UNIVERSITI TEKNOLOGI MARA

MECHANICAL PROPERTIES AND FAILURE MECHANISM OF HYBRID COMPOSITES C/GFRP

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ABSTRACT

Deformation of distinct layup of Hybrid Composites Carbon and Glass Fibre Reinforced Polymer(C/GFRP) unidirectional, off-axis shear dominated, balanced crossply and quasi isotropic under tensile, flexural and shear loading composite are subjected to debate. This study establishes comprehensive procedures of characterization and failure prediction of hybrid C/GFRP structural laminates based on the properties of CFRP and GFRP before utilized in structural design. It also established multi methods in mechanical properties extraction of Hybrid Composite C/GFRP using Laser Vibrometer, Strain Gauge, Digital Image Correlation (DIC) and Multi scale Finite Element Modelling. Novel positioning chart of Unidirectional, Off-Axis Shear Dominated, Quasi Isotropic and Balanced Cross Ply C/GFRP with respect to Tensile Strength and Flexural Strength, Tensile Modulus and Flexural Modulus, Strain to Failure (Tensile and Flexural), for composite design selection has been developed. The findings from tensile test on hybrid composite C/GFRP Symmetrical UD, Symmetrical Cross Ply, Quasi Isotropic shows that Modulus of Elasticity locates in between CFRP and GFRP respectively but Tensile Strength rely significantly on the delamination between C/GFRP layers i.e. interlayer delamination as major failure mode along with other combined failure modes such as intra layer delamination on carbon fiber, matrix cracking and propagation, fiber bridging, fiber kinking and fiber rupture. Strain to failure is observed to improve for unidirectional, cross ply and quasi isotropic hybrid composite under tensile loading due to effect of hybridization and presence of GFRP layups. 10° off-axis tensile test has been performed on hybrid composites C/GFRP and exhibits the trend of incremental Shear Modulus, G_{12} proportionately with respect to number of GFRP layers in hybrid composites C/GFRP. Hybrid composites with highest thickness of GFRP recorded the highest shear modulus due to increased occurrence of ductility of matrix and better interfacial bonding. Three point bending test has been performed on hybrid composites and observed that there is improvement of flexural strength, enhanced flexural modulus as compared to constituent GFRP and higher flexural strain to failure compared to constituent CFRP due to higher elongation capability of GFRP. It can be concluded that the tensile properties are mainly influenced by the strength and stiffness of the carbon fiber. The significant increase in flexural strength observed in hybrid composite C/GFRP has been attributed to the optimum harnessing of the compressive potential of the glass fiber during placement at the location of maximum compressive stress. The study on full field deformation using digital image correlation technique on both tensile and flexural found that deviation of median value of strain depends on the hybridization of C/GFRP where higher content of CFRP reduces the variation of strain computed from DIC in comparison with FEM. Finite element based failure prediction using maximum stress criteria on tensile test shows close agreement with experimental values but varies significantly for all other layup cases. It is due to limitation of FEM capability which does not incorporate failure mechanism such as matrix cracking, fiber rupture i.e. damage propagation. The study provides new insight on the deformation behaviour of hybrid composites under different mode of loading; tensile, shear and bending. It also offers good understanding on how variability in the carbon /glass fibre orientation can influence hybrid effects in composite laminates.

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

Composite is the combination of two or more materials that differ in properties and composition to form unique properties. Normally, composite provide increase of the durability or strength over many other materials at the same time may provide additional benefits such as resistance corrosion [1]. Fibre reinforced plastic (FRP) is a type of composite material produced by polymer matrix reinforced with fibres. Composite materials become a popular choice compared to the traditional materials due to their mechanical properties such as high strength and stiffness that are beneficial to application in the marine, automotive and aerospace industries [2]. Glass, carbon, graphite, and aramid fibres have been widely used, based on their applications although other materials are also available such as kevlar and wood. The availability of various composite materials ensures that range of FRP materials are used for many structural applications as shown in Figure 1.1. It depicts the practical application of GFRP and CFRP under the segment of combination of plastics and ceramics & glasses. The research under study is focussing on the use of CFRP and GFRP and hybridization of it. The major contribution of FRP composite can be seen in the designs of high performance and lightweight solutions in the automotive and aerospace industries. High strength to weight ratio of the FRP materials may be customized in order to design optimal structures compared to traditional structures which made using metal alloys [3]. The use of reliable design and prediction methods will ensure superior performance of composite.