Experimental impact damage tolerance evaluation of thick composite structures

Low- and high-velocity impact followed by compression-after-impact

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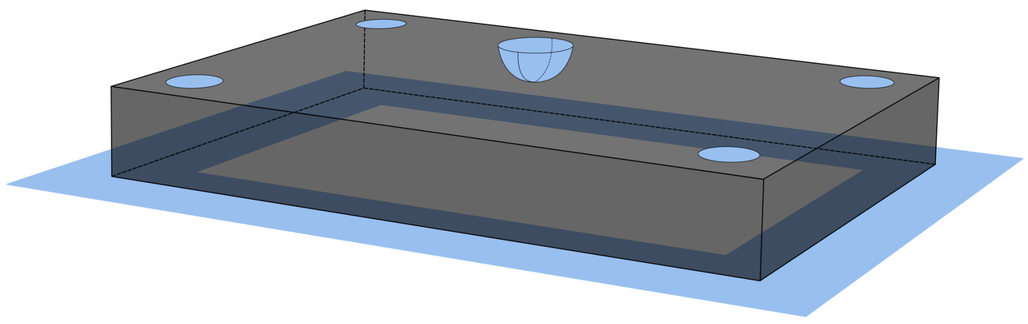
INTRODUCTION

Gear rib of the Affordable Low Cost Aircraft Structures (ALCAS) airliner wing [1].

Carbon Fibre Reinforced Polymer materials are being increasingly used in highly-loaded aerospace components, resulting in thick composite structures (e.g., 20-100mm)



The impact problem according to the ASTM D7136 standard [2]. It illustrates centre impact with a 16mm diameter impactor on a 150x100mm specimen clamped at four corners.

Problem:
Impact events are critical in designing a damage tolerant composite structure

Knowledge gap:
Experimental data for impact on thick composite structures is limited

Solution:
A new testing campaign is carried out to be used for validation of numerical models

IMPACT EXPERIMENTS

40 impacts: 10 tests instances with each four specimens

Thickness	20mm	40mm
Energy level	55J	100J
Layup	Quasi-Isotropic (QI)	Anisotropic
Impactor	Large-mass drop-tower	Small-mass gas-cannon

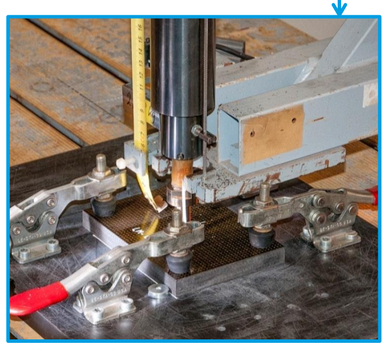
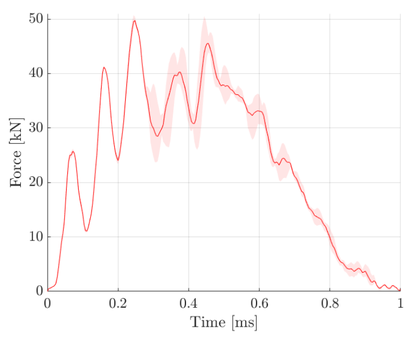
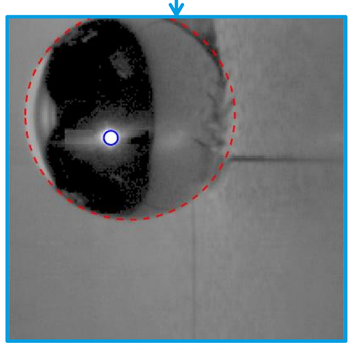


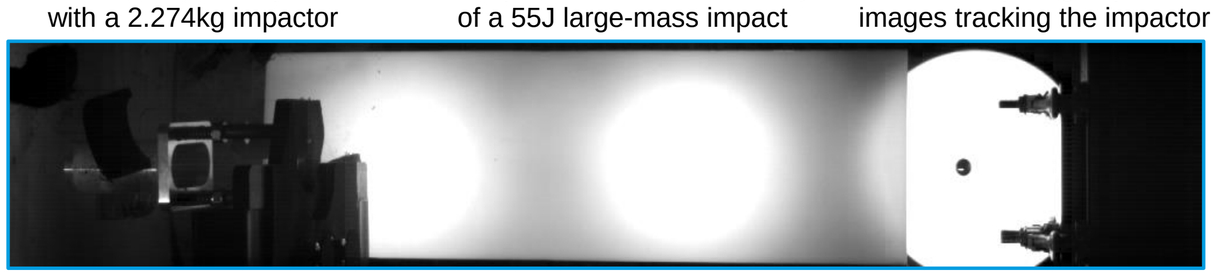
Illustration of the drop-tower with a 2.274kg impactor



