Design of crashworthy automotive composite structures

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Introduction

- Need to use composite materials to meet the EU's climate, energy, and transport policies
- Composite need to match the crash performance of metals with a lower weight and cost and similar predictability of damage
- Development of improved modelling methodology to predict crash behaviour in HyperWorks RADIOSS
- Design of composite crash box
- Design of fixture to test flat plates under impact to improve numerical analysis
- Integration of shell and solid elements and strain rate effects
- Validation using LS-DYNA
- Verification using experimental results

Strain Rate Testing

- High strain rate compression testing undertaken at University of Patras using Split Hopkinson Bar with 10 x 10 mm and 10 x 20 mm 2.7 mm thick specimen
- Major issue – Non-parallel edges cause specimen flip out
- Mechanical properties improve at higher strain rate, but decrease after a point
- Progressive damage observed using high speed camera
- More tests need to be conducted to understand point of inflection
- Tensile test to be conducted
- Compressive test to be conducted below 1000 s^{-1}

Strain Rate (s^{-1})	Compressive Strength (MPa)	Compressive Modulus (GPa)
1	468	--
1250	755	11
2100	437	6.7

Table 1: Strain rate effect on Compressive Strength and Modulus

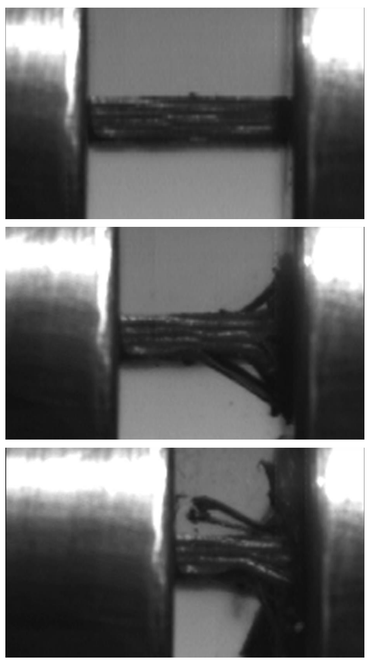


Figure 1: 10 x 10 mm CFRP specimen under compression loading at 2100 s^{-1}

Cohesive Element Integration

- Integration for out-of-plane tests complete
- Improved damage behaviour representation vs. only shells
- Next step – integration into in-plane tests

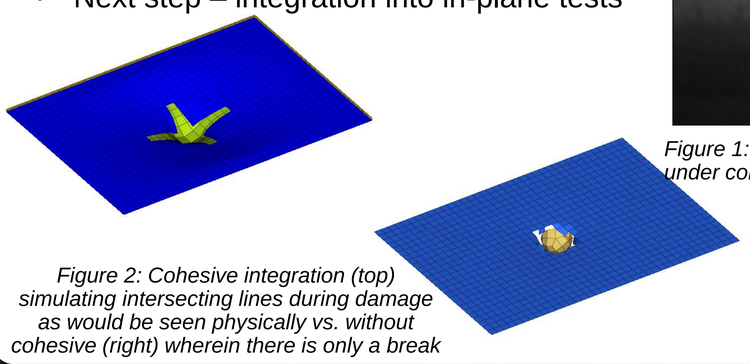


Figure 2: Cohesive integration (top) simulating intersecting lines during damage as would be seen physically vs. without cohesive (right) wherein there is only a break

Flat Plate Impact Test Fixture Development

Objectives

- Design fixture for 150 x 100 mm (same as Compression After Impact) Flat Plate Impact testing
- Obtain information to improve calibration of numerical model for crash behavior prediction of component level tests
- Intermediate step between coupon and component testing, therefore, saving time and money spent on component testing

