Investigation of Impact Damage of PMC Specimens using SEM

Channabasavaraj S.
Professor & HOD,
RRIT, Bangalore, India

Amarnath G.
Associate Professor,
RRIT, Bangalore, India

Gururaj Naik
Associate Professor,
RRIT, Bangalore, India

Naveen G.
Associate Professor,
RRIT, Bangalore, India

ABSTRACT

The work presented in this paper investigates the the results of microscopic examinations of delaminations and transverse cracks detected with scanned image microscopy, from which the initiation and propagation mechanisms of the impact-induced damage were discussed. Visual examination of the impacted samples reveals that the damage in the fibres was developed around the point of impact, which results in considerable strength loss.

INTRODUCTION:

The impact-induced damage is the most serious type of damage for fiber reinforced composites. In particular, delamination caused by impact loading is known to produce significant reductions in the residual compression strength of fiber reinforced laminated composites. This is a major problem associated with the structural integrity of composite compression components. Much effort has therefore been devoted to the study of the effects of impact-induced damage on the load-bearing capacities of these components in the past 30years. In the course of these studies, attempts have been made to investigate the damage mechanisms.

Scanning Electron Microscopy - SEM - is a powerful technique in the examination of materials. It is most widely in metallurgy, geology, biology and medicine. The user can obtain high magnification images, with a good depth of field, and can also analyse individual crystals or other features. A high-resolution SEM image can show detail down to 25 Angstroms, or better. When used in conjunction with the closely-related technique of energy-dispersive X-ray micro-analysis (EDX, EDS, EDAX), the composition of individual crystals or features can be determined. There are many different ways that scanning electron microscopy and X-ray microanalysis can aid studies of materials. The scanning electron microscope (SEM) uses a focused beam of high-energy electrons to generate a variety of signals at

the surface of solid specimens. The signals that derive from electron-sample interactions reveal information about the sample including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample. In most applications, data are collected over a selected area of the surface of the sample, and a 2-dimensional image is generated that displays spatial variations in these properties. Areas ranging from approximately 1 cm to 5 microns in width can be imaged in a scanning mode using conventional SEM techniques (magnification ranging from 20X to approximately 30,000X, spatial resolution of 50 to100nm).

Fig 1: SEM Equipment

The SEM is also capable of performing analyses of selected point locations on the sample; this approach is especially useful in qualitatively or semi-quantitatively determining chemical compositions (using EDS), crystalline structure, and crystal orientations (using EBSD). The design and function of the SEM is very similar to the EPMA and considerable overlap in capabilities exists between the two instruments'

REVIEW OF LITERATURE:

FRP composite structures are often subjected to out of plane loads during manufacturing and service conditions. In such cases, layered composites suffer severely by delamination cracking because of poor interlaminar fracture resistance. On further loading, the interlaminar crack propagates and thus weakens the structure. By introducing small amount of fibers in the thickness direction of the laminate, the damage tolerance and suppression of delamination crack initiation or rate of interlaminar crack growth can be enhanced [4]. Interface between reinforcing fibers and matrix is believed to play an important role in composite properties. The effectiveness of load transfer at the interface depends upon the extent of chemical and mechanical bonding [5].
The combination of properties allows for longer life and lower maintenance costs over the lifetime of a structure when compared to conventional structural materials. A considerable amount of research has been done on the impact resistance of laminated composites. Experimental and analytical studies have confirmed that static indentation tests provide useful information about the failure mechanisms and failure loads for large mass impactors at low velocities [3-6].
As a consequence, current understanding of the dynamic damage growth mechanisms due to the impact is still limited although a vast amount of analytical data and some studies on the impact damage of laminates under low-velocity impact can be found in the literature. Choi et el. [5,6] analyzed the impact damage mechanism and mechanics of glass/epoxy laminated composites, in which they designed and built an impact tester, controlling impact loading by choosing different nose shapes of the impactor.
Luo et al. [9] developed an integrated procedure for modeling and testing glass/epoxy composite plates. Hosur et al. [8] examined the impact-induced damage in CFRP laminates through ultrasonic images. Ultrasonic C-scan using the pulse echo immersion method was utilized to read out the delamination area caused by the low velocity impact on composite laminates.

