Impact damage in aerospace structures: Investigating the impact characteristics of different standard aerospace grades of glass fibre reinforced aluminium laminate (GLARE®)

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4 authors, including:

Chirag Shah
University of Siegen

Tim Behrens
German Aerospace Center (DLR)

Axel von Hehl
University of Siegen, Germany

Impact damage characteristics of different standard aerospace grades of GLARE®

Chirag Shah[1], Tim Behrens[2], Daniel Schmidt[2] and Axel von Hehl[1]

[1]Institut für Werkstofftechnik, Lehrstuhl für Materialkunde und Werkstoffprüfung (LMW), Universität Siegen

[2]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Bremen

DFG Research Unit
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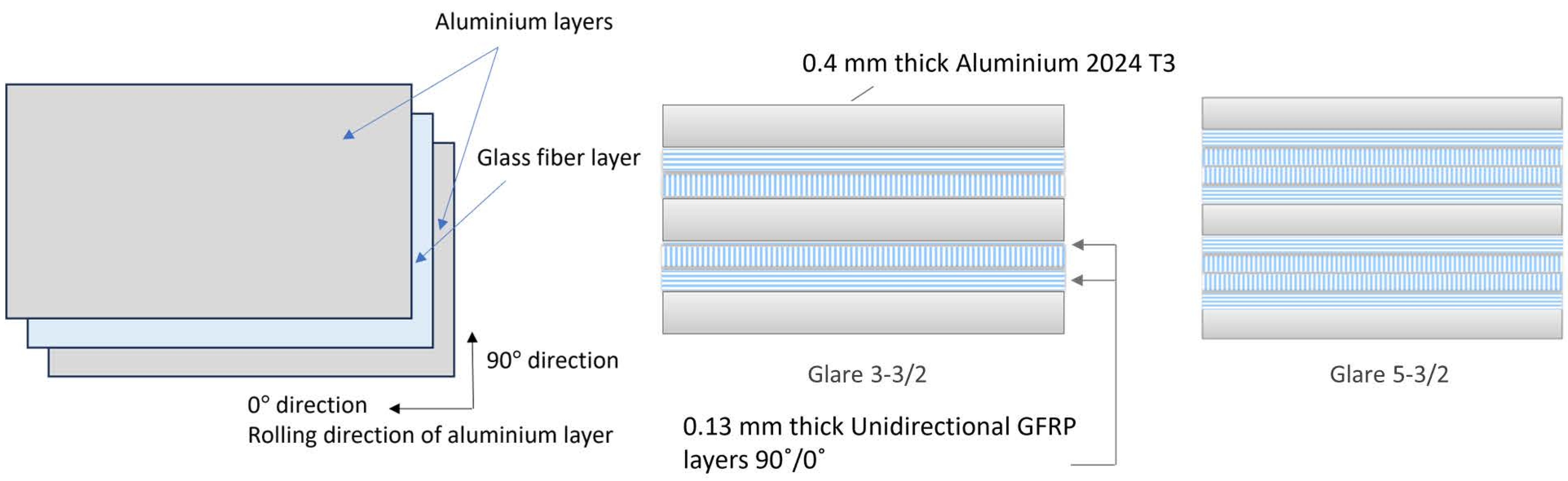
Ultrasonic Monitoring of
Fiber Metal Laminates Using Integrated Sensors

Introduction and motivation

- Fiber metal laminates (FMLs) are advanced materials made by bonding metal and fiber-reinforced polymer (FRP) layers. They combine the strength-to-weight ratio of metals with the fatigue resistance of FRP composites.
- Used in aerospace, automotive, and marine fields, FMLs endure high loads and fatigue cycles, enhancing structural integrity while minimizing weight.
- However, FMLs are vulnerable to impact damage due to their complex structure, which can lead to delamination and compromise structural integrity. Such damage may not be visible externally, making assessment difficult.
- Impact damage can also accelerate fatigue and eventual failure under cyclic loading conditions, particularly in aerospace and automotive applications.

