# Ballistic Performance Investigation

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RESEARCH ARTICLE



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# Ballistic Performance Investigation of Hybrid Ramie-Hard Facing Metal Reinforced Polymer Composite

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This research studied Level III-A-IV NIJ standard ballistic performance of Hybrid Ramie-Hard-facing Metal Reinforced Polimer Composite. Hard-facing metal layers were expected to withstand the sharpness of bullets and residual impact energy absorbed ramie fiber layer. Hybrid biocomposite panels were manufactured by hand lay up-press molding method. The panel had volume fraction of fiber about 60%. Bullet speed before and after penetration were also measured to determine the remaining impact energy that occurs. The panels had been tested according to National Institute of Justice (NIJ) standard balastic testing for Level III-A-IV. The test results showed that Hybrid Composite Panels had a resistant to high impact penetration of the bullet for level III-A but failed to level IV of NIJ standard.



**Keywords:** Biocomposite, Ramie Fiber, Hardfacing, Level III-A-IV.

## 1. INTRODUCTION

Over the last few decades, the search for lighter armor materials with better performance armor materials has continued unabated due to increasing sophistication in the weapons industry.[1] Polymer Matrices Composites (PMCs) have been the focus of modern research for high performance armor materials. They possess excellent mechanical properties such as high specific strength, high specific stiffness, high fracture toughness, increased fatigue life and high corrosion and puncture resistance. In addition, PMCs are popular due to ease of fabrication. Hybridization is one of the effective ways of improving energy absorption capability of PMCs. The behavior of hybrid composites under ballistic impact loading conditions should be well understood.[2]

Many researchers have investigated the response of natural fiber composite materials to ballistic impact.[3] Investigated Preliminary Investigation on Bulletproof Panels Made from Ramie Fiber Reinforced Composites for NIJ Level II, II-A, and IV while.[1] Report on the response of natural fiber composites to ballistic impact by fragment simulating projectiles. Rohen et al.[4] studied Ballistic Efficiency of an Individual Epoxy Composite Reinforced with Sisal Fibers in Multilayered Armor.

The armor systems consist of a number of layers performing a specific role in destroying a projectile and absorbing the impact energy. In general, there can be distinguished hard and soft layers.[5] From the references, no previous study has investigated the natural fiber composite hybrid with high hard-facing material. The function of hard facing material is to destroy of the bullet sharpness. While, the soft layer obtained from ramie composite.

## 2. EXPERIMENTAL DETAILS

The epoxy resin used in this research is eposchon–bakelite EPR174 Bisphenol A-epichlorohydrin and its hardener eposchon–Versamide 140 Polyaminoamide. The composition between epoxy and hardener were 1:1. The Epoxy resin was provided by PT Justus Kimia Raya. The ramie (*boehmeria nivea*) was retrieved from Koppontren Darussalam, Garut, West Java, and then wattle with ATBM in Gamlong region, Yogyakarta. The SMAW Electrode wire used HV 800 and MG DUR 65 that were supplied from Nikko Steel and Tira Austenite. Hard facing materials were manufactured by SMAW process. Stainless steel was 8 mm thick used as a parent metal and was purchased from commercial market.

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**Fig. 1.** Processing of ramie.

(a) (b) (c)

**Fig. 2.** (a) One layer HM welding (b) weld metal on stainless steel parent metal (c) the metal after turning process.

**Table I. Average hardness before and after hardening.**

| Electrode type | Average hardness before hardening (HRC) | Average hardness after hardening (HRC) |
|---|---|---|
| NIKKO steel HV 800 | 32,32 | 53,73 |
| MG DUR 65 | 43,37 | 52,30 |

The processing ramie and ramie fibers woven shows in Figure 1. Ramie fibers were soaked 5% wt NaOH during 2 hours, then dried it naturally. Next, it were weaved by manual weaving tool process (ATBM). It was 100 mm × 100 mm wide, about 3 mm thick and 20 ± 5 gram weight every layer.