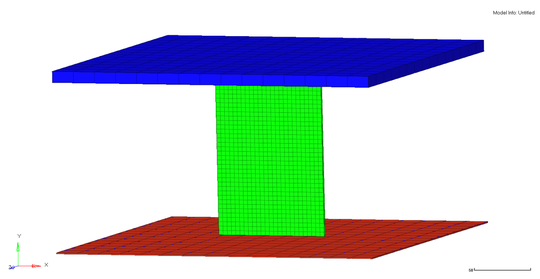


Figure 4: Basic preliminary iteration

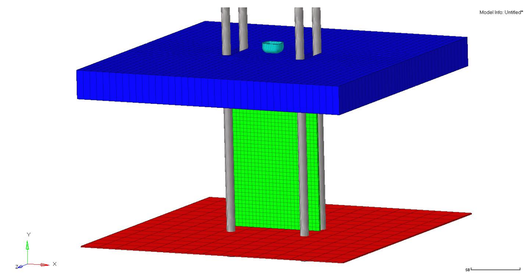


Figure 5: Top plate optimization to avoid plasticity and inclusion of supports

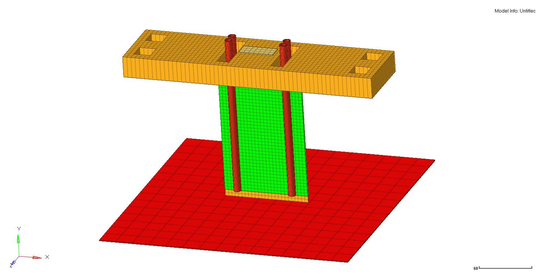


*Figure 5: Top plate optimization to reduce weight – **Final Design***

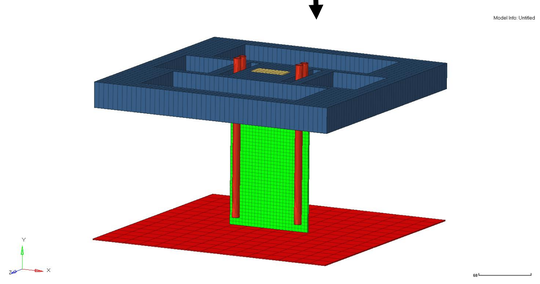


Figure 5: Top plate optimization to reduce weight and impact with different impactor shape

First test showed integrity of fixture compromised on impact – need for reinforcement

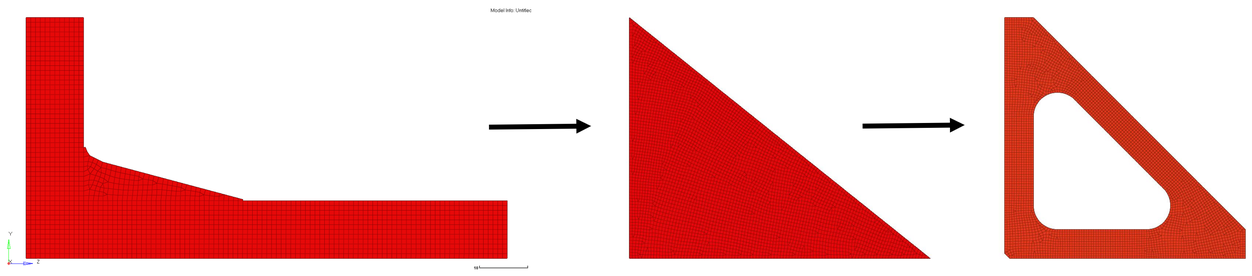


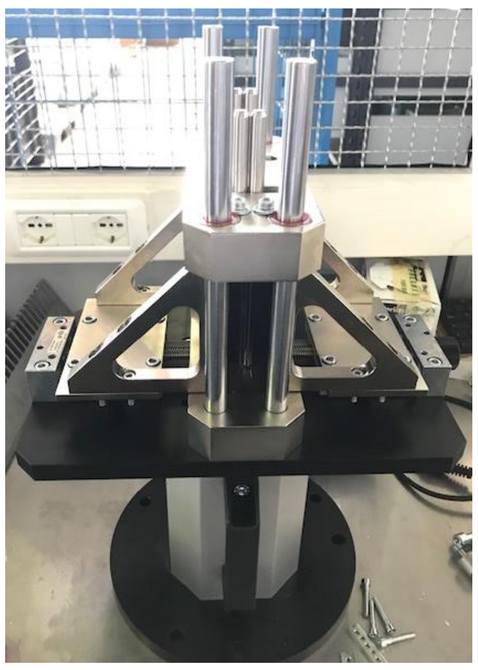
Figure 6: Hinge optimization: Using a taller, thicker and triangular hinge, that was optimized for weight

Results

- Structural integrity intact at 800 J impact
- Obtained progressive failure up to 50 mm on CFRP specimen

Future Work

- Tune numerical model with results from testing to understand improvement in predictability of composite crash box damage
- Minor mechanical improvements needed in the fixture



Conclusion

- Material has high strain rate dependency that needs to be incorporated in the numerical model
- Cohesive elements improve impact behaviour and will be used to model in-plane impact – stacked shell approach will not be used
- New fixture for flat plate testing designed, manufactured, and tested and should aid numerical models to improve damage behaviour prediction

References

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