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Experimental Investigation of Low Velocity Impact on Hybrid Composite

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Abstract: ***The effect on the reinforced material was considered experimentally under low velocity impact test as well as hardness test. The used material is an Intraply Hybrid Composite of ultra-high molecular weight polyethylene, nylon-6, 6, and Carbon Fiber. Experimental test were performed as per ASTM guidelines using falling weight impact testing machine instrument. In order to maximize the output of the Current work, studies were done on various combinations of ply arrangements. Impact test were led to describe the type and extent of damage observed in laminate of 13.26 mm thick plate subjected to different impact energies. Penetration vs impact energy and % deformation vs impact energy curves were extracted from the experimental data. The delamination due to impact and permanent indentation deformation were precisely caught. Hence, it is observed that the values of impact resistance and hardness of the Specimen A is higher than the Specimen B.***

Keywords: Low Velocity Impact, Interply Hybrid Composite, Impact Energy, and deformation

1. Introduction

A composite material is a material that composed of two or more constituent materials which have dissimilar physical or chemical properties, when combined, produce a material with different characteristics from individual components. The individual components stay discrete and distinct within the finished structure, separating composites from mixtures and solid solutions. The new material might be favored for many reasons: some common examples are stronger, lighter, or more affordable when compared to traditional materials. . Hybrid composites contain more than one fiber or matrix system in one grid framework in an overlay as shown in Fig 1.

Figure 1: Hybrid Composite of Carbon/ Glass

1.1 Types of Composites

Composite materials are usually categorized by the type of reinforcement used. This reinforcement is embedded into a matrix that grips it together and mainly used to strengthen the composite. The reinforced phase material may be in form of fiber, particles or flakes. The matrix phase material is generally continuous are mainly polymer, metal ceramic and carbon.

Hybrid composites contain more than one fiber or matrix system in one grid framework in an overlay. They are mainly four types of hybrid laminates are:

- Interply Hybrid Laminates
- Intraply Hybrid Laminates
- Interply-Intraply Hybrid Laminates
- Resin Hybrid Laminates

with low-velocity impacts can be insecurely defined as being caused by projectiles travelling at velocities measured in m/s that do not result complete perforation, only solid laminates will be considered. Impacts on sandwich structures with composite face sheets are treated in earlier references [1]. Effect of core thickness and core density on low velocity impact on sandwich panel of woven glass fiber as face panel while polyurethane form as core is used. The study shows that on increasing in core density higher energy absorption was noticed similar variation to core thickness [2]. The appraisal of the impact behavior requires tensile tests to decide the elastic-viscoplastic conduct of the composites. The impact analysis of the glass fiber-reinforced polyamide demonstrated that the impactor velocity effectsly effects on the impact response of the composite plates. Additionally,, the contact force changes relatively with the impactor velocity [3]. Behaving like brittle material on low strain of composite material are subjected to possible impact damage during manufacture, maintenance and in use. Under high velocity impact loading in six layers woven roving on E-glass/polyester composite plates under the influence of tension, compression and hybrid preloading in uniaxial and biaxial directions. Result shows that with the altered preloading condition the ballistic resistance of the samples decreased compared to without preload case. Delamination and fiber break constituted the major fracture modes look after by matrix fracture [4]. Low velocity impact behavior of woven glass fiber epoxy matrix composite laminates observing damage in laminates for the range of thickness subjected to different impact velocity. A crack from the center of the laminates to the edge, or significant damage consisting of dent localization in the impact region which synthesize the dependency of the energy parameters and force threshold values on the impact velocity [5].

Today use of composite laminates in application leads many factors but some of the unique properties leads its application is mainly due to their agreeable strength to weight ratio and ability to quickly response on exposed loading environment, due to which composites are being utilized as variables alternative to metallic materials in structures e.g. aerospace structure, High speed boats and trains.

However, unknown object impact on composite material is a major concern, and highly trending topic for Research and Industrial Purposes. Studies focus on recognition of impact Parameters becomes very important for safety factors. The relationship between structure response and impact parameters has been widely scrutinize in the publish works, which is the basis of research on the parameters recognition.

2. Methodology

The material used in this study is ultra-high molecular weight polyethylene (UHMWPE), nylon and Carbon fiber. An epoxy matrix based on resin 520 and Hardener D was selected for making composite panel. A flow distribution medium was used on the upper and lower surfaces of the perform to ensure finish wetting. The material properties of the ply used for making the interplay hybrid composite material are given below:

Table 1: Properties of Material

Property	*UHMWPE*	*Nylon-6, 6*	*Carbon Fiber*
Density (Kg/m3)	940	15	1763
Yield Strength (Pa)	2.205e7	7.5e6	2.9e9
Young Modulus (Pa)	9.285e8	1.5e9	1.43e10

The tested material is an interply hybrid composite of ultra-high molecular weight polyethylene (UHMWPE), nylon and Carbon fiber is prepared in two different combination keeping thickness of composite constant (12 mm) by hand lay-up process. An epoxy matrix based on resin 520 and Hardener D was selected for making composite panel. For making interplay hybrid composite the material used is unidirectional ply of UHMWPE, Nylon and carbon fiber having thickness 2mm, 3mm & 2mm. The combination series of tested specimen is in given below Table: 2.

