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Impact Damage Behaviour of Woven Glass Fibre Reinforced Polymer Composite

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Abstract: This study investigates and characterizes the impact damage of woven E-glass Fibre Reinforced Polymer (GFRP) composite under drop weight impact event. The experimental tests are performed according to ASTM standards (D7136/D 7136M-05 and D5687/D 5687M-05) utilizing a blunt conical impactor and drop weight testing rig. Four groups of specimens have been utilized for the impact event with various drop height. The event resulted in a series of linear damage growth that is proportional to the absorbed impact energy. From the micrographic observation, the specimen damage is found to form cross shape cracking on the front surface or known as effect of orientation of delamination.

Key words: Woven E-glass fibre reinforced polymer composite, impact behaviour, mechanical testing, damage mechanics

INTRODUCTION

Currently, the interest of fibre based polymer composite as primary structural material in various application such as aerospace, marine, transportation and others have greatly increased. Fibre based polymer composites are an alternative material over metal based materials as it has advantages such as higher corrosion resistance to various corrosive metal mediums, light weight and capability of tailoring structure to applications. In order to enhance the material applications, the material behaviour or mechanical properties must be further understood and characterized. Fibre based polymer composite are utilizing the polymer resin as the matrix to bond the layer of fibre. Most of the polymer matrix are brittle and resulted in the composite materials sensitive to impact damage (Sutherland and Soares, 1999). Hence, the studies of composite material failure behaviour due to low or high velocity impact loading are stressed and concerned.

Impact testing is one of the important mechanical properties testing approaches for material performance characterization. In composite material, impact testing is applied for characterizing the material damage resistance to impact energy penetration. Hence, the impact loading behaviour of glass fiber reinforced polymer composites has been studied primarily to evaluate stress wave progression in these materials (Zaretsky *et al*., 2004). Other studies have used drop weight impact testing to provide comparative results of the damage resistance of different material types (Naik *et al*., 2004; Ku *et al*., 2005). These studies measure the force, acceleration, velocity, displacement and energy during the impact event and focus mainly on the energy absorbed by the samples and visible damages as an impact behaviour characterization process.

The present study by Hebert *et al*. (2008) focuses on a series of woven E-glass reinforced polymer resin sheets (manufactured by Vector- Ply, Rhode Island) subjected to both shock wave loading and drop weight impact loading. These panels display variations in the polymer resin material and in the area weight of the fibre pre-forms. Post-shock loading measurements include the visual damage assessment, residual compressive strength and plots of permanent deformation. Drop weight impact test measurements include total energy absorbed, depth of penetration and extent of radial internal damages. The assessment method is primarily comparative which judges material performance as a function of resin type and internal structure.

In this study of impact damage behaviour is carried out on the self prepared woven E-glass fibre reinforced polymer composite specimen. The impact damage behaviour of the specimen are concerned and characterized for the material performance verification.

MATERIALS AND METHODS

The experimental studies on the impact damage behavior of the E-glass woven GFRP specimen are referred using ASTM D7136/D7136M. E-glass woven of NISER EWR600B (0°/90°) is utilized as the composite

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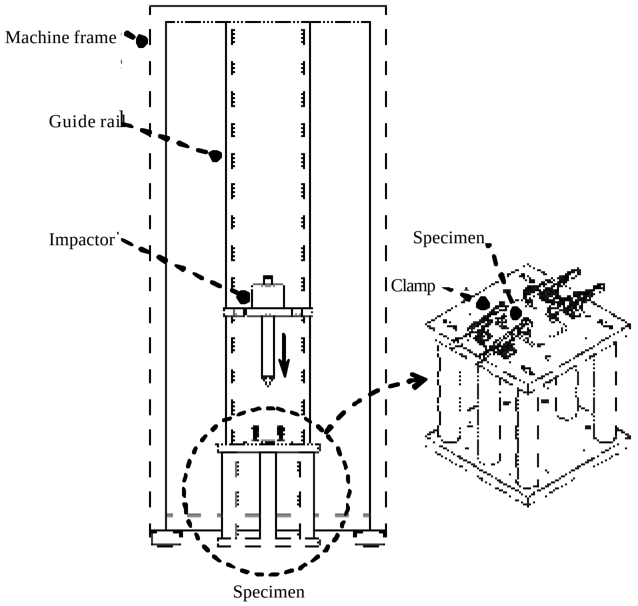


