Effect of Rice Husk Ash Filler of Resistance Against of High-Speed Projectile Impact on Polyester-Fiberglass Double Panel Composites

N Koto¹ and B Soegijono²,*

¹Research and Development Defence Ministry, Jati No. 1 Pondok Labu South Jakarta 12450, Indonesia
²Department of Physics, FMIPA Universitas Indonesia, Kampus UI Depok, West Java 16424, Indonesia

*Email: naufal@ui.ac.id

Abstract. This article discusses the process of projectile impact resistance on polyester fiberglass composite panel with ash rice husk as filler. The composite panel consists of polyester resin (unsaturated polyester BQTN 157) and reinforced woven roving S-glass with 3, 5, 7, and 9 wt% rice husk ash variations. Then it was observed the decrease of panel performance into projectile ballistic impact. The structure characterizations of materials were carried out by Fourier transform infrared (FTIR) spectroscopy and X-ray diffractometer (XRD). The impact tests were carried out with calibre ammunition of 9 mm bullet FN gun. The result showed rice husk additions decreased the panel density. There is a chemical interaction influence between the filler and polyester, the composite becomes more crystalline. Then it also showed significant influence of rice husk ash on the strength of composite panels against the high impact of a bullet.

1. Introduction

The armor system is one of the most important requirements in the military equipment under hostile conditions. An armored military vehicle, such as the main battle tank (MBT), allows them to withstand projectile impacts. These armors are usually made of high strength metals, such as homogeneous rolled armor (RHA), titanium or uranium. Instead of primary amour material, there is a secondary armored layer, usually installed as a secondary ballistic protection next to the exterior armor. Secondary protection, also known as a spall liner, is mostly installed in armored combat vehicles (AFVs) to protect onboard crew and equipment from fragmentation released from high-speed impacts. Its main function is to reduce the formation of armor remains. Polymer materials in the form of ballistic laminate composites are usually used as spall liners. Synthetic fibers such as aramid and ultra-high molecular weight polyethylene (UHMWPE) are widely used in ballistic laminating and many engineering applications [1].

Kevlar, the most famous aramid fiber used for protective systems, has high strength, high modulus, and good resistance, which is a desirable trait for ballistic applications. However, this is relatively expensive to produce because it involves a complicated process. Therefore, the use of synthetic fibers in composite reinforced fibers for ballistic protection has been explored. The fiber that is most widely
used but still a little to be applied in body armor materials is fiberglass [2]. Studies have also been carried out on hybrid ballistic composites, such as glass/carbon, kevlar/carbon/glass with polyester [3-7].

In this study, we conducted a fiberglass-polyester composite panel by adding rice husk ash filler [8-14]. Rice husk ash as filler aims to increase the performance of the composite and is environmentally friendly. This composite is expected to be used as a protective material for the body. The making of this composite was carried out by hand lay-up with 7 pieces of fixed fiberglass, polyester mixed with rice husk ash filler in a variety of fractions of volumes 3, 5, 7 and 9 wt% then the ballistic test is carried out according to NIJ Standard [15]. To determine the effect of rice husk ash on the composite bond, the characterization was carried out by using X-ray diffraction (XRD) and Fourier transform infrared (FTIR) spectrometer.

2. Experimental Methods

2.1. Materials

The composite was manufactured in the form of panel which consist of fiberglass, rice husk ash as a filler and polyester resin as a matrix. The constant fraction volume of fiberglass used in this study was a woven roving S-Glass denier 800 g/cm² as it is. Rice husk ash was manually prepared using a table loom. The density of the rice husk ash is 1.40 g/m³. The parameters of rice husk ash are provided. The resin used in this study is unsaturated polyester BQTN 157 with a density of 1.08 g/m³. The organic peroxide resin was cured by using methyl ethyl ketone peroxide (MEKP). The materials were then characterized by means of X-ray diffraction (XRD) PanAnalytical E’xpert Pro and Fourier Transform Infrared (FTIR) Spectrometer Perkin Elmer Spectrum 100 FT-IR. Rice husk ash supplied from the results of processing themselves. Polyester and fiberglass supplied from PT Justus Sakti (Jakarta, Indonesia). Bullet speed is measured by Chronograph Prochrono Digital brand. The gun used for ballistic testing is the Belgian Fabrique Nationale (FN) 9 mm calibre.