Example of a force-time history of a 55J large-mass impact



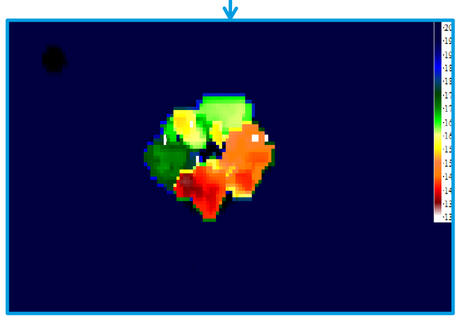
150,000fps high-speed images tracking the impactor



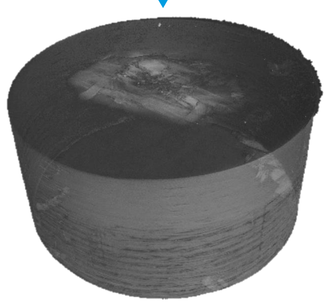
Small-mass gas-cannon with 20,000 fps high-speed images measuring the impactor velocity.

Damage inspection to determine the characteristic damage state

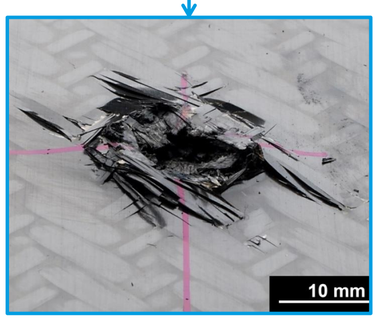
Ultrasonic C-scans



X-ray CT-scans



Dent depth



2D visual inspection of cross-sections

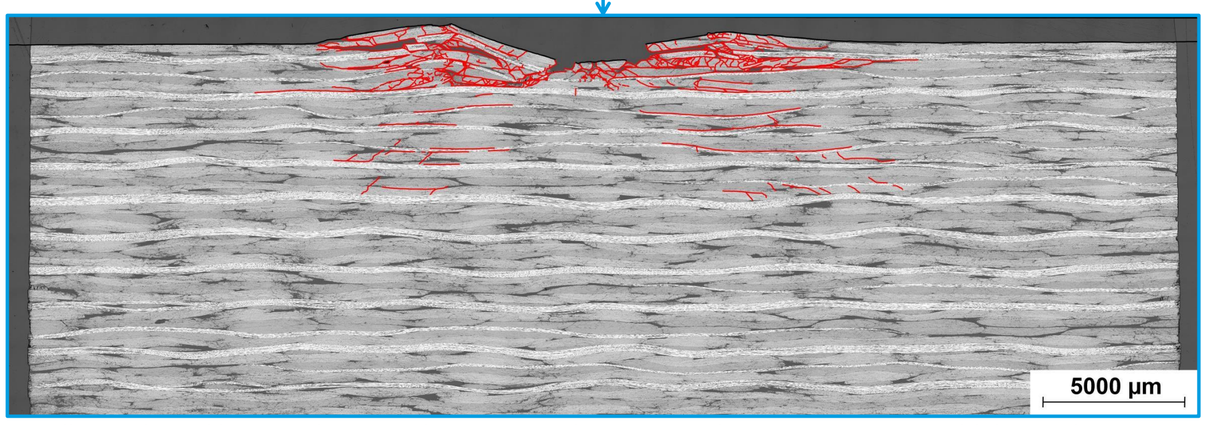


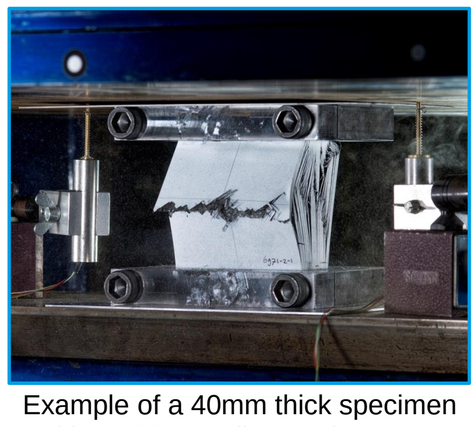
Illustration of impact damage due to a 55J large-mass impact on a 20mm thick specimen.