Table-2: Variable Specimen with Ply Series

S. No	*Interply hybrid composite Specimen Name*	*Plate Dimension*	*Ply Series*
1	A	150x150mm	Nylon - UHMWPE – Carbon Fiber - UHMWPE - Nylon
2	B	150x150mm	UHMWPE – Nylon – Carbon Fiber - Nylon - UHMWPE

Hand lay-up process is the simplest technique of preparing composite. The infrastructural requirements for this technique are additionally insignificant. The handling steps are very simple. As a matter of first importance, a discharge gel is splashed on the desire surface to maintain a strategic distance from the cling of polymer to the surface. The polymer is consistently spread with the support of brush. Second layer of mat isthen fixed on the polymer surface and a roller is moved with a smooth weight on the mat polymer layer to eliminate air trap and furthermore the overabundance polymer show. The procedure is repeated for each layer of polymer and mat, till the required layers are stacked.In the wake of curing either at room temperature or at some particular temperature, mold is opened or the created composite part is taken out and additionally prepared as shown in fig 2 & 3.

Figure 2: Interply Hybrid Composite Specimen A

Figure 3: Interply Hybrid Composite Specimen B

3. Experimental Results and Discussion

There has been a rising attention to use composite materials in structural applications by virtue of their unexpected properties compared to conventional materials. Consequently it increases high significance to predict or determine their response to an impact loading. In this work, variety of effect parameters such as contact force, displacement, impact velocity, and absorbed energy versus deflection is examined so as to make sense of damage process of hybrid composites in an impact event. The study is expected to be useful in understanding the general reaction of hybrid composite plates under impact loading Section.

We can characterize the work done by the external action son the system and the energy disseminated by the system, internal or external, which irrevocably transform kinetic or potential energies into irreversible energy, mainly due to the disintegration of the material and too little extent due to the friction between the specimen and the dart so, in place of manage this energy balance equation, the following approximation can be made:

1) The dart can be considered as a rigid body, so its elastic vitality is set to zero;
2) The specimen mass is negligible, if contrasted with the impactor mass, so its gravitational and kinetic energy variation can be viewed as immaterial

On free fall of the dart there can arise three conditions which are:

- Free fall, stop, rebound
- Free fall and perforation
- Free fall and stop

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This point of confinement circumstance happens when the dart stops without bouncing back. If the dart does not bouncing back the specimen does not have any leftover internal energy to exchange with the dart. Our tested result is belonging to this category shown in Fig: 4 & Fig: 5.

Figure 3: A after Low Velocity Impact Test

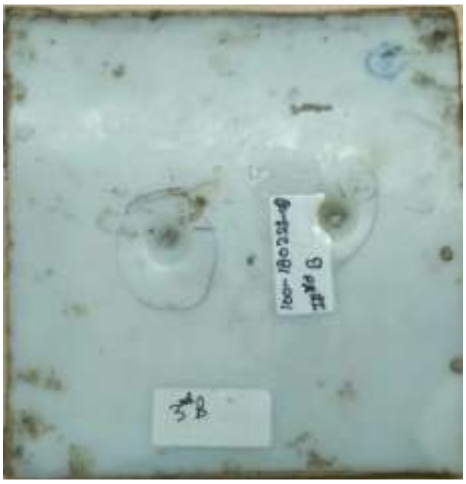

Figure 4: Specimen A after Low Velocity Impact Test

At the point when the dart stops, it has reached the maximum displacement: its ''maximum penetration'' into the specimen. At right now the specimen as dispersed the whole amount of energy, no further energy increment could be dissipated by mean of ''internal'' fragmentation. Perforation, which is the other dissipative mechanism, is early yet does not occur, in some sense the material is ''saturated''. The tested result of drop weight impact test is shown in Table: 4.1.

Table 3: Specimen Parameters and Testing Results of Drop Weight Impact Tests

Weight (kg)	*Impact Energy*	*Sample*	*% Deformation*	*Penetration*
5	24.5	A	0.94	0.6
			2.1	4.63
10	49.05	B	2.9	2.55
			3.14	6.52

The experimental tests were executed on two specimens each thickness of 13.26 mm. Tests were executed in two spells at two energy levels determined by the falling height 500mm. The corresponding values of the impact velocity is 3.13m/s.

From an energy point of view, Fig: 5 show curves of Impact energy versus % Deformation by the dart at various levels of impact energy. This is clearly shows that the on increasing the impact energy more gently increase in the % deformation. The peak load and out-of-plane displacement (indentation depth) additionally demonstrate a linear relationship with impact energy. The minimum % deformation is shown in Sample A as compare to sample B.

While, Fig: 6 the curve of Impact energy versus Penetration shows an increase in permanent indentation with estimating impact energy. The minimum Penetration shown in sample A as compare to Sample B.

