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EFFECT OF LOW VELOCITY IMPACT DAMAGE ON COMPOSITE PLATES

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ABSTRACT

In this study unidirectional E-glass/epoxy composite plates were tested. The panels were cut into specimens of 140x140 mm in dimension with an average thickness of 3 mm and stacking sequence of $[+45/-45/90/0]_{2s}$ The impact tests performed with impactor mass (18 kg) at five different impact velocities (2.0, 2.5, 3.0, 3.5 and 4.0 m/s) were conducted with a specially developed vertical drop weight testing machine. The diameter of the impactor with a hemispherical nose was 24 mm. The center of each plate was exposed to impact loading. The differences in the impact responses of specimens with varying impact velocities are characterized.

KEY WORDS

Low velocity, impact damage, Composite plates, E-glass/epoxy.

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INTRODUCTION

The fiber-reinforced composite plates as used in space vehicles, aircraft, modern vehicles and light weight structure are very susceptible to low velocity transverse impact damage such as matrix cracking, delamination and fiber breakage these damages imply significant reductions in the strength and stiffness of materials. Low velocity impacts which may occur during manufacture, maintenance and by careless handling are considered to be dangerous for a composite structure because the damage caused tends to be created on the back face or within the laminate and hence is difficult to detect [1-6].

The sensitivity of composite laminates to impact loads in the thickness direction is however a serious obstacle to more widespread use, since in this class of materials the energy dissipated during impact is mainly absorbed by a combination of matrix damage (intralaminar and interlaminar cracks), fibre fracture and fibre–matrix debonding, thus leading to significant reductions in the load-carrying capability of the material. While in ballistic impacts the damage is localised and can be easily noticed by the naked eye, low-velocity impacts produce global structure deformation and may therefore generate internal damage difficult to identify by external inspection. The latter form of damage is of most concern since it can degrade the residual properties of the material and grow undetected under service loads leading to sudden failure of the component [7].

The aim of this research was to evaluate the low velocity impact effects of a hemispherical rigid projectile from a drop tower facility on composite plates. The center of the each plate was subjected to low velocity impact loadings. The damage effects of different impact velocities of the weight were evaluated.

EXPERIMENTAL PROCEDURE

The unidirectional E-glass/epoxy composite plates were cut into specimens of 140x140x3 mm in dimensions and stacking sequence of $[+45/-45/90/0]_{2s}$. The mechanical properties of a layer are given in Table 1.

The specimens were firmly fixed at all edges and were impacted producing damage up to perforation. After the first impact of the specimen, a catcher mechanism was activated to prevent a second strike. The impact test machine was used for the test and the drop-tower arrangement is shown in Fig. 1.

Force and time data are obtained from the force sensor by using National Instruments (NI) Signal Express data acquisition software. Acceleration the mass of the impactor is calculated by using Newton’s second law of motion. The first integration gives the velocity and the second integration gives the displacement as a function of time. The equation of motion can easily be integrated imposing initial conditions (see [8]). Time axis has its origin at the contact time, while the reference quote h which is at a fixed, known distance from the upper undeformed surface of the specimen. So, the impactor coordinate is $y(0)=0$ at time $t=0$. Considering the impactor as a free falling rigid body, the order of magnitude of its impact velocity at the contact time is obviously given by $v_0=\sqrt{2g\Delta h}$. Δh is defined as the height loss of the gravity center of the impactor mass with respect to the reference surface. This simple integration can be performed on the acceleration (that is equal to the force signal divided by the impacting mass) to obtain, every time, the velocities and, then, the coordinate of the impactor. By integration of the force vs. displacement, the energies time history during the evolution of the test can be evaluated. The formulations of kinematic analysis are given in [8].

The weight of cross-head was maintained at 18 kg. Samples were impacted with 24 mm diameter instrumented tap having a hemispherical end. Rest of the parameters is calculated using the laws of motion. Energy that goes into the sample is calculated based on the conservation of energy principles which is calculated based on the initial kinetic energy of the impactor at the time of impact, instantaneous kinetic energy, potential energy and the energy that goes into the sample. The impact tests were performed for five different impact velocities (2, 2.5, 3, 3.5 and 4 m/s). To obtain different velocities the load cell placed at different positions.

RESULTS AND DISCUSSION

The peak load is obtained from the *F-t* diagrams. The Load–time curves from the impact testing are shown in Fig. 2. Table 2 shows the comparison of the impact parameters.

The representative features of impacted plates on front surface are shown in Fig. 3.

The results show that when the velocity (energy) increase the load peak increase too. After the peak value there is a sudden drop in force. Also the damage areas increase until the perforation of the specimen. For the velocities of 2, 2.5 and 3 m/s the part of the energy is absorbed and used for matrix cracking and delamination (Fig. 3 (a)-(c)) and the other part of energy is used for the elastic energy (to make the impactor jump). For the velocities of 3.5 and 4 m/s, in addition to the matrix cracking, delamination and elastic energy, the part of the energy is used for fiber breakage and this resulted with the perforation.