2.2. Fabrication of composite laminates

Panel laminated composites of 20 cm x 20 cm size were used for the ballistic testing. The hand-lay-up method was used to fabricate laminates of woven roving fiberglass and rice husk ash as filler in polyester resin. The samples consisted of 7-layers of woven roving fiberglass in the same direction (0/90°). The woven roving fiberglass fabrics were hand-laid up with the polyester + rice husk ash matrix by mixing resin and MEKP catalyst in the ratio of 5%. Two thick mild steel plates were used as a mould (20 cm x 20 cm) in the fabrication process. The composites were cured by applying compression pressure using load which is equal 150 Kg on the top of the mould and cured at room temperature for 48 h. The samples with the variation number of ‘1’ and ‘2’ indicates consisting of one and two panels of double-panel respectively which located in the first and second panels of the configuration when ballistic test, as shown in Figure 1.

2.3. Ballistic testing

The ballistic impact experiment was conducted using 9 calibres (diameter of 9 mm) fragment simulating projectiles (FSPs) with a weight of approximately 8.1 g. Each sample was impacted according to BA 9000 NIJ standards in 2012 on the requirements of body armour system (Type IIIA in armour level). The ballistic testing setup used is shown in Figure 1.

3. Results and Discussion

3.1. The density of the composite

Figure 2 shows the composite with the addition of the fraction of the volume of rice husk ash will reduce the weight of the composite panel. The polyester-fiberglass composite panel shows density 1.613 g/cm³. With the addition of filler 3% volume fraction of rice husk ash of the sample type 3 composite panels, the density is dropped to 1.610 g/cm³. With the addition of 5% volume fraction of rice husk ash, the density is 1.609 g/cm³. Furthermore, the addition of 7% volume fraction of rice husk
ash, the density decreased further to 1.606 gram/cm$^3$. Then in the volume fraction of 9% rice husk ash decreased more to 1.604 g/cm$^3$. The results show that the trend of density values decreases with the increasing of filler number.

The ballistic test for the double-panel composite with 9 wt% filler shows the best results. This indicating that by increasing the fraction of the volume of rice husk ash as filler improves the performance of the double-panel composite as the body armour, the complete results as indicated in figures 5 to 8.

3.2. The X-ray diffraction (XRD)

Figure 3 shows the X-ray diffraction pattern of fiberglass-polyester and rice husk ash-fiberglass-polyester composite. From XRD pattern of Polyester resin, it shows the amorphous pattern. The fraction of amorphous decrease when the polyester is mixed with rice husk asks. Polyester has a peak that shows there is crystalline and the other is amorphous. With the addition of rice husk ash as filler, the amorphous fraction decreased. So the composite becomes crystalline as the amorphous decreases.

There is an effect of rice husk ash as filler in increasing the crystalline phase as from the XRD diffraction pattern which was previously more amorphous. It turned out that from ballistic testing also proved there was an increase in the ability of double-panel composites to resist the rate of bullet projectiles.
3.3. The Fourier transform infrared (FTIR)

Figure 4 show FTIR pattern of fiberglass-polyester and rice husk ash-fiberglass-polyester composites. The transmittance increase when fiberglass and rice husk ash mixed in polyester resin. The presence of filler in polyester resin matrix leads to partly chemical reaction. The vibration of the molecule in the matrix which corresponds to each peak in the pattern seems to decrease in the number. This chemical reaction probably induces the degree of crystallinity of the matrix, as shown in XRD results (figure 3). Reducing the amorphous part will enhance such a homogeneous propagation of energy when the samples exposed to high energy impact. Figure 4 shows the interpretation of FTIR spectrum from these 3 samples that showing the influence of fiberglass on the polyester resin characterized by a shift in wave numbers in the bonding group of O-H and the formation of peaks in the wave number range of 3550 - 3250 cm\(^{-1}\). This influenced by the addition of rice husk ash experiencing the similar manner in the O-H bond function group.