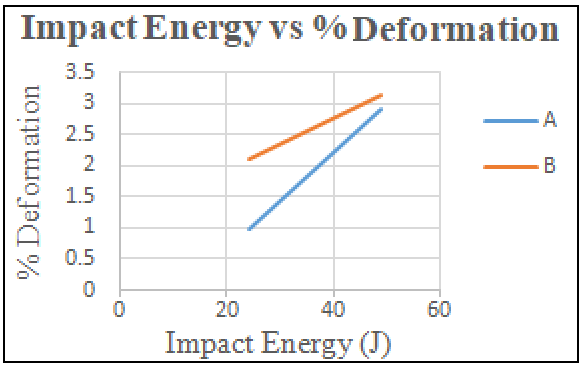

Figure 5: Impact Energy vs % Deformation

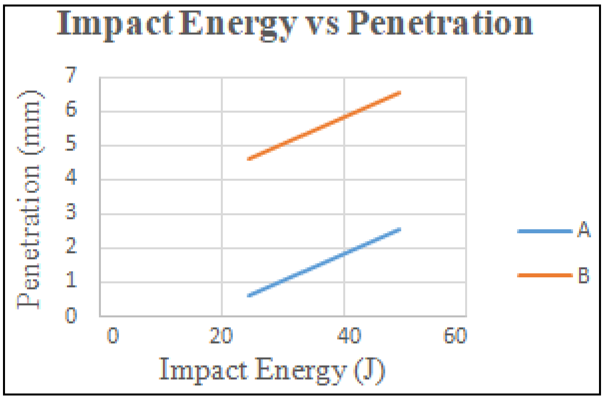

Figure 6: Impact Energy vs Penetration

Fig: 7 & Fig: 8. Shows the time histories of the dart displacement of the Specimen A and Specimen B. In Specimen Ait can be read a maximum value equal to 2.55 mm while in Specimen B maximum value read equals to 6.52mm.At right now the specimen has dissipated the entire amount of energy, no further energy increment could be dispersed by mean of ''internal'' fragmentation. Perforation, which is the other dissipative mechanism, is early yet does not occur. In some sense the material is ''saturated''.

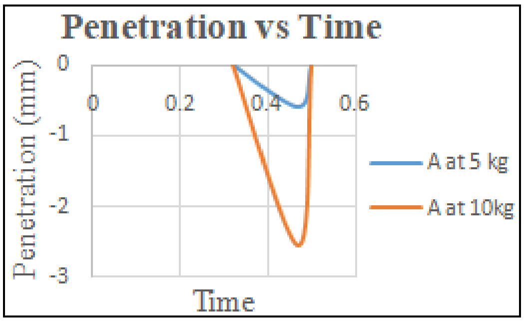

Figure 7: Penetration vs Time Graph of Specimen A

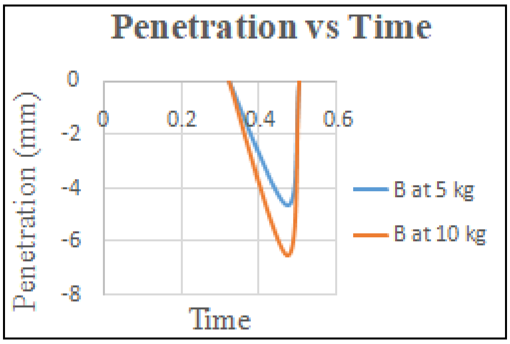

Figure 8: Penetration vs Time Graph of Specimen B

Specimens have been analysed after the impact test with the point of setting up a correlation between the test conditions and the plate damage. For examination, images of some damaged specimens are given in Fig: 3 & Fig: 4. Damage degree at both front (impacted) and back side of the specimens are given. For a low energy level (falling height of 500 mm, velocity at the impact3.132 m/s), shows good impact resistance characteristics, all the energies are stopped by the specimen within its thickness. The maximum energy 49.05 J is stopped in minimum penetration of 2.55mm by Specimens A shows more efficient results compared to specimen B.

4. Conclusions

This work displayed an experimental investigation of hybrid composite laminates subjected to low-velocity impact, submitting to the standard instrumented falling weight test a number of plates made by Nylon, UHMWPE, and Woven Carbon Fiber ply reinforcement having 13.26 mm thicknesses. The impactor stopped on the specimens, when subjected to impact at different energy levels. On the basis of the potential energy initially supplied to the dart by fixing its dropping height.

An experimental programmer demonstrated that:

1) In low velocity impact tests, maximum damage area was shown to be linearly related to impact energy. Nonetheless, the contact time was independent of impact energy and introduced a constant value for each lay-up investigated.
2) The specimen lay-up can affect the impact response of composite laminates by changing the series of the ply arrangement. The involvement of Nylon - UHMWPE – Carbon Fiber - UHMWPE - Nylon series plies not only reduced the response time but also promoted the growth of delamination along the transverse direction.
3) For the material system utilized as a part of this examination, the main failure mode observed in the impact event was delamination, which is observed on a great extent in the Interply Hybrid composite Specimen B.
4) This work exhibited a damage model for predicting the impact reaction of mixed composite material structures comprising of woven and unidirectional plies. The material response including Penetration/time curves, % deformation/energy curve and Penetration/energy curves were obtained from drop-weight impact tests. The delamination and depression presented by low velocity impact were reproduced in the impact test.

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