International Journal of Engineering Applied Sciences and Technology, 2021
Vol. 6, Issue 7, ISSN No. 2455-2143, Pages 1-5
Published Online November 2021 in IJEAST (http://www.ijeast.com)

LOW-VELOCITY IMPACT OF WOVEN GLASS FIBER/EPOXY COMPOSITE USING DIFFERENT FIBER ORIENTATION AND NUMBERS OF LAYERS: EXPERIMENT AND SIMULATION

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***Abstract*— -In this work, the synergistic effect of woven structure and asymmetric glass fiber epoxy composites on impact response was studied by experimental and numerical methods based on fiber orientation and number of layers. Three finite element models of G16, G26 and G4 (0/45/90)s, (+45/-45/90)s and (+45/-45)s respectively composites under low velocity impact were established in ABAQUS software and three samples was made same of samples on the finite element model to be tested on drop weight. All samples were manufactured by hand lay-up. Impacts with various energies 3, 9, and 15 J was applied to G16, G26 and G4. The FD curve obtained by simulation is well analyzed with the FD curve obtained by experiments, and the level of the higher values of force obtained from scalar is almost identical to the level of peak force values obtained from experimental tests with the difference in the level of displacement between them. In addition, the highest power obtained for the sample is G26, followed by G16, then G4.**

Keywords— **Composite - Drop-Weight – Finite element**

I. INTRODUCTION

At present, with the growing concerns on energy conservation and environmental protection, composites have been increasingly used in aerospace, transportation, defense, sport, etc. because of their advantages of light weight, high strength/weight, stiffness/weight, good corrosion resistant, anti-fatigue performance, vibration attenuation effect, thermoset able performance, damage safety, design flexibility and easy manufacturing [1].Composite materials are one of the most advanced and adaptable engineering materials. The strength of any composite depends upon volume/weight fraction of reinforcement, L/D ratio of fibers, orientation angles and other factors. The present work focuses on determination of mechanical properties of pure epoxy and random oriented glass fiber (mat) reinforced epoxy at 10% and 20% weight fractions of glass fibers. The numerical results obtained were in good agreement to the experimental results. However increased reinforcement increases the brittleness of material which may results in low impact strength[2]. some of impacts do occur during manufacture, normal operations, maintenance and so on. A list of the studies on the impact response of composite materials and structures can be found in previous literatures [3,4]. There are several studies have been done to investigate the energy absorption by low velocity impact composites of laminated from the design viewpoints of fiber orientation and thickness distribution of layers [5] and woven films[6] In this paper records the impact/ drop weight result of woven E-glass reinforced epoxy composite. The main purpose of study is to measure the impact/ drop weight response of woven E-glass composite materials and also to confirm the experimental results (Drop weight) with simulation results. These composites were formulated by hand layup route. Impact/drop weight tests were performed following ASTM D7136 standard

II. MATERIALS AND METHODS

Selection of material

In this study, composite material was made up by E-glass fiber and epoxy resin with different fiber orientations and number of layers. The biggest advantage of modern composite material is that they are light as well as more in strength. The strength weight ratio of composite material is high. By choosing an orientation of fiber a new material can be made that exactly meets the requirements of a particular application. The new material produced is totally different from base material and its properties are different. The composite material has orthographic structure. Hence its properties are different in all directions. These factors make this adhesive media highly suitable for Hand layup technique. The composite panels were first cured at room temperature for 24 h under ATM. The post-curing were carried out at 80C for 4 h and then cooled to room temperature.