COMPRESSION-AFTER-IMPACT EXPERIMENTS

Experiments to determine the Compression-After-Impact (CAI) strength

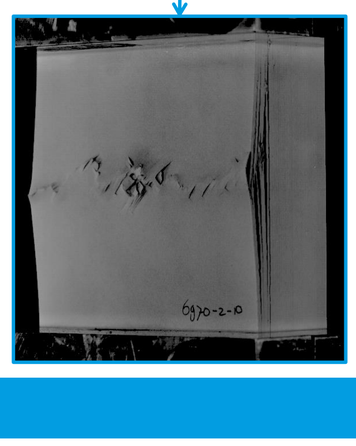
Compression using 2,000kN static test bench

Two high-speed cameras at 20,000fps tracking damage mechanisms

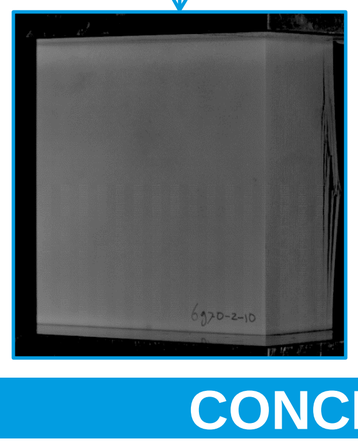


Example of a 40mm thick specimen with a 100J small-mass impact at the point of failure (i.e., 1234kN).

Front view

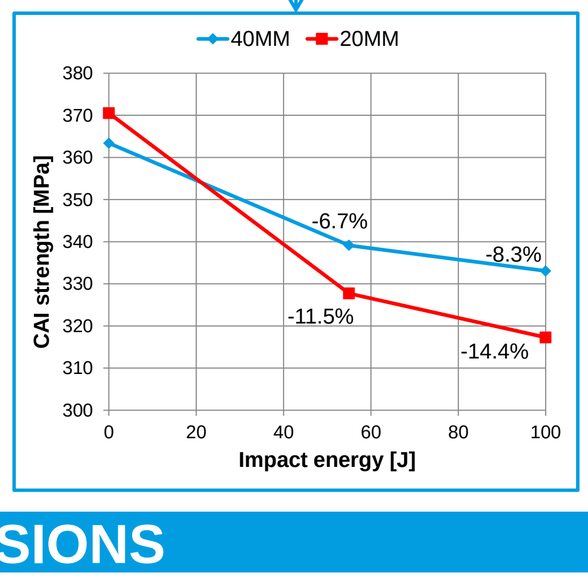


Rear view

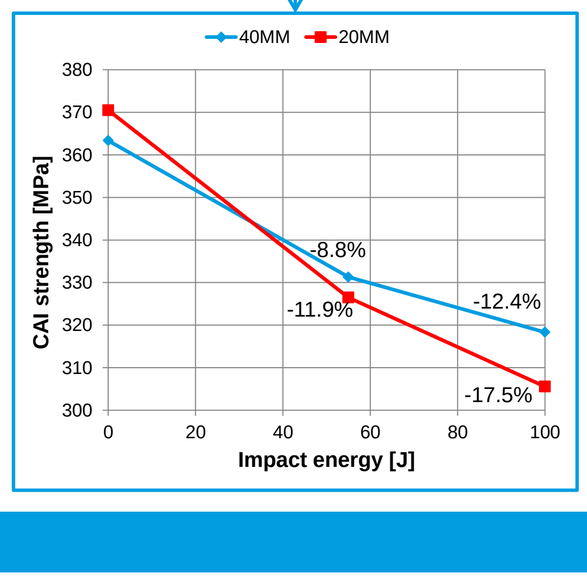


Results: CAI strength as function of thickness and impact energy

Large-mass drop-tower



Small-mass gas-cannon



CONCLUSIONS

- ✓ The experimental data is used for the validation of numerical models
- ✓ Anomalies for small-mass impact, compared to large-mass, are that...
  ...the delaminated area is significantly higher for 20mm specimens (+112% @ 100J)
  ...the layup has a considerable effect on the dent depth (+60% for the QI layup @ 55J)
- ✓ Residual CAI strengths show a relatively small effect of impact damage

[1] H.P.J. de Vries. Development of a main landing gear attachment fitting using composite material and resin transfer moulding. Techreport NLR-TP-2009-732, NLR – Netherlands Aerospace Centre, December 2010.
[2] ASTM International. *Standard test method for measuring the damage resistance of a fiber-reinforced polymer matrix composite to a drop-weight impact event,* number ASTM D7136/D7136M-15, West Conshohocken, PA, 2015

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