Fig. 1: Drop weight impact test rig

Table 1: Mechanical characteristics of NISER EWR600B E-glass woven fibre

Mechanical propert	Value
Modulus elasticity (E)	72.4 GPa
Ultimate Strength, (σ_u)	3.500 MPa
Specific modulus (E/ρ)	28.5 Mnm kg^{-1}
Specific strength (σ_u/ρ)	1.380 kNm kg^{-1}

Table 2: Specimen geometry characteristics

Specimen	Mass (g)	Average thickness, h (mm)
S1	179	7.17
S2	179	7.29
S3	174	7.02
S4	180	7.00

Table 3: Impactor energy components

Energy components	S1	S2	S3	S4
Drop height (m)	0.05	0.20	0.40	0.60
Impactor velocity υ (m sec^{-1})	0.99	1.98	2.80	3.43
Potential energy (kg m^2 sec^{-2})	7.36	29.43	58.86	88.29
Kinetic energy K.E (kg m^2 sec^{-2})	7.35	29.40	58.80	88.24

reinforcement material and bonded with polyester resin. The mechanical properties of the E-glass NISER EWR600B are tabulated in Table 1. Meanwhile, a drop weight impact test rig with blunt conical impactor, shown in Fig. 1, is designed according to the stated standard for low velocity impact event.

The woven GFRP composite specimens are fabricated through hand lay-up technique by laying a number of woven glass plies with polyester in a rectangular pressure mould. Preparation and curing process are carried out at room temperature and during the curing process; a distributed loading is subjected to the mould cover to ensure cured average thickness can be achieved. The lay-up been left for 48 h of curing period. The cured ten layers woven GFRP composite panel is cropped into standard specimen size of 100.0×150.0 mm with tolerance of ±0.25 mm. For these studies, four groups of specimens are prepared and an average geometry data are characterized as listed at Table 2. Overall, the woven GFRP composite specimens are selected to satisfy Guide D5687/D 5687M.

The main objectives of this study are to characterize the specimen impact behaviour due to a low velocity impact event. A 40 mm diameter blunt conical impactor shown in Fig. 2 is utilized to penetrate the specimen under the low velocity event. The impact damage behaviour characterization includes assessing the growth of damage in specimens with different impactor drop height (H) and theoretical approximated impact energy components.

Due to the limitation of measuring device or sensor on the test rig, impact energy parameters such as the impactor impact or drop velocity, travel time, impact loading and others can be only theoretical approximated through the conservation of energy principle while neglecting the friction variables. Hence, the energy components are defined in the Table 3 based on experiments carried out on impactor drop height ranging from 0.05 to 0.8 m from the specimen top surface.

By a simplistic assumption of no energy losses, the specimen absorbed impact energy is approximatel equaled to the impactor potential energy. Hence, the relationship between the impactor drop height and the specimen absorbed impact energy can be characterized as in Fig. 3.

