Impact Properties of Nanomodified Basalt Fiber Reinforced Polymer Composites

Nurul Emi Nor Ain Mohammad, Aidah Jumahat, Anthony Arthur, Mohd Fadzli Bin Ismail

Abstract: Basalt fibre reinforced polymer composite is a newly versatile material that has good potential to be used in many applications due to its high specific modulus and strength properties. This paper is aimed to evaluate the response and properties of BFRP composite when it is subjected to low-velocity impact loading. The BFRP laminates were fabricated using vacuum bagging method. The effects of 5, 10 and 15wt% nanosilica particles on density, impact load and energy absorbed were investigated using a drop weight impact test. The damage characteristics of the samples were examined using an optical microscope. The addition of 15wt% nanosilica into Basalt fiber reinforced polymer composite significantly improved the energy absorption properties of the specimens. This suggests that the nanomodified BFRP composite has better damage resistance properties when compared to the pure system.

Keywords: Basalt Fiber, Nanosilica, Fiber Reinforced Polymer, Nanocomposites, Impact properties

I. INTRODUCTION

Basalt fiber reinforced polymer (BFRP) composite is a newly versatile material that has a good potential to be used in many applications especially transportation industries such as aircraft, cars, and trains due to lightweight and high strength properties [1]-[3]. Moreover, basalt fiber exhibited good potential as an alternative to glass fiber for reinforcement polymer composite in various applications. This material could substitute the usage of synthetic fibers [4]-[6]. There is a problem concerning this fiber where the measured strength is significantly lower than the theoretical value due to the presence of surface and internal defects during handling and fabricating of the fibres [7]-[11].

The performance of BFRP composites is usually characterized based on their damage resistance and damage tolerance characteristics. Basalt fiber is one of the natural mineral fibers that have many advantages compared to synthetic fibers, for example, low weight, recyclable and biodegradable [12]. Basalt fiber has a high tensile strength and excellent fiber using conventional process and equipment [13-15]. Besides, basalt fiber also renewable and has the relatively high strength and stiffness and cause no skin irritations [16-19]. Although basalt fibers have these advantages, its brittle nature caused poor impact properties. It opens a new paradigm to modify the polymer matrix to have enhanced properties. Several methods have been used to enhanced mechanical properties of fiber reinforced polymer composite like hybridizing, laminating, short fiber rearranging, z-pinning and stitching [20]

Recently the idea of nanomaterial reinforced polymer composites on basalt fibers has been explored. Ahmad et al [21] reported that the effect of nanosilica in terms of tensile stiffness and strength of the epoxy composites are higher than the neat polymer. However, Jumahat et.al [22] found that the addition of 1, 3 and 5wt% of nanoclay reduced the compressive strength of the epoxy polymer where a weak nanoparticle-matrix interface constrains the capability of shifting load and plastic deformation. This causes the nanocomposites to fail prematurely. Inorganic nanoparticles such as nanoclay and nanosilica have gained wide interest as potential reinforcing material because of their low cost and ease of fabrication [23].

In this study, a series of three different nanosilica weight percentages (5, 10 and 15wt.%) is used to prepare the nanosilica filled woven BFRP composites. The composite laminates were fabricated using vacuum bagging technique in order to observe the energy absorbed by the BFRP composites during impact loading. Drop weight impact test was used to evaluate the effects of nanosilica on impact load and energy absorbed. The results are compared to the pure BFRP composite system.

II. METHODOLOGY

A. Material

The material used to fabricate FRP composite in this study was twelve ply woven basalt fiber as shown in Figure 1 (a). The epoxy and hardener purchased by Miracon (M). Sdn.Bhd. (MIRACAST PART A & B). Nanosilica (Nanopox F400) was mixed with epoxy resin to fabricate nanomodified BFRP as shown in Fig. 1(b).

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Fig 1 (a). Woven Basalt Fiber (b) BFRP composites

B. Fabrication of Unmodified and Nanomodified BFRP

Basalt fibres were used to mix with nanosilica-epoxy resin to form the laminate composites using vacuum bagging technique as shown in Fig. 2. Three different weight percentages of nanosilica-epoxy resin was used, i.e 5wt%, 10wt%, and 15wt%. The nanosilica-epoxy resin was mixed using a mechanical stirrer at 400 rpm for 90 minutes. The hardener was then poured into the nanosilica-epoxy resin. The size of the mould was 300 mm x 300 mm and twelve layers of fibre were laid up onto the nanosilica- epoxy resin. The process was repeated for all three different percentages of nanomodified BFRP composites laminates. The vacuum bagging was then constructed using the impregnated fibre in epoxy-nanosilica resin in order to apply constant pressure and remove all air entrapped in the resin and in between plies. The BFRP composites laminates were left at room temperature for 24 hours to ensure the composite laminates was hardened and properly set. After curing, the BFRP laminate plate was cut into 50mm x 50mm specimens for conducting the drop impact testing.

