Preliminary study of fragment simulating projectile on epoxy-ramie composite

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Abstract. This research is a preliminary study to determine the feasibility of the ballistic test equipment using fragment-simulating projectiles (FSP) and the ability of the rami-epoxy composite against bullet penetration. Tests have been conducted in which FSP were fired at epoxy ramie composites. Ballistic test equipment was equipped with a chronograph and high speed camera. The composites were manufactured using manual hand lay-up compression moulding 60% volume fraction. Based on the high speed camera result shows that the FSP projectile when crashing into the specimen was not in perfect position (tilted) and the ramie-epoxy composite was fail in 6, 9, and 12 layers.

1. Introduction

In line with technological development in weaponry, hence the use of products for body protection (body armor) is highly developed and varies according to the type of weapon and needs. One body protection that is widely used in the military world is bulletproof panel. Furthermore, the desire to make transportation easier makes composites as an alternative material for bulletproof panels.

Ramie fiber is natural fiber has very good mechanical properties, i.e. tensile strength 849MPa [2] and has a potential as a reinforced fiber in bulletproof panel. Ramie trees has been successfully cultivated by PT Rabensa Wonosobo from 1999. The feasibility of ramie fiber as a base material of bulletproof panel was tested by researcher team using a optimal thickness formula for level II (2010) [3].

There are studies that are interested to enhance the strength and stiffness of desired composites of cellulose micro/nano fillers or fibers in polymers [4-7]. Lately, adhesive bonding is one of the most used techniques in joining materials. Wide range of materials such as polymers, metals, ceramics and the combination of those could be joined by adhesives [8-9]. The common adhesive used in industry is epoxy resin due to its high strength, high modulus elasticity, low creep and good thermal strength [10]. However, the structure of this type of polymer can cause brittleness where also has low resistance to
crack initiation and propagation properties [11-12]. It is a challenge for researcher to produce high properties of the composites made of polymer combined with natural fibers.

The research aim is the characteristic study of fragment simulating projectile on epoxy ramie composite. This research is a preliminary study to determine the feasibility of the ballistic test equipment using FSP and the ability of the rami-epoxy composite against bullet penetration.

2. Methods

The research material used in this research is epoxy-ramie composite. Epoxy resin used as binder matrix, ramie’s woven fiber lamina as shown in Figure 1. Epoxy matrix is a thermosetting polymer that has been used in various application, as such as machinery component, automotive, tank, aircraft component. The epoxy resin were used in this research are eposchon–bakelite EPR174 Bisphenol A-epichlorohydrin and its hardener eposchon–Versamide 140 Polyaminoamide and was supplied by PT Justus Kimia Raya. The composition between epoxy and hardener were 1:1.

Figure 1. Research material: (a) ramie fibers  (b) epoxy

Basic selection of ramie fiber as a research material is environmentally friendly, abundant availability, has good mechanical strenght. Ramie fiber used in this study comes from PT Rabersa Wonosobo.

The first process was weighing ramie woven. This process to know the volume fraction of panel. Figure 2 shows the weighing of ramie woven process. The woven process used manual woven machine or Alat Tenun Bukan Mesin (ATBM) in Gumplong, Sumberagung, Sleman. Figure 3 shows the manual woven machine. Figure 4 shows the woven result.

Figure 2. Weighing of ramie woven process
Epoxy ramie composite made by method hand lay up then press mold. Composite will made in volume fraction 60% with 3 variation of layer arrangement (6, 9 and 12 layers) , see Table 1. Ramie fiber layer arrangement in the molding 135 mm x135 mm with various thicknesses, next moistened with epoxy using the hand lay up method.

| No | Stacking of sequences | Number of layers | Thickness | Weight (g) | Density (g/cm³) |
|----|-----------------------|------------------|-----------|------------|-----------------|
| 1  | 0/90/0/90/90/0/90      | 6                | 5.8       | 125        | 1.18            |
| 2  | 0/90/0/90/90/0/90/0   | 9                | 7.9       | 170        | 1.18            |
| 4  | 0/90/0/90/0/90/0/90/0/90/0/90/0/90           | 12              | 9.4       | 207        | 1.20            |

The molding pressed using press machine until volume fraction of fiber 60%. After 24 hour. Molding will open and composite ready to ballistic test. Figure 5 showed the dies of panel and Figure 6 showed the molding process used press machine.
Figure 7 shows the ballistic test machine. The velocity of bullet before and after through the panel measured by chronograph. Chronograph put infront and back of the panel. The video of bullet recorded by high speed camera. Figure 8 shows the process of bulletproof measurement, operated by technision. The bullet used is made of brass commercial material with the dimension shown in the Figure 9.
3. Result and Discussion
Ballistic test recorded by high speed camera showed in Figure 10-11. The bullet penetrated epoxy-ramie for 6, 9 and 12 layers. The position of bullet in three condition, i.e horizontal, tilted and vertical.
Figure 10. Bullet proof before attach the panel

Figure 11. Bulletproof attached panel
The velocity of bullet before and after penetration for all layers can be seen in the Table 2. The velocity decrease significantly after penetrate compared before penetrate. Using high speed camera, the bullet movement can be captured on camera. The picture of bullet movement can be seen in Figure 10, 11 and 12. Figure 10 shows the bullet before crashing into the panel. Figure 11 shows the bullet in crashing the panel and Figure 12 shows the panels after the bullet was pierced. The movement of bullet before and after hitting a panel in some condition, i.e horizontal, tilted and vertical condition. The velocity of bullet after penetration depend on the velocity of bullet before penetration, epoxy-ramie’s layer and the position of bullet before penetration.

| No  | Lamina 6 | Lamina 9 | Lamina 12 |
|-----|----------|----------|-----------|
|     | V before (m/s) | V after (m/s) | V before (m/s) | V after (m/s) | V before (m/s) | V after (m/s) |
| 1   | 241      | 76.4     | 240        | 80.9        | 243          | 79.3         |

Table 2 shows the velocity of bullet before and after hitting a panel. The bullet penetrate a panel but the velocity was decrease significantly. The velocity of bullet before hitting panel was around 240 m/s and after hitting was around 80 m/s for 6, 9 and 12 layers. Composite thickness should affect bullet penetration resistance, the thicker of panel with the same volume fraction, the higher the resistance to bullet penetration. However the velocity of bullet after penetration for panel 12 layers shows faster than others due to the position of bullet before penetration was horizontal. The velocity of bullet after penetration for panel 6 layers shows lower than others due to the position of bullet before penetration was vertical. This can be seen from the macro photo of panel front surface. Figure 13 shows that the composite with 6 layers has shot marks most extensive compared 9 and 12 layers.
4. Conclusion

The method of firing with the FSP system on this equipment unable to control the position of the bullet collision so that the shape of the collision was different. The position of bullet is in three conditions which are in horizontal, tilted and vertical condition. The velocity of bullet depend of the position of bullet before penetration, the velocity of bullet before penetration and the number of panel’s layer. In addition, the epoxy-ramie composite 6, 9, and 12 layers did not able to be bulletproof panel.

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