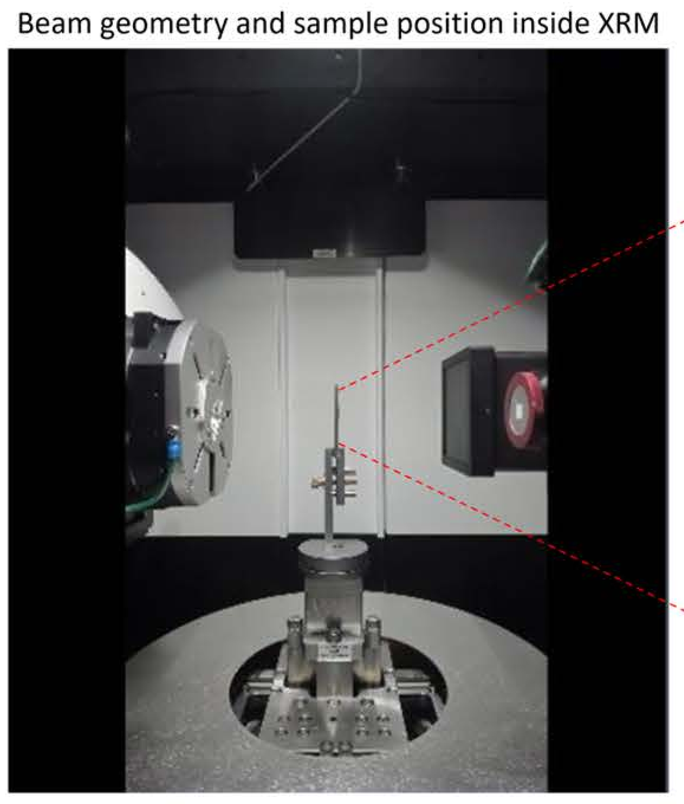


Experimental setup and results

X-ray imaging workflow: From scan to data inspection

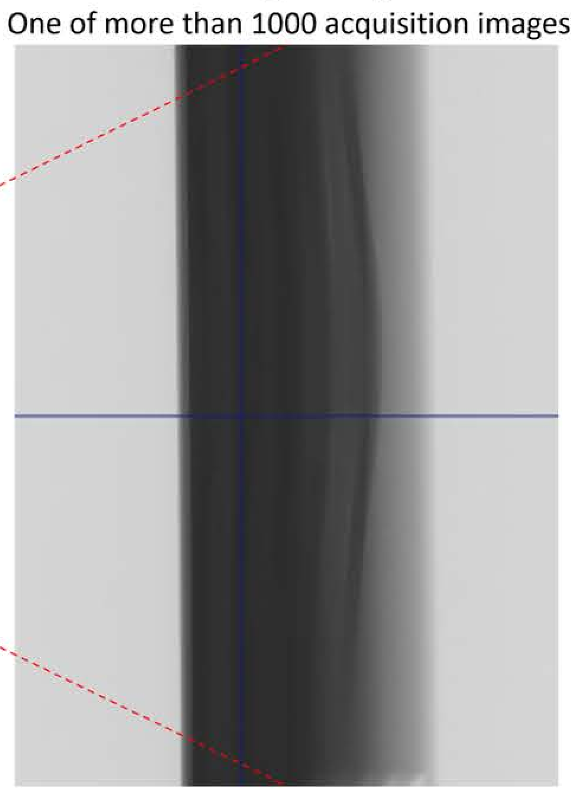
Acquisition of tomography data → Reconstruction of the 3D data volume → Image inspection and volume rendering → Quantitative 3D image analysis

