1st European Conference on Crashworthiness of Composite Structures – ECCCS-1
19-21st November 2019, Queen's University Belfast
www.qub.ac.uk/sites/ecccs-1

SIMULATION STUDIES ON THE CRASHWORTHINESS OF CARBON FIBRE COMPOSITE FLAT SPECIMENS

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Composites made from Carbon Fibre Reinforced Plastic (CFRP) have tailorable and superior specific characteristics compared to metals for use in structural components. Higher specific tensile modulus and strength of CFRPs allow designers to achieve improved performance with a lower weight. However, owing to complex failure modes, impact behaviour of CFRPs is not well understood resulting in underutilization of their potential as primary crash structures [1, 2]. The approach proposes using both in-plane and out-of-plane data to better calibrate numerical models, thereby improving impact behaviour prediction. The paper also presents a newly developed fixture for in-plane flat specimen testing and a methodology to computationally assess the crash performance.

After calibrating the simulation model using material characterization data, it is calibrated for out-of-plane and in-plane impact, using HyperWorks and RADIOSS. Out-of-plane calibration is performed using drop tower impact tests on a 150 x 100 x 3 mm specimen and in-plane calibration using saw-tooth triggered flat specimens of similar dimensions. A fixture designed by Centro Ricerche Fiat, Instron CEAST, and Politecnico di Torino is used to test flat specimens with different unsupported heights and thicknesses and is shown in Fig. 1 below. Fig. 2 below shows the effect of different unsupported heights, an analysis performed during the design stage of the fixture. As the fixture can test specimen with dimensions 150 x 100 mm, same as that of Compression After Impact and drop tower impact tests, it allows for standardisation of testing. The mesh size is kept between 4 – 5 mm to remove mesh dependence while scaling up to component and full body tests, thereby making the approach more robust. A sensitivity analysis is performed to arrive at the best combination of elements (shell, solid, cohesive) to accurately predict impact behaviour with minimum computational effort.

Additionally, in-plane simulations are also performed using damaged specimens that mimic out-of-plane damages that might be observed in-service or during manufacturing to assess the residual crashworthiness after damage. The damage predicted by the simulation model is compared with results from X-ray radiography to assess the robustness of the simulations in predicting the force-displacement graph and the damage.

It is expected that until critical delamination, the specific energy will not change drastically; however, after the crack starts to propagate, the energy absorption would decreases. In addition, a model calibrated to include both in-plane and out-of-plane loadings should be able to predict impact damage mechanics and behaviour of component level structures more accurately, thereby making flat specimen testing integral to predicting crashworthiness of CFRP materials. The fixture will be

modified to test sloped flat specimens in the future to better improve modelling capabilities and understand crushing behaviour in case of a real crash scenario.