All of the damage pictures were retrieved from Adobe PhotoShop. Damage zones were colored and transferred to AutoCAD at a scale of 1:1. Each overall damage areas were contoured and measured by using *spline* and *area* commands, respectively (Table 3).

When the strike velocity increases up to 3 m/s the overall damage area increases. On the contrary, the damage area decreases for 3.5 and 4 m/s velocities due to the perforation occurred and most of the absorbed energy dissipated for perforation.

CONCLUSION

Total energy of the weight is used for matrix cracking, delamination, matrix cracking, fiber breakage and elastic energy to make the indenter jump (other unimportant energy loss can be neglected). The relation among the impact velocity, force and time was obtained after subjecting the specimens to the low velocity impact. The results show that while the impact velocity increases the peak in force increases but there is a drop at the beginning of the perforation. For the used weight, the perforation starts after the strike velocity increases up to 3 m/s.

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Table 1. Mechanical properties of a layer.

Young's modulus (GPa)	Tensile Strength (MPa)	Shear Modulus (GPa)	Poisson's ratio
42	690	3.5	0.34

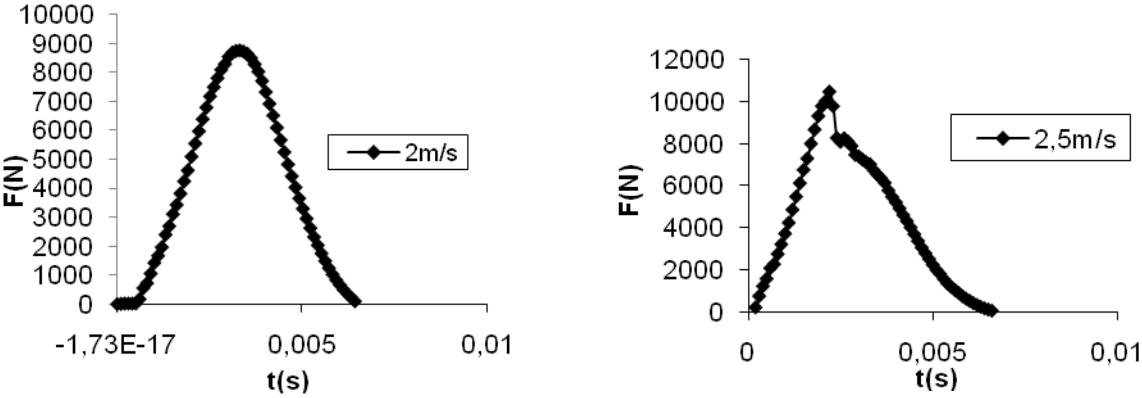
Table 2. Comparison of impact parameters.

Impact Velocity (m/s)	Height (cm)	Total Energy (J)	Absorbed Energy (J)
2	20.4	36.0	25.4
2.5	31.8	56.1	45.8
3	45.3	80.0	76.7
3.5	62.5	110.3	105.9
4	81.6	144.0	141.9

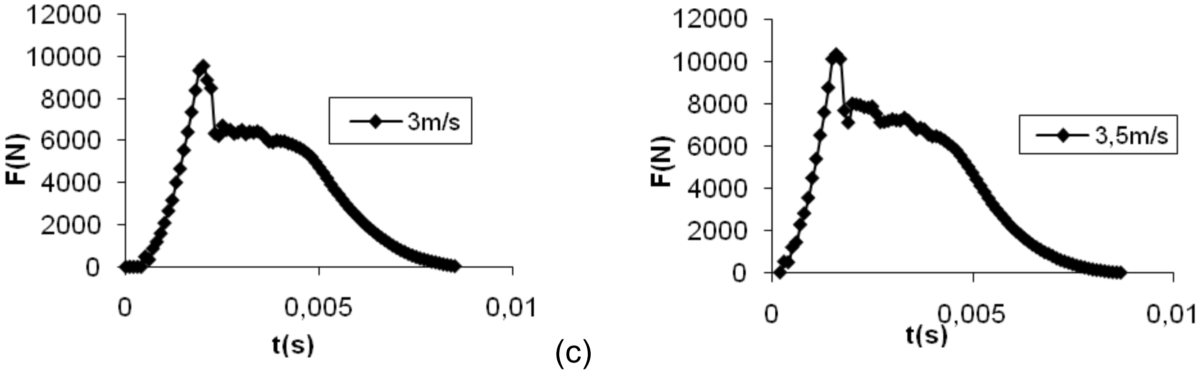
Table 3. Overall damage areas.

	Impact velocity [m/s]	Absorbed energy [J]	Damage area [mm^2]
No perforated	2	25.4	278
	2.5	45.8	499.19
	3	76.7	683.75
Perforated	3.5	105.9	655.24
	4	141.9	558

Fig. 1. Instrumented falling weight impact test machine.