Beam geometry and sample position inside XRM



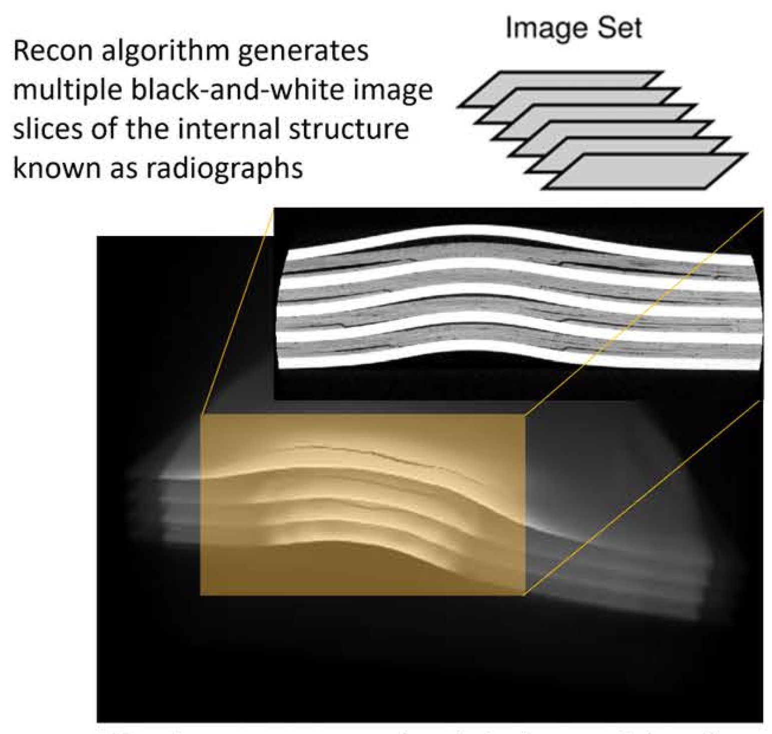
Sample in scout position, 0.4X objective for an overview

One of more than 1000 acquisition images



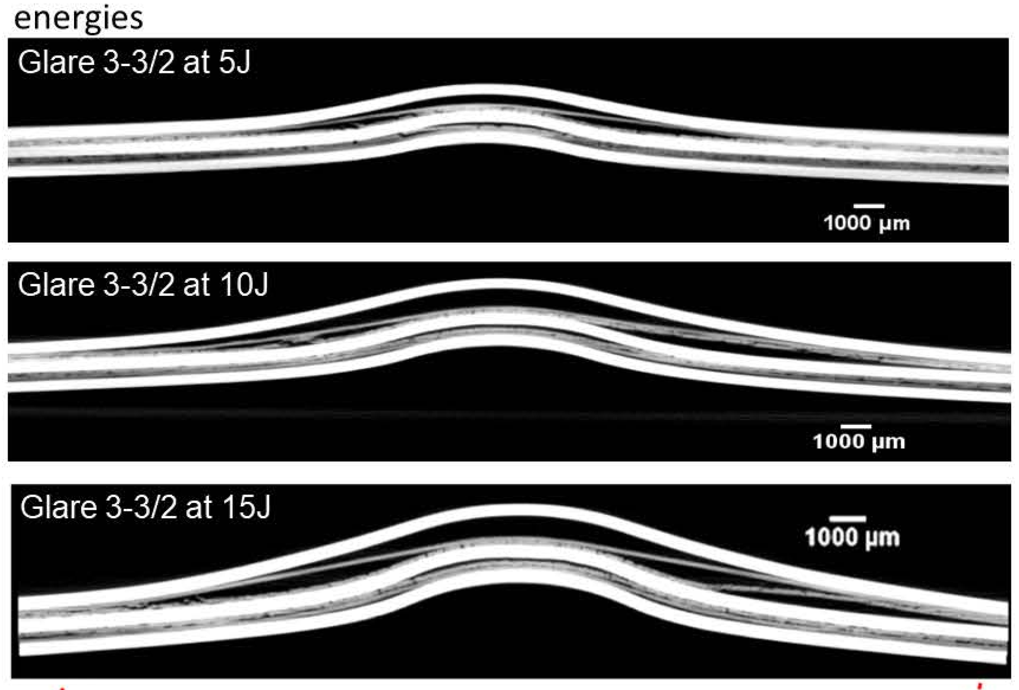
Binning 1000 detector voxels: 18.254 µm, duration 3.5 h