Preparation of composites

There are many composite manufacturing techniques available in industry[7]. Compression moulding, vacuum moulding, pultruding, and resin transfer moulding are few options. The hand lay-up[8] manufacturing process is one of the common techniques to combine resin and fabric components. This process allows manual insertion of fibre reinforcement into a single-sided mould, where resin is then forced through fibre mats using hand rollers. A primary advantage to the hand lay-up technique is its ability to fabricate very large, complex parts with reduced manufacturing times. Additional benefits of hand lay-up process are simple equipment and tooling that are relatively less expensive than other manufacturing processes. All composite specimens were manufactured using hand lay-up process. Three samples of composites, sample one four layers(-45/+45)s(G4), sample two six layers(0/+45/90)s(G16) and sample three six layers(45/-45/90)s(G26) were manufactured from one different type of fabric(E-glass) using hand layup. Different specimens were formulated by hand layup method as shown in Table 1.

Sr. No	Stacking sequence	Designations	Samples No.'s
1	Glass/Glass/Glass/Glass (-45/+45)s	G4	G11
			G12
			G13
2	Glass/Glass/Glass/Glass/ Glass/Glass (0/+45/90) s	G16	G21
			G22
			G23
3	Glass/Glass/Glass/Glass/ Glass/Glass (45/-45/90)s	G26	G31
			G32
			G33

Table 1. Stacking sequence and samples designation

Drop weight test:

In accordance with ASTM D 3029 standard [9]a batch of square, thin (150 mm side, 1.6 mm thick for G16 and G26 , 1.2 mm for G4) specimens is clamped on a fixture with a rectangular slot (sq100mm). The dart has a hemispherical head of 10 mm radius. Instron-Dynatup 9250 HV Drop-Weight device Fig.1.was used to expose the compound coupons to multiple natural effects, in the center of each coupon, until a hole in the target was observed. This drop weight device can be used to generate impact velocities of up to 5 m/s. The impact up is modular, and by varying the cross-mass and firing height, impact energies from 1 to 500 J are possible. In this study, the impact velocity was fixed at approximately 2 m/s, and the total mass of the collision was fixed at .1.5, 4.5 and 7.5 kg, resulting in kinetic energy of 3, 9 and 15 joules of impact, respectively. The position and acceleration of the collider was continuously monitored. This type of arrangement has been successfully used to test the effect of composite materials in many researches [10] The drop weight device is equipped with an automated lifting track, and the cross head is designed to engage or separate the track by remote control. This arrangement provided a means of stopping strikes between strikes. The data collected after each hit was stored, and the collider returned to its original starting altitude. Using this technique, a suitable velocity of approximately 2 m/s (3, 9 and 15 J) was obtained, respectively. Since the target holder was rigidly attached to the frame of the test device, the tup hit the target each time in the same location. The tup chosen for this probe was cylindrical round, with a diameter of 15 mm and a hemispherical nose. Stainless steel was selected for its relatively high hardness and corrosion resistance. In the energy balance from the kinetic energy equation, the tup deformation work is neglected. Equipped with steel handles, the square target plates are secured to a solid base to prevent the target material from slipping.

Numerical analysis for drop weight test

ABAQUS CAE 2014[11] In this study, the material used was woven glass fiber as reinforcement for the epoxy matrix. For laying woven e-glass fibers, there are a number of directions for arranging the corners of the fibers with different stacking sequences for the fibers that can be suggested in each design. Since the main objective of this study is to validate numerical analysis with experimental results, as the main objective of this study is to validate numerical analysis with experimental results, three designs were proposed. One design is specifically set up for all (+45, -45) fiber orientation angle in order to briefly verify that the drop weight of the composite is more dependent on the fiber orientation. While the other two designs had a larger number of layers, one of them was with an increase of 90 layer from the inside and the other was changed the inner two layers at an angle of 90 and the outer at an angle of 0 while keeping the 45 layer in the middle, which was expected to have a good value for shock resistance based on the analysis of the previous work compared to the value The other is for the direction of the angle[12]. Therefore, these two designs fig.4. Were proposed to find out the effect of increasing the number of layers with a change in their angles on the shock absorption value and to compare it with the first design. All proposed designs were analyzed using ABAQUS. From this method, the ability of each proposed design to achieve maximum shock absorption can be determined[13]. An acceptable error rate is expected, the finite element models of the composite were chosen as the most similar representation of the actual composite materials. Thus, only the best design from ABAQUS analysis which shows the highest shock tolerance value will be selected to be fabricated and analyzed empirically. During the analysis of ABAQUS, the three finite element models are a composite of 4 layers for the first design and 6 layers for the second design of woven glass fiber reinforced with epoxy. The thickness of each layer is fixed to be 0.20 mm for woven glass fibers with a density of 2.55 g/cm^3. So approximately 2mm thickness can be achieved for finite element models of glass/epoxy composite. All three proposed designs for finite element models are presented in table2.