Electrode used to made hardfacing material, i.e., Nikko steel HV 800 and MG DUR 65. Welding process of SMAW using

**Table II. Bullets and guns.**

| No. | Stacking of sequence | Speciment code | Hard facing thickness (mm) | Composite thickness (mm) | Composite density (g/cm$^3$) | Reinforced type | Ballistic level |
|---|---|---|---|---|---|---|---|
| 1 | 0/90/0/90/0/90/0/90/0/90/0/90/0/90/0/90 | $C_1$ | 5–6 | 24 | 2,7 | Ramie | IIIA |
| 2 | 0/90/HF/0/90/0/90/0/90/0/90/0/90 | $C_2$ | 5–6 | 29 | 2,4 | Ramie + HV800 | IIIA |
| 3 | 0/90/M/0/90/0/90/0/90/0/90/0/90/0/90 | $C_3$ | 5–6 | 31 | 2,1 | Ramie + HV800 | IV |
| 4 | 0/90/M/0/90/0/90/0/90/0/90/0/90/0/90 | $C_4$ | 5–6 | 31 | 2,1 | Ramie + MGDUR 65 | IV |


**Fig. 3.** Types and sizes of different kinds of bullets.

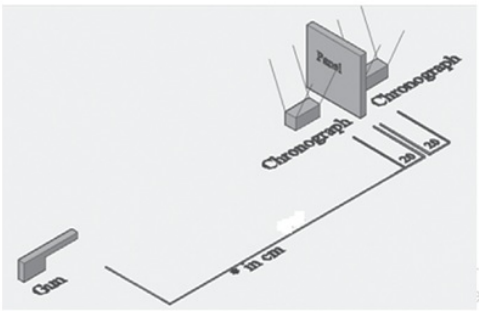


**Fig. 4.** Chronograph setting up.

current 120 A on the stainless steel material. It was welded parallelly and 2 layers (Fig. 2). Then parent metal layer was removed by turning machine process until the main weld metal layer. The thickness of weld metals was aproximately 5–7 mm. Hard facing material hardened to increase the hardness of hard facing materials showed in Table I.

Futhermore, ramie lamina was heated at 110 °C for an hour to decrease moisture. The dimension of the composite is about $100 \times 100$ mm. Volume fraction of the composite had 60% with different thickness which depends on the number of ramie layers, see Table II. The composite was made with hand lay up method and molding pressure.

Guns and bullets used in this research based on NIJ standard level III-A are a magnum gun and FMJ 9 mm 124 gram bullets, see Figure 3. The test level IV using SS2 gun and the projectile had $5.56 \times 45$ mm NATO calibre is shown in Figure 3.

Bullet speed before and after hit the panel were measured using Chronograph Prochrono produced by Competition Electronic. Chronograph were placed 20 cm from bulletproof panel. Bullet proof panel were placed 5 m for level III-A and 20 m for level IV from weapon, see Figure 4. All speciment shot one time from in front of bulletproof panel.

## 3. RESULTS AND DISCUSSION

Ballistic test result for level IIIA and IV shows in Table II. From the table shows that ballistic test in speciment $C_1$ and $C_2$ able


(a) (b)

**Fig. 5.** (a) $C_2$ speciment (b) $C_4$ speciment.

Table III. Ballistic test result of speciment in level IIIA–IV standar NIJ.

| No. | Specimen | Results | Projectile speed before the crash (ft/s) | Projectile speed after the crash (ft/s) |
|---|---|---|---|---|
| 1 | $C_1$ | Not through | 1360 | – |
| 2 | $C_2$ | Not through | 1337 | – |
| 3 | $C_3$ | Through | 3218 | 948 |
| 4 | $C_4$ | Through | 3040 | Not detected |

to withstand the projectile penetration level III-A. Delamination ramie layer using hardfacing so clear, see Figure 5.

The ballistic test shows that specimen $C_3$ and $C_4$ did not able to withstand the projectile penetration level IV. The failure mode was fiber fracture, delamination and shear cutout. The dominant failure modes of the composites suggested similar results to that reported by Wambua et al.,[1] here the delamination occurred between hard-facing layer and ramie layer.

## 4. CONCLUSION

To sum up this experiment, ballistic test level III-A shows that the composite speciment of ramie 14 laminas hybrid with one layer hardfacing material able to withstand the projectile penetration. Also ballistic test level IV shows that all of speciment of ramie 14 laminas hybrid with one layer hardfacing material did not able to withstand the projectile penetration. This failure influenced by fiber fracture, delamination and shear cut-out.

## References and Notes

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