RESEARCH METHODOLOGY:

The Test laminates, E-Glass/Epoxy, Graphite/Epoxy & Kevlar/Epoxy of 150mm X 150 mm of 3mm & 2mm thickness were initially fabricated to conduct impact test by vacuum bag moulding method. The laminates are prepared by hand layup process later vacuum bag is applied on it to get exact thickness and to distribute matrix uniformly. Finally the specimen was allowed to cure for 48hrs in RT after that specimens are kept for post curing. Post curing is a technique used to take to completion in the process of curing as well as to ensure the enhancement of the service temperature limits. The post curing, in essence, increases the glass transition temperature (Tg) of the cured composite laminate. Impact testing was carried out on a Instron impact testing machine for various test specimens varying heights & weights. The impact tested specimens were subjected to inspections using ultrasonic c-scanning & SEM techniques.
SEM samples must have an appropriate size to fit in the specimen chamber and is generally mounted rigidly on a specimen holder. Specimens must be electrically conductive, specially the surface, for imaging, and electrically grounded to prevent the accumulation of electrostatic charge at the surface of the specimen during electron

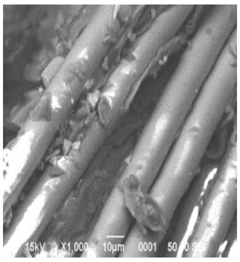
irradiation. Metal objects require little special preparation for SEM except for cleaning and mounting on the specimen holder. Nonconductive specimens tend to charge when scanned by the electron beam, especially in the secondary electron imaging mode. This causes scanning faults and other image artifacts. They are therefore usually coated with an ultrathin electrically-conducting material, commonly gold, deposited on the sample either using a low vacuum sputtering machine or a high vacuum evaporation unit.

Fig 3.1: Impacted surface & back surface of Graphite /Epoxy Test Specimens after Impact

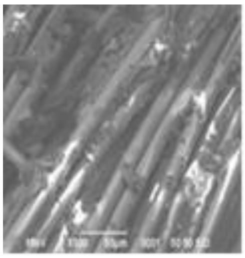
Fig 3.2: Impacted surface & back surface of Kevlar /Epoxy Test Specimens after Impact

RESULTS AND DISCUSSION:

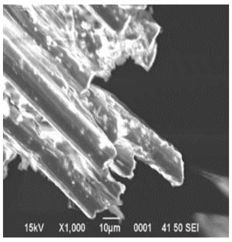
The impact damaged specimens (fig 3.1 & 3.2) were inspected with scanned image microscopy (i.e., Scanning Electron Microscopy, SEM). The damage was confined locally to the areas centred at the impact location, which suggests that the interior damage was characterized by delamination and cracks. The delamination damage was due to the bending-induced stresses.



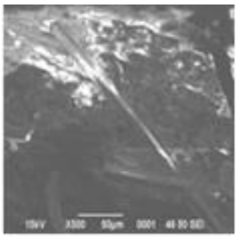
E-Glass/Epoxy 1000X



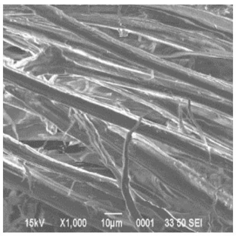
E-Glass/Epoxy 500X



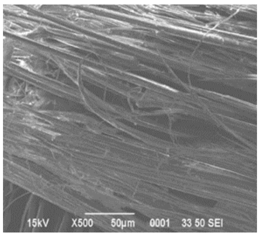
Graphite/Epoxy 1000X



Graphite/Epoxy 500X



Kevlar/Epoxy 1000X



Kevlar/Epoxy 500X

The cracks can be classified in the form of matrix cracks or fiber/matrix deboning's. Cracks parallel to the specimen surfaces were found to correspond to the delamination damage. Cracks detected mainly between interfaces, and the impacted surface, were more or less associated with the delamination onset at interface. Vertical cracks were detected mainly between interface and the back surface, and they were supposed to be greatly associated with the delamination onset at interface. A smaller size impactor with higher velocity tends to produce greater delamination area and more transverse cracks when impacted at the same kinetic energy, while a larger size impactor exhibits more increase in delamination area when impacted at the same velocity.