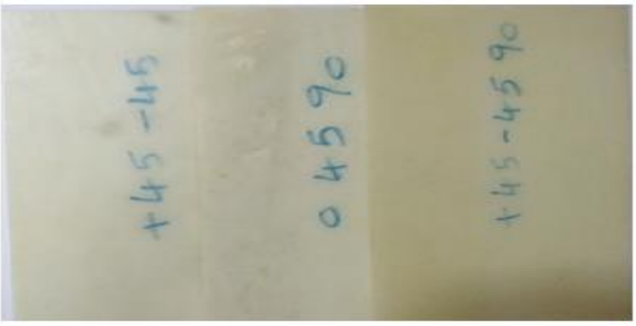

Fig. 1. Fig1. Drop-Weight specimens (G4, G16 and G26)

Fig. 2. Drop-Weight device

Physical property	Glass/epoxy lamina
E_1 (GPa)	135
$E_3 = E_2$ (GPa)	8
G_{23} (GPa)	2.76
$G_{12} = G_{13}$(GPa)	5
V_{23}	0.34
$V_{12} = V_{13}$	0.3

Table2. Engineering constants used in simulation

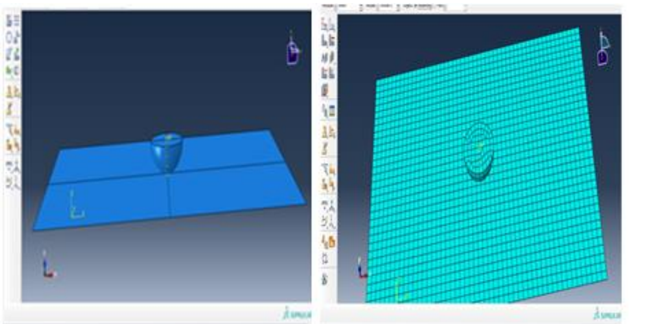

Fig. 3. Finite element model of composite laminate before impact loading.

III. RESULTS AND DISCUSSIONS

The main factors for analyzing the contact force and energy absorbed in the low-speed impact analysis process[29]. Therefore, the comparison of the contact force behavior and the amount of energy absorbed from experiments and simulations is clearly presented in this section. The typical Force–Displacement (F-D) curve consists of an ascending section of loading until reaching a peak load and descending section of unloading. In the F-D curve, the oscillations demonstrate the possibility of failures in the material caused by the reduce stiffness of the material, and no sudden force drop implies that the material have higher resistance under low-velocity impact. The peak force on the F-D curve is an important index to evaluate the maximum load of composite laminates after impact. On the F-D curve we find the elastic response of the composite sheets, and the first sudden drop in strength reveals that a crack develops on the affected side of the composite sheets or that loosening has occurred fig.5-10. After reaching the highest value of the force, the decrease in the amount of force indicates a change on the affected side of the composite material. Figs.12-14 shows typical some force and displacement curves for the different layers from the experimental and numerical results for the case of 3,9 and 15 J respectively of impact energy, and indicate the plate types of G4, G16 and G26, respectively. And the F-D curve obtained by simulation matches well with the F-D curve obtained by experiments, And the level of the upper values of the force obtained from numerical is almost identical to the level of the values of the peak force obtained from experimental tests with the difference in the level of displacement between them, In addition, the highest force obtained for the sample is G26, followed by G16, then G4. This difference is due to the different that G26 and G16 have more layers than G4, and that the force in G26 is higher than G16 because the orientation of the layers has a great effect to withstand higher force[14].