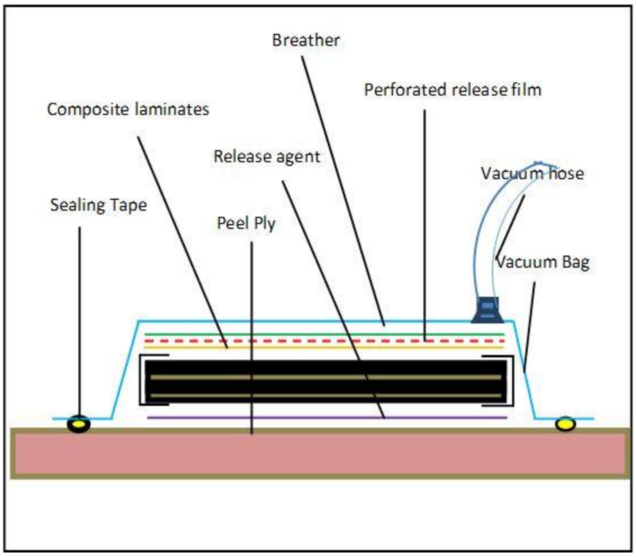


Fig. 2. Schematic diagram of vacuum bagging

C. Density Measurement

The density of the specimens was measured using an analytical balance machine according to the ASTM D792. The measurement was conducted using 250 ml of distilled water with a density of 0.9982 g/cm^3, taken at the temperature of 24ºC. The specimens with dimensions of 20 mm x 20 mm x 5 mm were prepared for this test. Five specimens were tested for each system.

D. Low-Velocity Impact Test

Low velocity impact response of all specimens was evaluated using drop weight impact test, in accordance to the ASTM D7136. The size of BFRP composite laminates was 50 mm x 50 mm with average thickness of 4 mm. An Instron Dynatup 8250 drop tower machine as shown in Fig. 3 is used for the low-velocity impact test. A hemispherical tip striker with the diameter 10 mm and the impactor with 6 kg weight were used. The dropping height of the impactor was adjusted to a maximum constant height of 800mm. The damage pattern of samples after being impacted was examined using optical microscope.

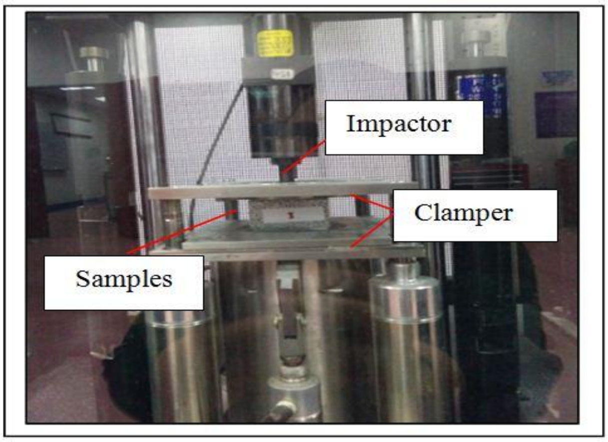


Fig. 3 Instron Dynatup 8250 drop tower machine

E. Optical Microscopy

The localized damage of samples after impact test was inspected using optical microscopy. Failure behaviour of the impacted specimens was also investigated. Both impacted surfaces, front and back, of the composite specimens were observed to examine the relationship between the damaged patterns and the absorbed impact energy levels.

III. RESULTS AND DISCUSSION

This study focuses on the impact response of the unmodified BFRP and the nanomodified BFRP with three different percentages of nanosilica; 5wt%, 10wt%, and 15wt%.

A. Density Test

The density is shown in the Table-I for unmodified and nanomodified BFRP polymer composite. The density of the unmodified BFRP and nanomodified BFRP increased as the weight percentage of nanosilica increased. The nanomodified BFRP with 15 wt% nanosilica recorded the highest density of 1.624g/cm^3.

