THEORETICAL PREDICTION OF MEAN CRUSHING FORCE IN PROGRESSIVE FAILURE OF WOVEN FRP COMPOSITE BOX STRUCTURES

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Introduction

The fibre reinforced polymer (FRP) composites can absorb impact energy very efficiently and they are used in advanced vehicular structures. During the progressive crushing of CFRP and GFRP composite box the combination of brittle fracture, lamina bending, local buckling and transverse shearing crushing modes is observed. The first mode is *transverse shearing* (fragmentation) which is characterised by a wedge-shaped laminate cross section with one or multiple short interlaminar and longitudinal cracks. In this mechanism interlaminar crack propagation and bundle fracture control the energy absorption. The second mode is *lamina bending* which is shaped with long interlaminar, intralaminar, and parallel to fibre cracks. This mechanism causes the formation of continuous fronds which spread inwards and outwards. Friction and inter/intra laminar fracture controls the energy absorption of lamina bending mode. The combination of fragmentation and lamina bending modes is called *brittle fracture* mode. The highest energy absorption of composite tubes has been observed in combination of brittle fracture and lamina bending crushing modes [1,2]. The third mode is *local buckling* which is consists of the formation of local buckles by means of plastic deformation of material.

Theoretical prediction

This paper proposed the new theoretical prediction based on friction, bending and fracture mechanisms to predict the mean crushing force for the combination of failure crushing modes. The brittle nature of the most of FRP composites yields they show high capability in absorbing the crushing energy by introducing various fracture mechanisms. The bundle fracture, frond splitting and delamination crack growth are the most important of them. This kind of fractures contributes to shape lamina bundles and consequently increasing of friction and bending resistance. Compared to other analytical methods, the present work relatively introduces the comprehensive prediction of mean crushing force for combination of all failure modes (see Figure 1).

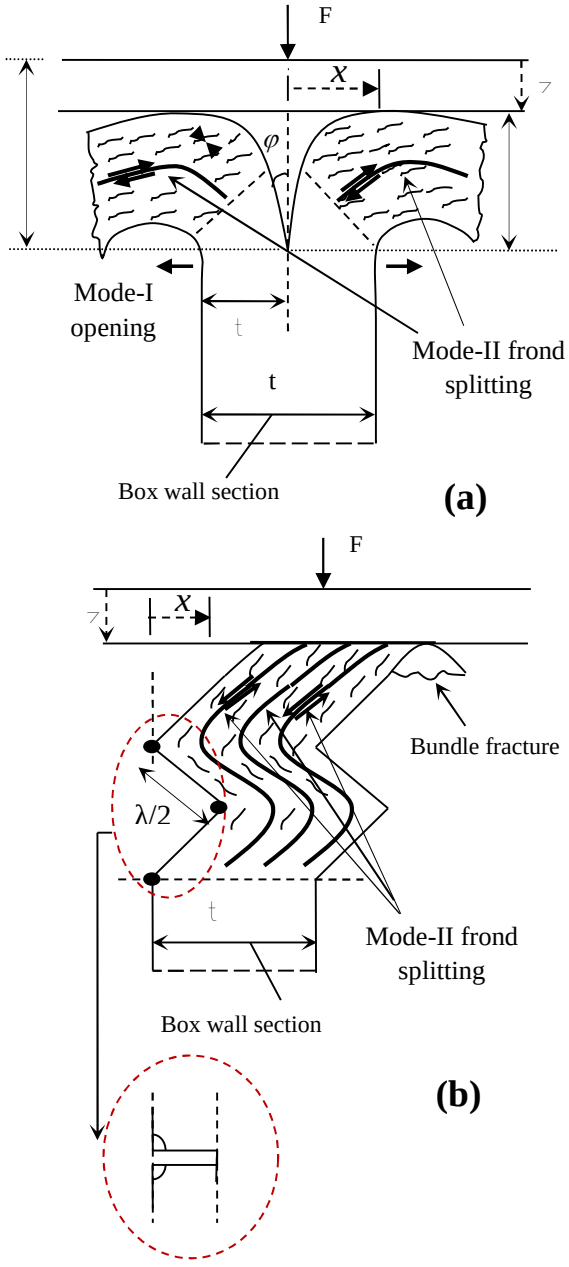

Fig. 1. Ideal crush zone, (a) Lamina bending/brittle fracture crushing mode and (b) Local buckling/transverse shearing crushing mode.

Results and discussion

The comparison of experimental and analytical mean forces of FRP composite boxes in various crushing modes are presented in Table 1. In brittle fracture/ lamina bending crushing mode the highest value which plays an important role on energy absorption during crushing process is for axial splitting and after that for bundle fracture. It should be mentioned these mechanisms are coupled together and they act at the same time in a crushing process. This fact shows higher resistance for delamination crack growth in different delamination modes directly affect on the bending and friction resistance of internal and external fronds against the crushing load.

Table 1. Comparison of experimental and analytical mean force (F_m) results of CFRP & CFRP composite box in brittle fracture crushing mode.

Laminate Lay-up	**Crushing mode**	F_m(Exp) kN	F_m(Ana) kN
$CFRP[0]_4$	LB/BF	65	59.4
$CFRP[0/45]_2$	LB/BF	67	59.3
$CFRP[45]_4$	BU/TS	52	58.5
$GFRP[0]_{10}$	BF	50	48

References

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[2] Hadavinia H and Ghasemnejad H. Effects of Mode-I and Mode-II interlaminar

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