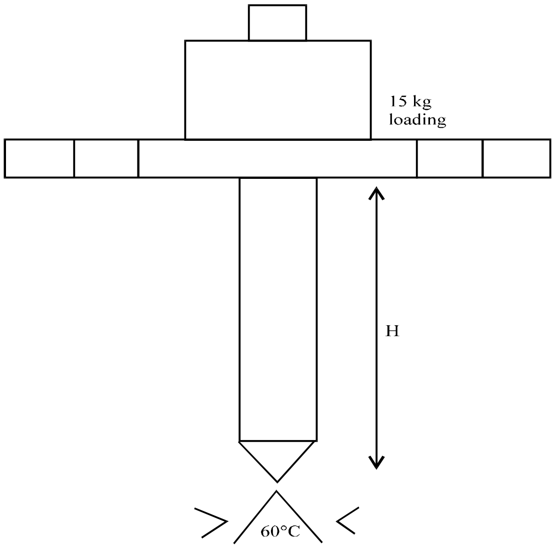


Fig. 2: 8 mm tip diameter blunt conical impactor

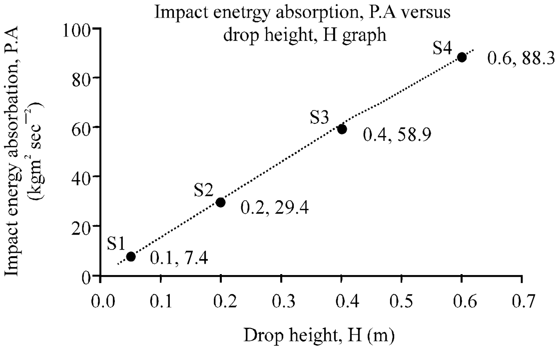
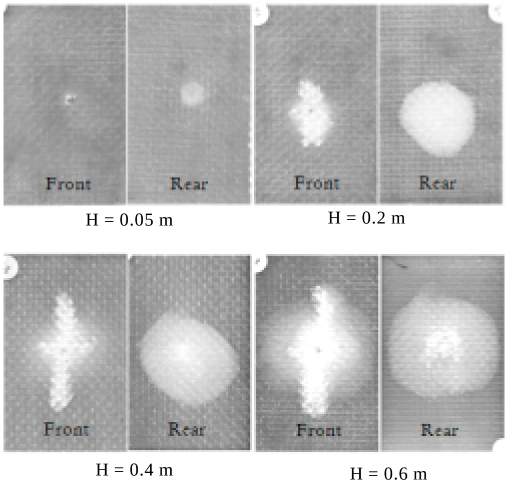


Fig. 3: Impact energy absorption versus drop height graph



H = 0.05 m H = 0.2 m

H = 0.4 m H = 0.6 m

Fig. 4: Specimen impact damage observed on front and rerar face

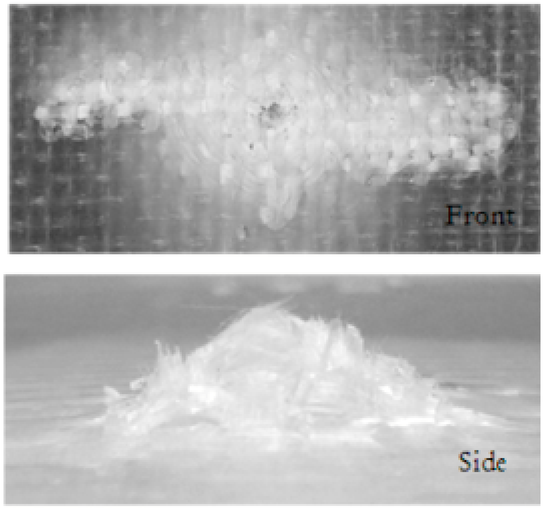


Fig. 5: Specimen impact damage observed on front and rear face

The specimen absorbed more impact energy as the impactor drop height is increased.

Through the experiment, each specimen has resulted different depth of impact damage that are related to the drop height as shown at Fig. 4.

RESULTS

Damage initiation and growth in the thick laminates under impact loading using a blunt conical impactor constitutes a very complex process since several damage mechanisms such as matrix cracking, fibre-matrix debonding, delamination and fibre fracture can occur depending on the level of the drop height. These damage mechanisms usually interact with one another, with one or two of them being dominant. Figure 5 showing the limited matrix cracking at the immediate impact contact surrounding area and the surface microbuckling is propagating along both fibre directions in the shape of a cross. But there is no fibre shear-out in the form of permanent indent can be observed at the impact site.