Table-I. Density of unmodified and nanomodified BFRP

Systems	Average Density (g/cm3)
Unmodified	1.5678
Nanomodified 5wt%	1.5812
Nanomodified 10wt%	1.5952
Nanomodified 15wt%	1.6245

B. Impact Properties

Fig. 4 shows the energy absorption for unmodified and nanomodified BFRP composites. It can be seen that unmodified BFRP exhibited the lowest energy absorption when compared to the modified BFRP which marked 49.228 Joule. This is because the unmodified BFRP has low adhesive bonding strength between the epoxy resin and the reinforcement interface of which weaken the BFRP structures [12]. The nanomodified BFRP specimens demonstrated that the 15wt% nanomodified BFRP has higher energy absorption value compared to the others BFRP structures. Thus, by adding the nanosilica into the BFRP composite enhances the energy absorbed. Consequently, maximum peak load attained.

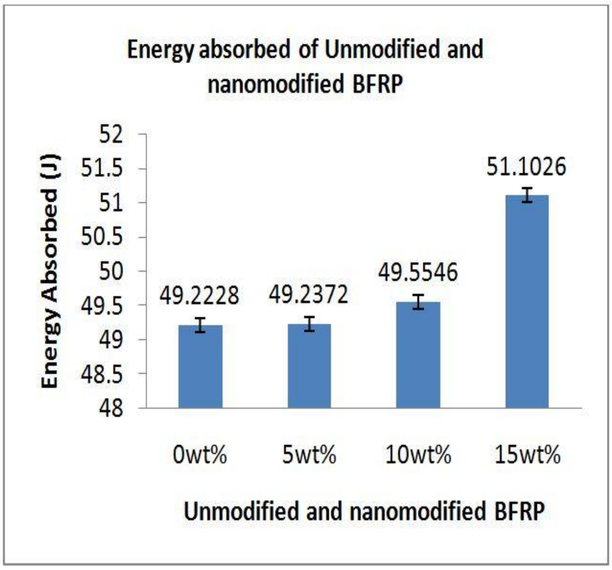


Fig. 4. Energy absorbed of unmodified and nanomodified BFRP

The deflection of the specimens was characterized as the function of nanosilica content as depicted in Fig. 5. The deflection is observed lower for the 15wt% nanosilica in BFRP composite laminates. The interaction between the fibre reinforcement and epoxy resin reveals the strongest with higher ductility when 15wt% nanosilica filler is presence. This means that nanosilica gives a better resistance and stiffness to the resin. Therefore, it provides a better support to the fibre and enhances the strength, toughness and energy absorbed of the composite [13]-[15]. This means that nanosilica gives a better resistance against microbuckling to the fibre and plastic deformation to the matrix, which introduces mechanism of energy absorption during impact [16]-[18].

