

# Pultruded composite tubes for crashworthiness

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## I. INTRODUCTION

The need for safer vehicle design which (i) absorbs energy (ii) keep the occupant compartments intact and (iii) ensures tolerable deceleration levels for driver and passengers during the crash event increases due to high speed operation (Figure 1). The above said factors depend upon the design architecture and the materials which are used in the automobiles. Due to superior specific energy absorption, ease of manufacturing and less maintenance the composite tubes can be used in automobiles for crashworthiness. However, the current numerical modelling approaches do not provide the correct failure patterns and the crushing parameters (peak crush load and the energy absorption). Capturing these parameters is absolutely necessary to calculate the accurate tolerable deceleration levels of the occupants in an automobile [1].

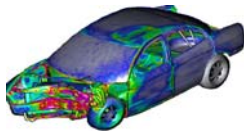


Figure 1: Crashworthiness of an automobile.

## II. IMPORTANT PARAMETERS FOR ACCURATE PREDICTION OF CRUSHING PARAMETERS

To achieve the initial damage of composite tubes (to achieve a lower deceleration values during a crash event) an initiator is needed.

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These initiators are called as “triggering mechanism”. Generally the 45° chamfering (triggering profile) is widely used (Figure 2). The correct modelling of triggering has a great influence on the prediction of accurate peak crush load.

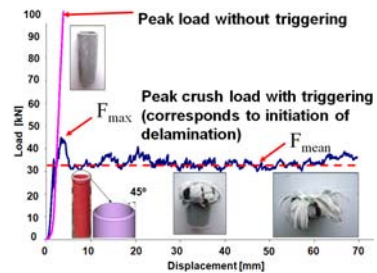


Figure 2: Effect of triggering.

Secondly, the consideration of the delamination (decohesion of composite layers or laminates) in the numerical modelling is also very important. The initiation of the circumferential delamination corresponds to the peak crushing load of any composite tube. Hence without capturing the delamination the correct prediction of the peak crush load is impossible. The above facts are proved for the circular and square cross sectional pultruded glass polyester composite tubes two different triggering profiles.

## III. CURRENT NUMERICAL MODELLING APPROACH

Generally the composite tubes are modelled with a single layer of shell elements. However, the 45° chamfering cannot be modelled with a single layer of shell

elements. Furthermore, the single shell layer approach cannot capture the delamination failure mode.

#### IV. PROPOSED NUMERICAL MODELLING APPROACH AND ITS RESULTS

The above said factors can be achieved with the finite element modelling using two layers and multiple layers of shell elements and with cohesive elements. The typical failure modes of pultruded composite tubes (delamination, axial cracks, lamina bending and fracturing of fibres) can be achieved with these approaches.

##### A. Numerical modelling

For two shell layers, the tube was divided into two equal thicknesses which represent the outer and inner sub laminate. The shell elements were located at the centre of each sub-laminate. The delamination was modelled with cohesive elements (elements with zero thickness and capture the decohesion of the composite layers). For the multiple shell layers approach, the thickness of the composite tube was modelled with six layers of shell elements and five layers of cohesive elements. The appropriate damage criteria were used for shell and cohesive layers. The numerical analysis was carried out for the initial impact velocity of 9.3 m/s. The energy absorption of the composite tubes was calculated based on Equation 1

$$E_d = \int_0^{l_{max}} P(l).dl \quad (1)$$

where,  $P(l)$  is the instantaneous crushing load corresponding to the instantaneous crushing deformation length  $dl$ .  $l_{max}$  is the maximum crushing length.

##### B. Results

Figure 3 shows the comparison of failure patterns of the experimental and numerical cases. Furthermore, Figure 4 shows the comparison of the energy absorption for the circular tubes. It can be noticed that there was a good correlation obtained for the crushing parameters.

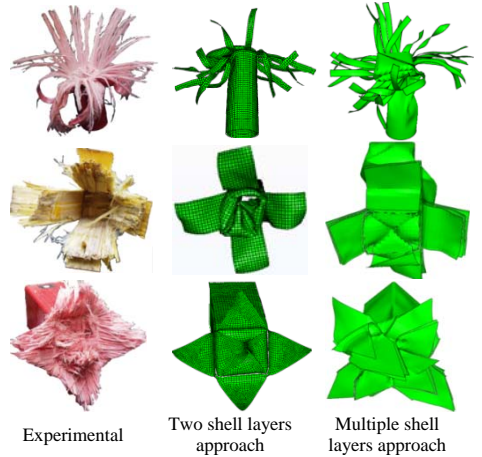


Figure 3: Comparison of failure patterns.

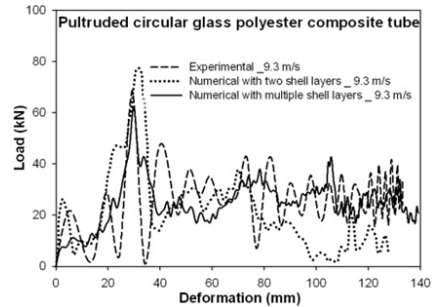


Figure 4: Comparison of experimental and numerical energy absorption.

#### V. CONCLUSION

In order to predict the accurate crushing parameters the delamination approach and the correct modelling of triggering are absolutely necessary. This can be achieved with two and multiple shell layers approach. The modelling approach with a single layer of shell elements cannot capture the correct impact parameters.

#### REFERENCES

- [1] Zarei Hamidreza, Kröger Matthias and Albertsen Henrik, *An experimental and numerical crashworthiness investigation of thermoplastic composite crash boxes*. Composite Structures. 85(2008): pp. 245-257.