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Fig.4 .Back surface for G26 15j

fig.5 . Front surface for G26 15j

Fig.6 .Back surface for G16 9j

Fig.7 .Back surface for G16 15j

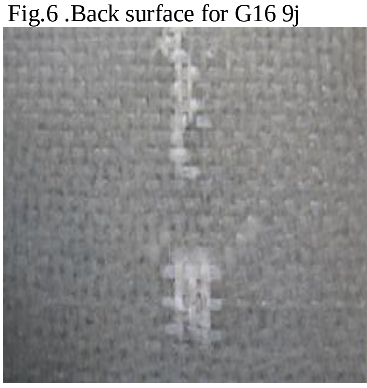


Fig.8 .Back surface for G4 9j

Fig.9 .Back surface for G4 3j

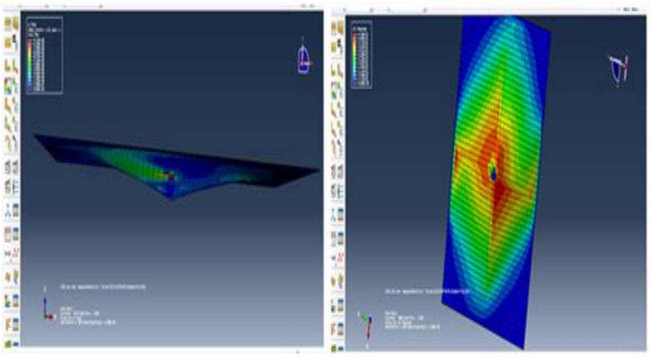
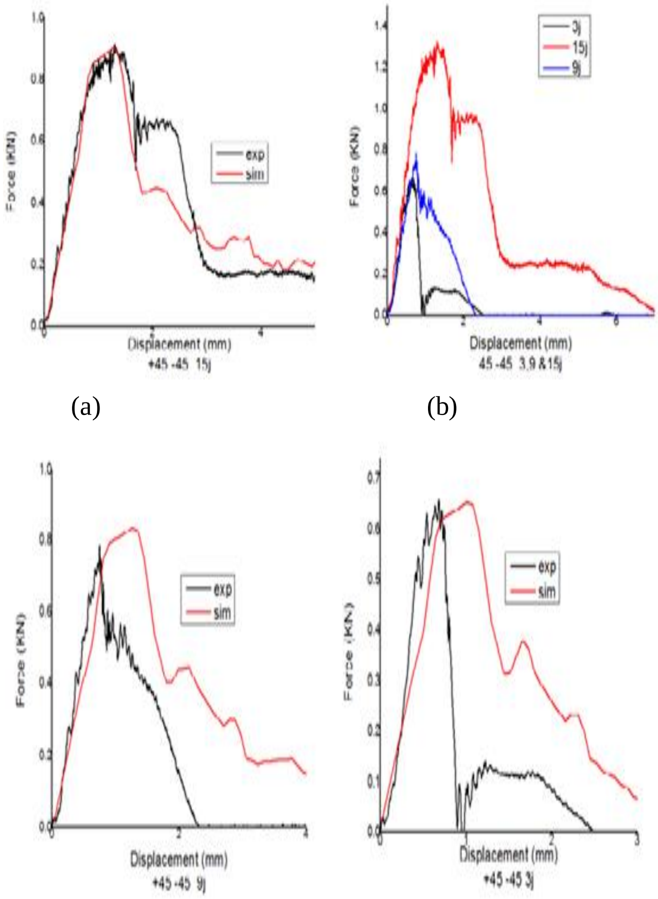


Fig.10. finite element model of composite laminate after impact loading.