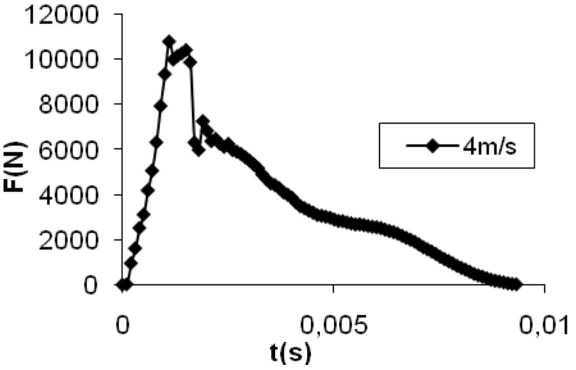


(a) 2 m/s (b) 2.5 m/s



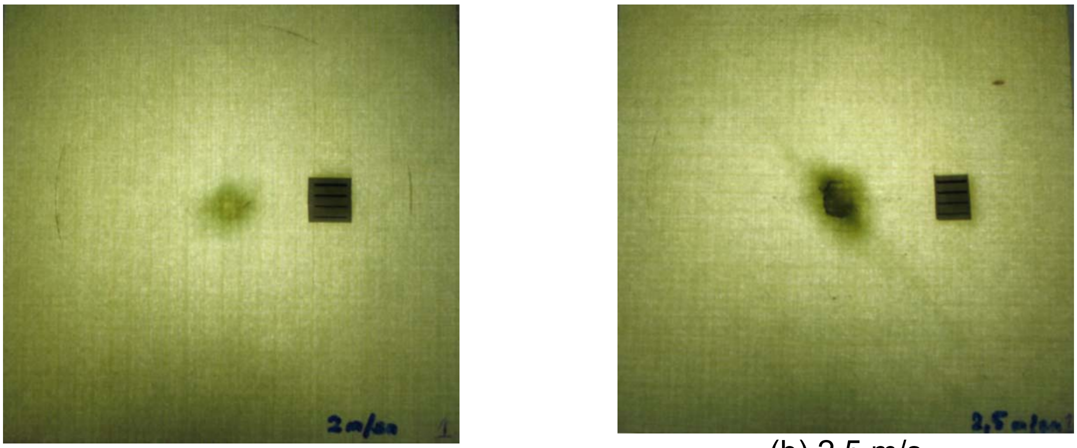
(c) (d)

3 m/s 3.5 m/s

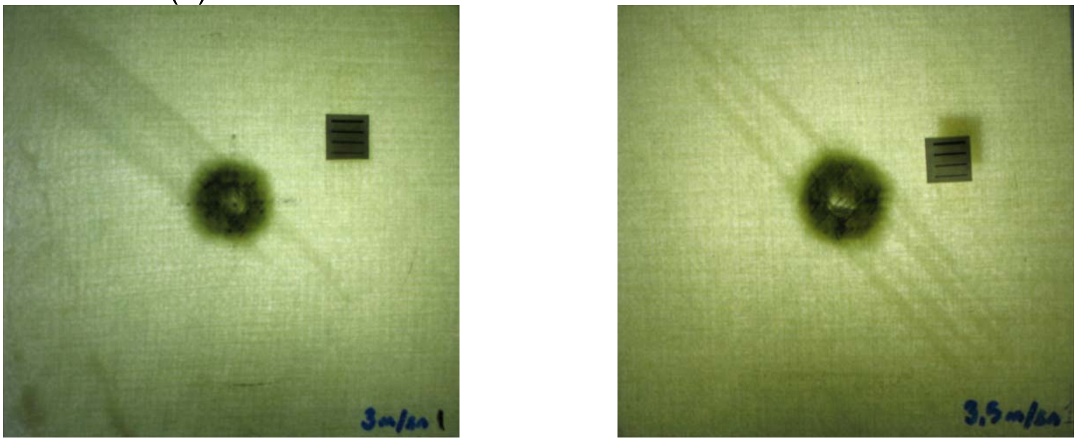


(e) 4 m/s

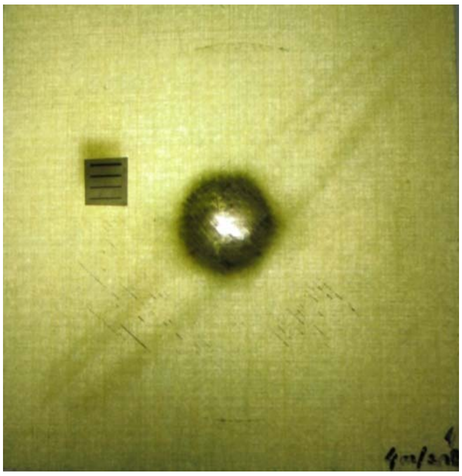
Fig. 2. Force/time traces of five impact events with incremental incident velocities.



(a) 2 m/s (b) 2.5 m/s



(c) 3 m/s (d) 3.5 m/s



(e) 4 m/s

Fig. 3. Front surface of impacted specimens.