Furthermore, in the wave number range 2980-2850 cm\(^{-1}\), there is a shift in the peak between the polyester resin and polyester-fiberglass resin and polyester-fiberglass-ash resin of rice husk in the C–H bonding function group. However, the spectrum ratio between polyester and polyester - rice husk ash is not very visible in the difference in wave numbers in Carbon-Hydrogen bonds.

At wave numbers 1493 cm\(^{-1}\) there is an aromatic C-H bond for all spectrums of polyester, polyester-fiberglass, and rice husk ash-polyester-fiberglass. Then in the wave number range 1780-1720 cm\(^{-1}\), there is a double bond C=O (ester) for all the spectrums of these three samples. Then at wave numbers 1290-1180 cm\(^{-1}\) there is a single bond C-O-C (ester) for all spectrums of polyester, polyester-fiberglass, and rice husk ash-polyester-fiberglass. Then the double bond of C=C at wave number 979 cm\(^{-1}\) and other aromatic bonds C-H at wave number 697 cm\(^{-1}\) for all three samples. At ester bond of C=O, the intensity peak decreases, this means that the double bond of C=O decreases. Indicating that it can strengthen the polyester bond with fiberglass into a single bond C=O decreases. Also, the existence of a bond from SiO\(_2\) derived from rice husk ash also strengthens the bond. Meanwhile the bond C - H decreases. Thus, the bond changes that occur with the addition of rice husk ash as filler can be seen with changes in such new bond occurred which affect the better performance of the double-panel composite.
3.4. Ballistic test results

Figure 5 shows a picture of ballistic impact from panel 2 of variation 1 (see figure 1 (a)). The fracture area decreases with increasing filler. However, there was an anomaly when fillers are 5 and 9%, the panels are piercing. But there is an effect with the increasing the fraction volume of rice husk ash, the performance of the composite double-panel increased which was marked by a reduced damage area of the matrix.

Figure 6 shows photograph of the ballistic impact of panel 1 variation 2 (see figure 1 (b)). The fracture area decreases with increasing filler. There was an effect of filler with the increasing fraction volume of rice husk ash, the performance of the composite double panel increased which was marked by the damaged area of the matrix to be reduced. The ability of this panel is quite good as indicated by the absence of piercing panels and projectiles stuck in panel 1.

Figures 7 and 8 show variation 3 of panels 1 and 2 (see figure 1 (c)). This shows that the bullet did not pierce through panel 1 and the projectile is stuck. Panel 2 in figure 8 showed the damaged area is decreasing which is indicated by the damaged area matrix of these three variations, variation 3 shows to be the best with 9% wt. rice husk ash filler. So for the best performance to withstand ballistic impacts, double-panel composites must be filled with larger rice husk ash fillers. This has not been discussed in this paper.

![Figure 5. Variation 1: Damage area of the front and back view panel 2 with filler 3%, 5%, 7%, and 9%](image1)

![Figure 6. Variation 2: Damage area of the front and back view panel 1 with filler 3%, 5%, 7%, and 9%](image2)
4. Conclusions
Based on variations in rice husk ash fillers in double panel composites, the density becomes lighter with an increase in volume fraction. Also, this rice husk ash can increase the crystalline fraction that was previously predominantly amorphous which can affect the performance of double-panel composites to be better as a body protector. The ability of the new SiO$_3$ bond derived from rice husk ash also increases composite performance in holding the rate of bullet projectiles.

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