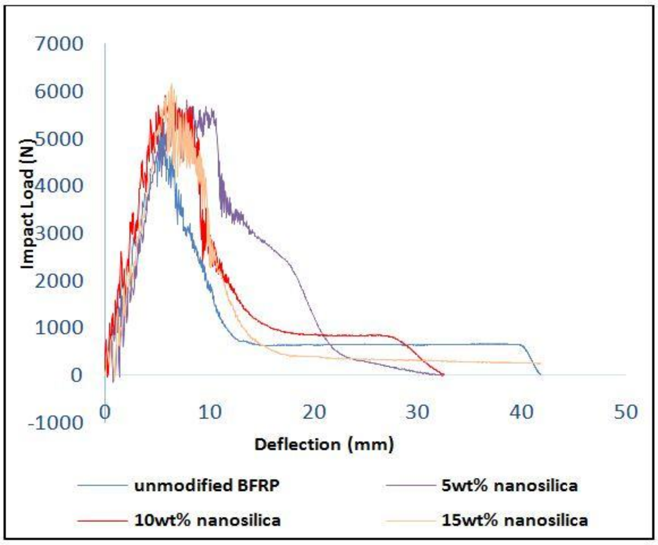


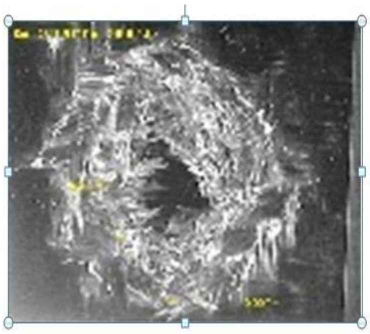
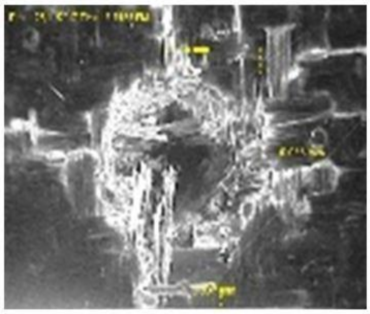
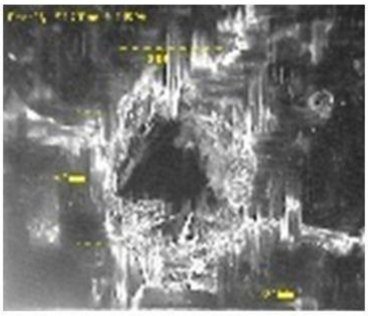
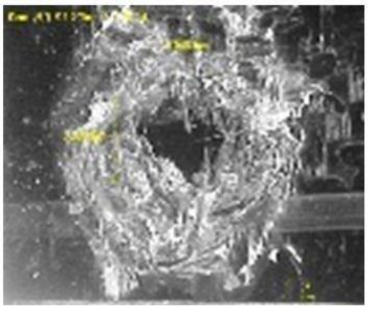
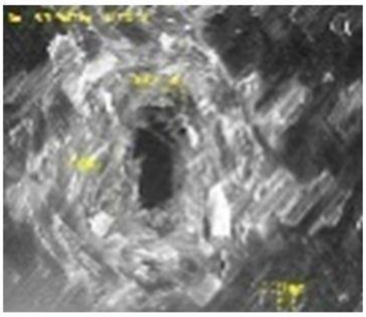
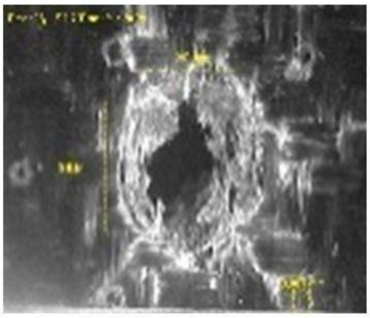
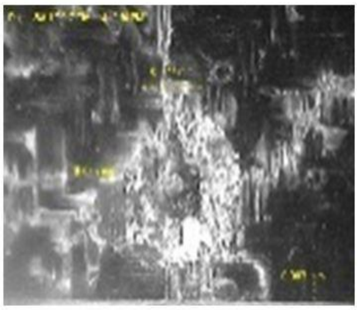
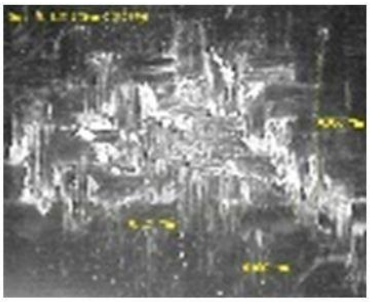
Fig. 5. Load versus deflection of unmodified and nanomodified BFRP composite

C. Damage Characterisation

The fracture surfaces of the impacted specimens were examined using the optical microscope. The damage area of the impacted samples was observed and shown in Table-II. It was observed that the penetration or damage area of the unmodified BFRP are larger than the nanosilica modified composite laminates. It clearly shows that the impacted images of the unmodified, 5wt% and 10wt% BFRP composite specimens were completely punctured at both, top and bottom surfaces.

Meanwhile, the addition of 15wt% nanosilica into BFRP composite offered a better energy absorbed compared to pure (unmodified BFRP). BFRP containing 15wt% of nanosilica showed localized damage and crack propagation from the top to the bottom surface of the specimen. As a result, the BFRP containing 15wt% of nanosilica specimens were not fully penetrated. This shows that the stiffer epoxy matrix, that contains nanosilica, provides more support to the basalt fibres hence absorbs more load when compared to the unmodified system.

Table-II: The damage area of the impacted samples

Systems	Top View	Bottom View
Unmodified		
Nanomodified 5wt.%		
Nanomodified 10wt.%		
Nanomodified 15wt.%		

IV. CONCLUSION

Low-velocity impact test was performed to investigate energy absorption of unmodified and nanomodified BFRP composite. Four different types of samples consisted of BFRP with and without nanosilica epoxy resin were used to compare their energy absorbing capability. The energy absorption of 15wt% nanosilica filled BFRP composite laminate exhibited the highest compared to the others. The stiffness and energy absorption were enhanced with the existence of higher nanosilica percentage in the structure. It can be concluded that the 15wt% nanosilica filled BFRP composites is a promising material with stiffer and tougher properties that could provide a good load transfer and lateral support to the fibre. In addition, the 15wt% of nanomodified BFRP structure has exhibited a good energy absorbing capacity when compared to the other structures. The optical microscopy showed the impacted specimens of the nanomodified BFRP has less penetration compared to the unmodified BFRP.

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