FATIGUE BEHAVIOR OF UN-NOTCHED AND OPEN-HOLE QUASI-ISOTROPIC PSEUDO-DUCTILE THIN-PLY CARBON/GLASS HYBRID LAMINATES

M. Fotouhi*, P. Suwarta2, R. Jenkin2, M. Jalalvand3, and M. Wisnom2
1 Department of Design and Mathematics, the University of the West of England, Bristol BS16 1QY, UK
2 Bristol Composites Institute (ACCIS), University of Bristol, Queen’s Building, University Walk, Bristol, BS8 1TR, UK
3 Department of Mechanical and Aerospace Engineering, University of Strathclyde, 75 Montrose Street, Glasgow, G1 1XJ, UK
* Corresponding author (mohammad.fotouhi@uwe.ac.uk)

1 General Introduction

There is rapid expansion of composite use in applications such as wind turbine blades, sporting goods and civil engineering infrastructure due to their excellent properties. Conventional composites such as carbon fibre reinforced plastics have outstanding mechanical properties: high strength and stiffness, low weight, and low susceptibility to fatigue failure. Despite these advantages, failure in conventional composites is usually sudden and catastrophic, with little or no warning or capacity to carry load afterwards.

Recently, Unidirectional (UD) and Quasi Isotropic (QI) thin-ply hybrids with different types of low strain and high strain fibres were introduced that generated the desired nonlinear stress–strain response and pseudo-ductility that avoids catastrophic failure in laminated composites [1-2]. This hybridization concept was found useful in improving the notch sensitivity that is another important limiting factor in conventional composite laminates [2]. The pseudo-ductility and notch insensitivity result from subcritical damage mechanisms, i.e. fragmentation and stable delamination, which prevent catastrophic failure of the hybrid composite after the first carbon layer fracture. These damage mechanisms are illustrated schematically in Fig. 1. for a three-layer UD hybrid laminate made from standard thickness glass/epoxy and thin-ply carbon/epoxy.

Appropriate material properties, and suitable values of relative thickness (i.e. thickness ratio of low strain material to high strain material and absolute thickness of low strain material need to be selected for an optimal design [2].

In order to apply these pseudo-ductile hybrid composites in real-life applications, their fatigue should be understood. Previously the fatigue behavior of a UD hybrid composite was investigated and it was concluded that the UD composite has a good resistance against cyclic load even after the appearance of damage, and only a gradual increase in damage was observed over thousands of cycles [3].

![Fig. 1. A microscopic image from the surface of typical 2TR30-S-glass/epoxy laminate [1].](image)

Abstract:

This paper investigates fatigue behaviour of a QI composite made from thin carbon plies and standard thickness glass plies. As illustrated in Fig. 2, this orientation-dispersed QI thin-ply carbon/glass hybrid laminate showed a successful pseudo-ductile un-notched behaviour with improved notch-insensitivity and suppression of free-edge delamination [2].

In this study an experimental program has been carried out to investigate the damage development throughout the life of un-notched and open-hole thinly carbon/glass hybrid configurations consisting of thin ply T300 carbon/epoxy and S-glass/epoxy prepregs, before having any pseudo-ductile damage and at two different stress levels. The fatigued samples are illustrated in Figs. 3 and 4. The knee point is determined at the intersection of the lines fitted through the initial linear and the plateau parts of the
individual stress-strain curves. It was observed that, for the un-notched samples, there is no stiffness reduction, after 100,000 cycles, for a stress level of 80% of the knee-point stress at which significant damage starts. By increasing the stress level to 90% of the knee point stress, there is a gradual stiffness reduction due to the appearance of matrix cracking and delamination.

A similar behavior was observed for the open-hole laminates (see Fig. 4.), where no damage was observed for the low stress level (50% of the final failure stress), however a gradual delamination growth was observed for the high stress level (70% of the final failure stress). Overall good fatigue performance of pseudo-ductile hybrid composites, with gradual fatigue damage growth was observed, that shows their applicability for real industrial applications.

References