(a) (b)

(c) (d)

Fig.11. F-D curve of G4

IV. CONCLUSION

The composite plates were subjected to low velocity impact. It is seen that while the energy increases the peak in force increases but there is a drop at the beginning of the perforation. The total energy is used for matrix cracking, delamination, fiber breakage and elastic energy to make the indenter jump. It is seen that when the impact energy increases the damaged area also increases perforation is occur and the part of the energy, used for matrix. The impact resistance in terms of energy-absorbing capacity and penetration threshold is improved by increasing the number of layers and the direction of the angles of the fiberglass layers. The finite element model at the spinning level showed accurate prediction ability for textile composite, which will be a promising method to study the damage and failure mechanism of textile composite materials.

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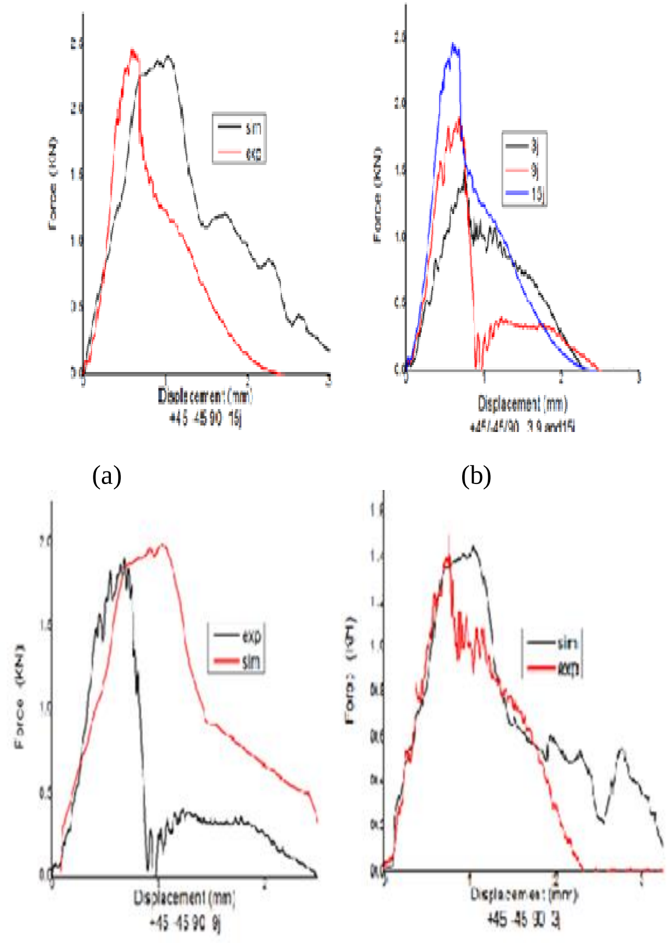
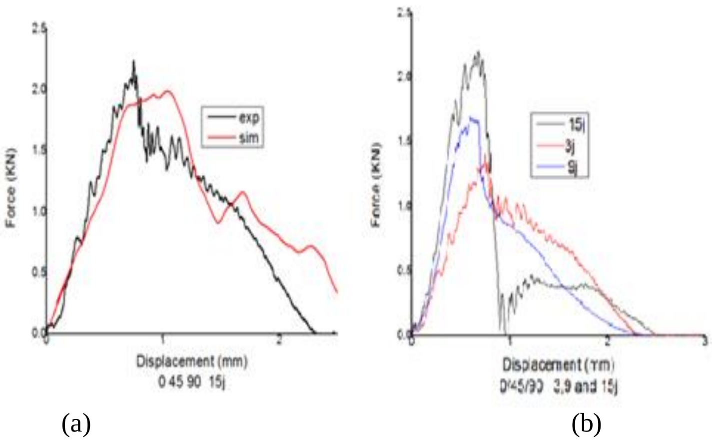


(a) (b)

(c) (d)

Fig.12. F-D curve of G26



(a) (b)

Fig.13. F-D curve of G16

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