Visual examination of the impacted samples reveals that the damage in the fibres was developed around the point of impact, which results in considerable strength loss. This is observed as steep decrease in impact force in the curves. Some curves show a zigzag (several humps) pattern suggesting that there exists a multiple step failure mode during the impact.

Certain curves show bilinear behaviour (valleys and humps) following an initial linear response. The valleys are due to reduction of the stiffness of the core caused by the onset of crushing. The interface of the core and the skin resist further crushing, which is manifested as humps. Further valleys are due to the interface failure caused by debonding. This behaviour, which continues throughout the second region, probably means that the local rigidity, rather than the overall structural rigidity, is involved in the impact phenomenon.

Contrastingly, the present investigation did not reveal this type of damage, which evidences that a strong adhesive bonding exists between the layers of the composite panel. Damage of the backsheet under the impactor is either visible or hidden. The impact force can produce high through-thickness shear in the skin, which causes local delamination of the skin. These delaminations can grow during the impact process, and if spring-back occurs, part of the skin below the delamination may remain attached to the core as the remainder of the skin recovers, opening the delamination further.

CONCLUSION:

In general, internal delaminations are peanut shaped and elongated in the fiber directions as indicated in Fig 3.2 and Fig 3.3 for Graphite/Epoxy as well as Kevlar/Epoxy respectively.

Also, delamination growth in thin laminates occurs in a conical region by growth of delamination towards the lower face of the laminate.

A smaller size impactor with higher velocity tends to produce greater delamination area and more transverse cracks when impacted at the same kinetic energy, while a larger size impactor exhibits more increase in delamination area when impacted at the same velocity.

REFERENCES:

Choi, H.Y. and Chang, F.K. (1992). A Model for Predicting Damage in glass/epoxy Laminated Composites Resulting from Low-Velocity Point Impact, J. Composite Materials, 26(14): 2134-2169.

Choi, H.Y., Downs, R.J. and Chang, F.K. (1991). A New Approach toward Understanding Damage Mechanisms and Mechanics of Laminated Composites Due to Low-Velocity Impact; Part I-Experiments,

Davies, G.A.O., Hitchings, D. And Wang, J. (2000). Prediction of Threshold Impact energy for Onset of Delamination in Quasi-Isotropic glass/Epoxy Composites Laminates under Low-Velocity Impact, Composite Science and Technology, 60: 1

Ganapathy, S. And Rao, K.P. (1998). Failure Analysis of Laminated Composites Cylindrical/Spherical Shell Panel Subjected to Low-Velocity Impact, Computers and Structures, 68

Hosur, M.V., Murthy, C.R.L., Ramamurthy, T.S. and Shet, A. (1998). Estimation of Impact- induced Damage in CFRP Laminates through Ultrasonic Imaging, NDN&E International, 31(50): 359-374.

Hou, J.P., Petrinic, N., Ruiz, C. And Hallett, S.R. (2000). Prediction of Impact Damage in Composites Plates, Composites Science and Technology, 60: 273-281.

Kistler, L.S. and Waas, A.M. (1999). On the Response of Curved Laminated Panels Subjected to Transverse Impact Loads, IJSS, 34: 1311-1327.

Luo, R.K., Green, E.R. and Morrison, C.J. (1999). Impact Damage Analysis of Composite Plates, Int. J. Impact Engineering, 22: 435-447.

Oguibe, C.N. and Webb, D.C. (1999). Finite-Element Modelling of the Impact Response of a Laminated Composite Plates, Composites Science and Technology, 59: 1913-1922.

Sun, C.T. and Chen, J.K. (1985). On the Impact of Intially Stressed Composite laminates, J. Composites Materials, 19: 490-504.

Sun, C.T. and Chen, J.K. (1985). On the Impact of Intially Stressed Composite laminates, J. Composites Materials, 19: 490-504.

Velmurugan.R, Solaimurugan.S, " Improvements in Mode I interlaminar fracture toughness and in-plane mechanical properties of stitched glass/polyester composites".

Wang Ying, Hahn Thomas H, " AFM characterization of the interfacial properties of carbon fiber reinforced polymer composites subjected to hygrothermal treatments." Composites.
