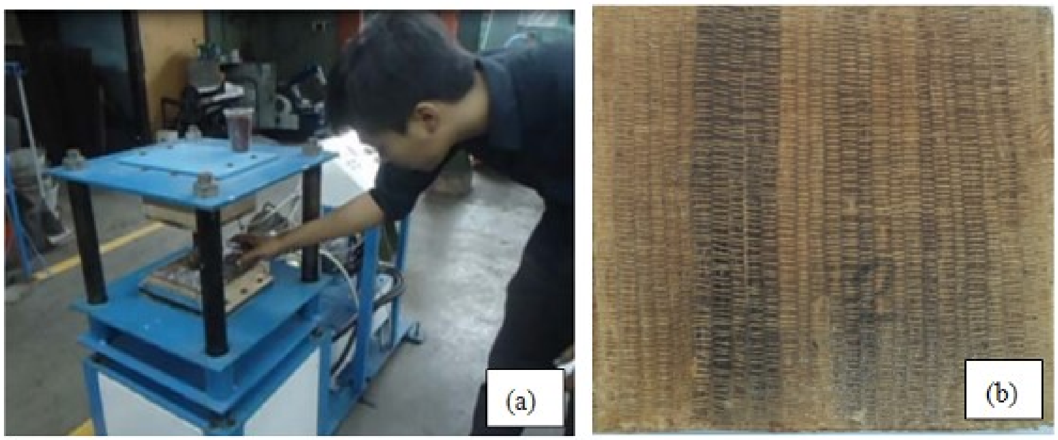

Fig.4. Manufacture process of RFRE composite

The volume of panels is 15 x 15 x 2,2 cm^3 equal to 495 cm^3. The volume of fiber is 60% x 495 cm^3 equal to 297 cm^3. The data showed that the fibers density is 1,4 gr/cm^3. So, the total weight of fiber is 297 cm^3 x 1.4 gr/cm^3 equal to 415.8 gr each panel. The weight of panel is 580 gr, so the density of panel is 580 gr devide 490 cm^3 equal to 1.17 gr/cm^3.

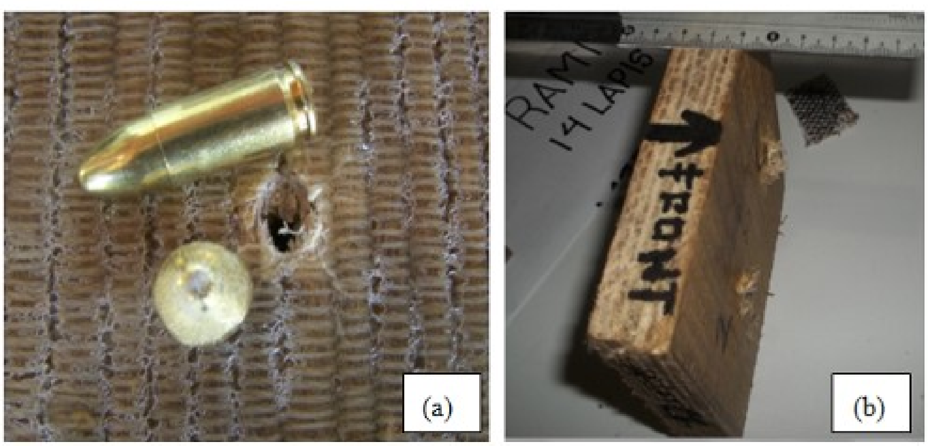

Fig.5. Ballistic test result for fist test

Chronograph measurement result showed that bullet full metal jacket 124 gram moved 1433 ft/s before tauching the RFRE panel. This speed in accordance with the NIJ standard level III-A. Based on NIJ standard level III-A. Research result showed that projectile could not be able to withstand the RFRE but stuck inside, see Fig. 5(a) and 5(b). Ballistic test was repeated on the panel using same bullet. The speed of bullet was 1431 ft/s. The result still same, i.e. the projectile could not be able to withstand the RFRE but stuck inside, see Fig. 6(b) and 6(c).

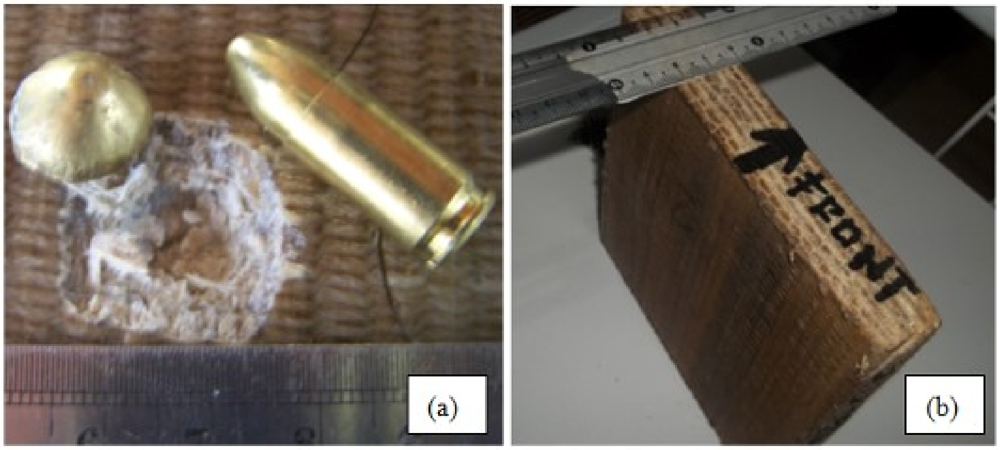

Fig.6. Ballistic test result for second tes

Focus on the projectile, it deformed up to 68%, see Fig. 7. The deformation of projectile was variative. The maximum deformation was 68%, initial length was 19 mm after hit the composite panel to be 6 mm. Based on the data above, we concluded that the panel able to withstand the projectile penetration in level III-A NIJ standard.

Fig.7. The projectile deformed

3. EXPERIMENTAL

Ballistic test was done according to NIJ standard USA, in which protection capabilities of bulletproof material classified lower level to higher level, i.e. I, II-A, II, III-A, III, IV and special type. Each level shows type and projectile speed which should be detained panel. Level specification include weapon type, bullet type, and shooting number allowed each panel, Sorrentino et al. [13]. This research using NIJ standard level III-A, gun, bullet specification weight 124 gram, dimension 9x19 mm, see Fig. 8. The composite panel put in the holder can be locked so it can not move. Composite panel flanked by two chronograph in front and back side. Chronograph put in front of panel to measure the projectile speed before touching the panel and put in back of panel to measure the projectile speed after through the panel.

Fig.8. Ballistic test setting
(a) RFRE composite which able to withstand the projectile (b) Projectile (c) Magnum gun

4. CONCLUSION

This study investigates the RFRE capabilities to ballistic test NIJ standard level III-A. The following conclusions are derived from this study:

1. This research successfully developed bulletproof ramie fiber reinforced epoxy
2. The woven roving of ramie fiber could function as reinforcement composite.
3. The composite epoxy reinforced ramie 14 laminas RFRE volume fraction 60% able to withstand the projectile penetration level III-A NIJ standard.

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