Delamination clearly exists as secondary characteristics of impact damage response. Since the nature of the impact damage is seen to be highly three-dimensional, it should be recognized that the impact kinetic energy is dissipated in the creation and propagation of major delamination. This suggest that the damage impact kinetic energy by delamination provides only a crude damage assessment unless complete absorption of the impact energy by delamination can be justified. Therefore, it suggest that impact force should

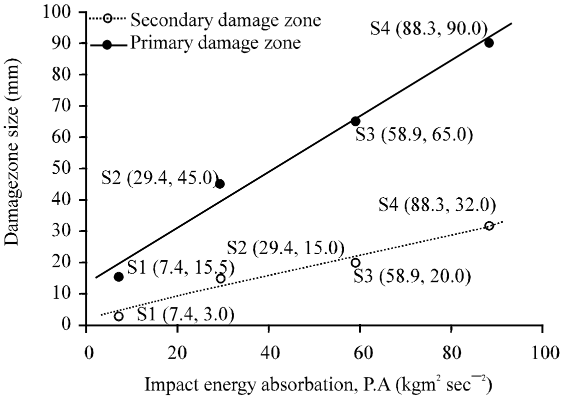


Fig. 6: Graph of specimen damage zone size versus absorbed impact energy

also be used as an important impact parameter to assess damage, to be shown later which has to be measured in an instrumented impact test. The use of force not only allows strain rate effect to be examined directly but also gives a better indication for damage initiation. This is particularly logical in recognition that delamination is driven by force.

The result from the experiment shown in Fig. 4, is a significant cross damage formation or known as the orientation of delamination. All the specimens are lay-up align to each lamina according fibre orientation (0°, 90°). Also, the damage zone can be divided into primary and secondary damage zone. Referring to the specimen rear face with back illumination technique, the primary and secondary damage zones is clearly visible and characterized by colour intensity. The high contrast zone is the primary damage zone where the fibre and matrix fails and fractures into fragmentation or matrix cracking because of the high bending stresses occurred due to the impact energy. Whereas, the less contrast zone is the secondary damage zone that only involves the delamination of laminas and barely a visible damage. From this area, the matrix is anticipated to fail. The matrix adhesion to the fibre is still expected, unless a maximum stress is reach before being completely failed. The size of primary and secondary damage zone for each specimen is also consistently increased with the absorbed impact energy as shown in Fig. 6.

CONCLUSION

The fundamental studies of low velocity impact damage characteristic of woven GFRP composite has been carried out based on the ASTM D7136/D 7136M-05 test standards. Four groups of specimens tested under the low velocity impact event with blunt conical impactor, resulted in degrees of damage mechanism that are linearly increasing due to the impactor drop height and impact energy.

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REFERENCES

Hebert, M., C.E. Rousseau and A. Shukla, 2008. Shock loading and drop weight impact response of glass reinforced polymer composites. Compos. Struct., 84: 199-208.

Ku, H., Y.M. Cheng, C. Snook and D. Baddeley, 2005. Drop weight impact test fracture of vinyl ester composites: Micrographs of pilot study. J. Compos. Mater., 39: 1607-1620.

Naik, N.K., M.N. Joglekar, H. Arya, S.V. Borade and K.N. Ramakrishna, 2004. Impact and compression after impact characteristics of plain weave fabric composites: Effect of plate thickness. Adv. Compos. Mater., 12: 261-280.

Sutherland, L.S. and C.G. Soares, 1999. Impact tests on woven-roving E-Glass/polyester laminates. Compos. Sci. Technol., 59: 1553-1567.

Zaretsky, E., G. de Botton and M. Perl, 2004. The response of a glass fibres reinforced epoxy composite to an impact loading. Int. J. Solids Struct., 41: 569-584.