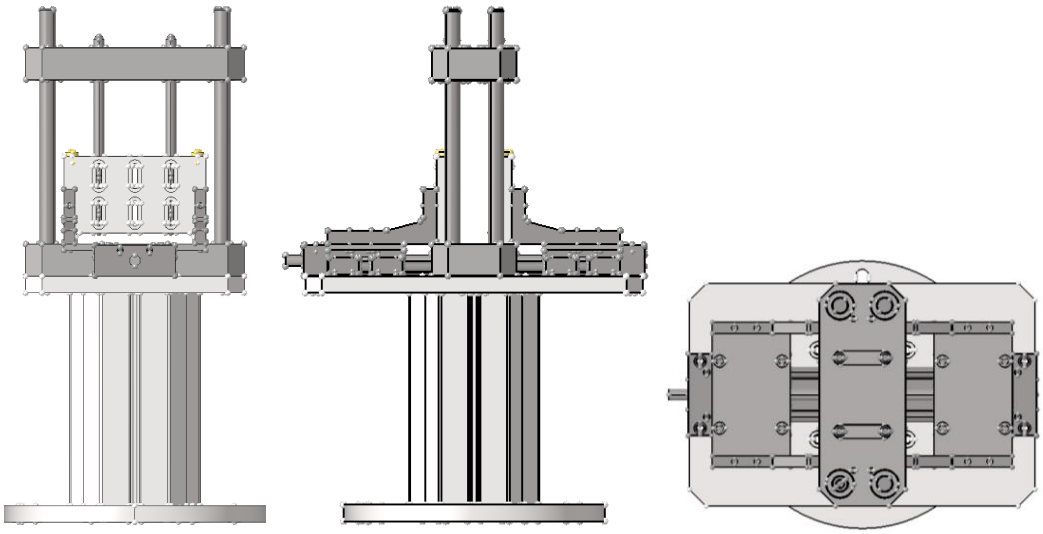

Figure 1. Fixture for flat and curved composite testing (Left: Front view, Centre: Side View, Right: Top View).

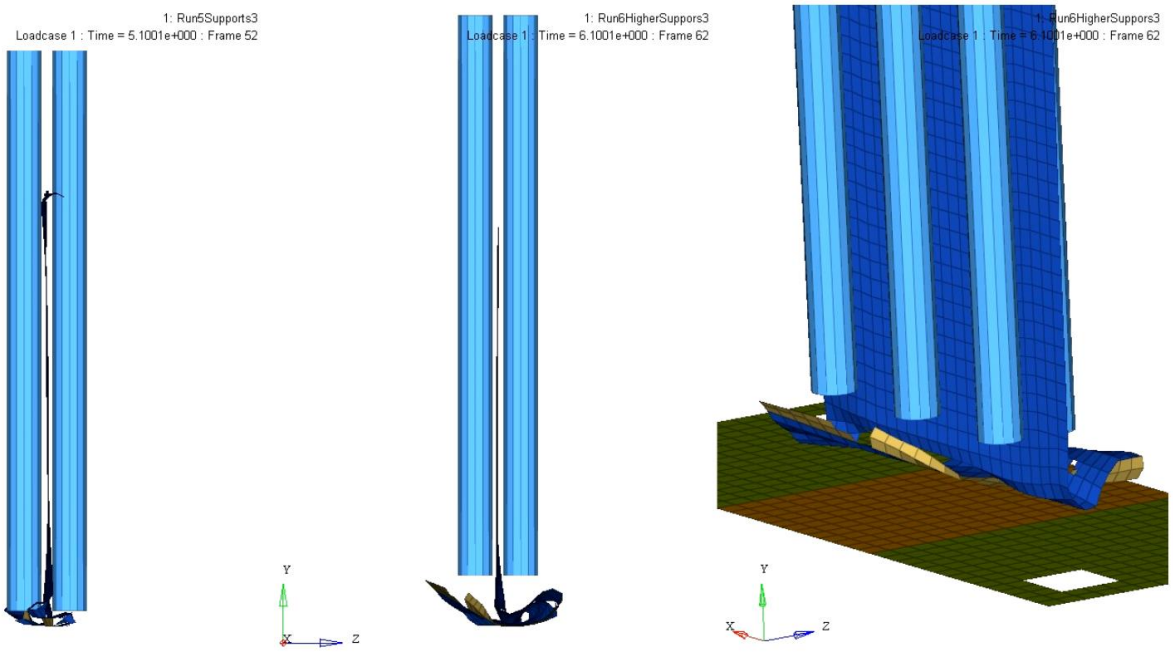

Figure 2. Preliminary results of effect of different unsupported heights on flat specimen crushing. Increase in unsupported height from 10 mm to 20 mm causes the specimen to not crumple up, and instead to form fronds as would be expected under impact.

[1] David (2014). Experimental and Numerical Investigation of Polymer Composite Energy Absorbers under Dynamic Loading. University of Stuttgart. **5 – 7**

[2] Composite Materials Handbook (2012). *Crashworthiness and Energy Management.* SAE International.