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EXPERIMENTAL STUDY ON DELAMINATION ONSET OF UNIDIRECTIONAL GFRP DCB SPECIMENS UNDER IN-PLANE FIBER WAVINESS DEFECT

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ABSTRACT

This study focuses on the effect of in-plane fiber waviness on fracture toughness and crack propagation as determined from the double cantilever beam (DCB) experiment. A through thickness in-plane fiber waviness was intentionally induced inside the DCB specimens made up of unidirectional E-glass/epoxy. Two variants of wave induced specimens having different crack initiation front were prepared along with a set of defect free DCB specimens. For the first set of specimens, the crack initiation front was close inside to the fiber waviness area ($[0]_{6w}$) and for the second set the crack initiation front was ahead of waviness defect ($[0]_{8w}$). This was to differentiate the effect waviness defect on crack initiation and crack propagation respectively. Comparison of the results showed that the fracture toughness and crack propagation rate varies based on location of crack initiation front on the wavy fiber area.

Keywords: glass fiber composite, in-plane waviness, DCB, fracture toughness.

INTRODUCTION

In wind power industries, most of the turbine blade components are made up of fiber reinforced polymer (FRP) composites. For getting maximum output from a single wind turbine, the size of the whole wind turbine need to be increased which makes the design of blades more demanding, complicated and critical. Although the FRP composites blades have good engineering qualities, their service life expectancy which is influenced by the existence of manufacturing defects, can be improved. Even a small defect in manufacturing has been known to critically affect the operation of blade in service leading to catastrophic failure of the whole structure. This paper focuses on the effect of one of the common manufacturing defects called in-plane fiber waviness, which can be found throughout the thickness of the laminate.

Double cantilever beam (DCB) testing is widely used for the experimental determination of Mode-I fracture energy release rate (G_{IC}). Thus, this method was employed to determine the variation in fracture energy release rate and variation in crack propagation due to the presence of fiber waviness defects. Four sets of specimens were prepared with and without fiber waviness defect ($[0]_{6w}$, $[0]_{8w}$ and $[0]_6$, $[0]_8$). Standard testing based on ASTM D5528 was followed to characterize the fracture properties of double cantilever beam specimens. Previous experimental work (Shokrieh, Heidari-Rarani et al. 2012) has shown the

delamination resistance to be independent of specimen size and geometry within a specified initial crack length to thickness ratio. Hence, the focus of study is on the position of fiber waviness defect as shown in fig 1.

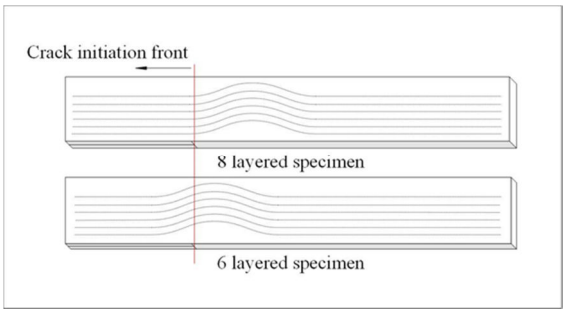

Fig.1 - Specimen diagram of $[0]_{8w}$ and $[0]_{6w}$ with fiber waviness

RESULTS AND CONCLUSIONS

In all the test samples, the response was linear up to the crack initiation point or point of non-linearity (NL). Due to fiber waviness, a drop in stiffness was observed in the $[0]_{6w}$ specimen arm which effected the slope of the $P - \delta$ curve compared to the $[0]_6$ specimen. But as shown in fig 2 (a), no drop in stiffness of the $[0]_{8w}$ specimen arm was observed as compared to the $[0]_8$ specimens,. A difference in the crack propagation rate was observed along the transverse width plane in the wavy specimens (see fig 2(b)).

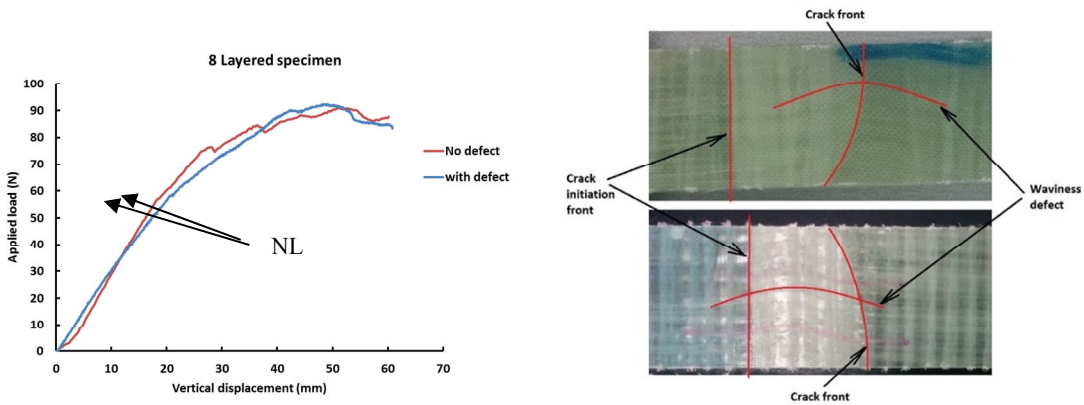

Fig. 2 - (a) $P - \delta$ curve of defected $[0]_{8w}$ and a no defect specimen $[0]_8$, (b) Shape of crack front along the fiber waviness area.

The present study shows that the delamination initiation toughness ($G_{IC\text{-}init}$) for both the defective and no defect specimens were nearly same. However, the steady state crack propagation energies ($G_{IC\text{-}prop}$) of $[0]_{8w}$ and $[0]_{6w}$ specimens were less than that for the $[0]_8$ and $[0]_6$ specimens.

ACKNOWLEDGMENTS

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