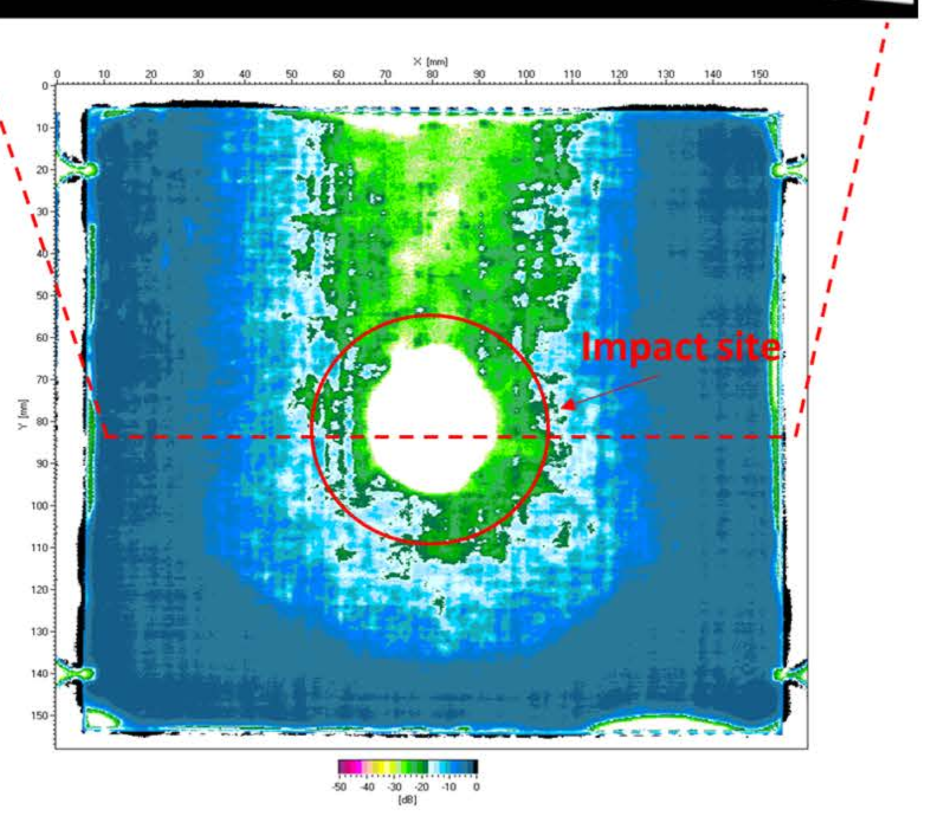
Visualization of selected, reconstructed image slices



3D volume reconstruction (whole sample) and location of high-resolution scans

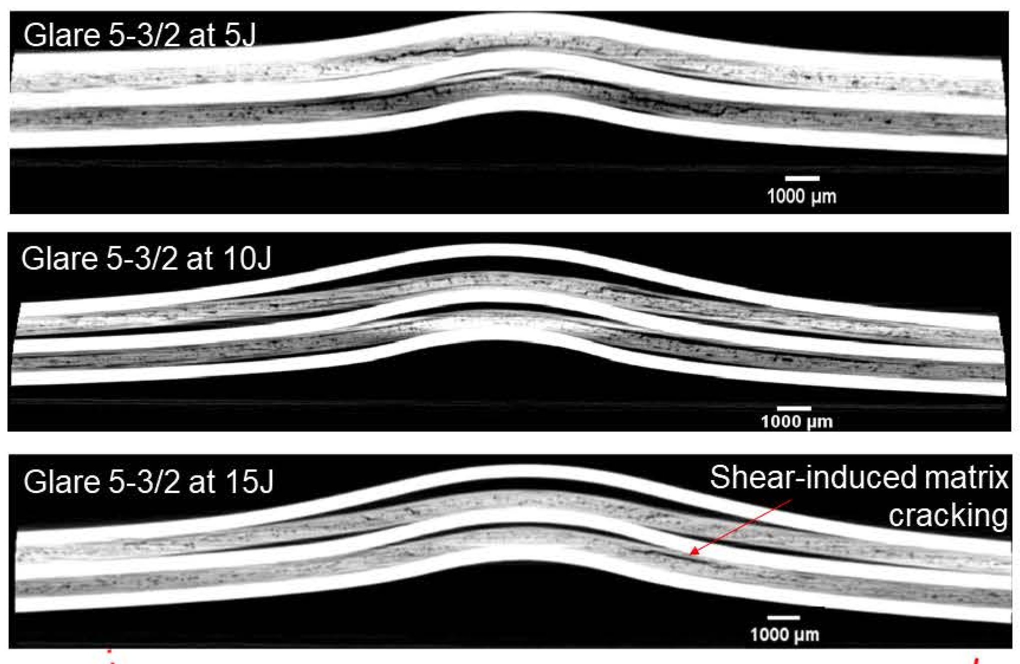
Cross-sectional view of Glare 3-3/2 impacted at different impact energies

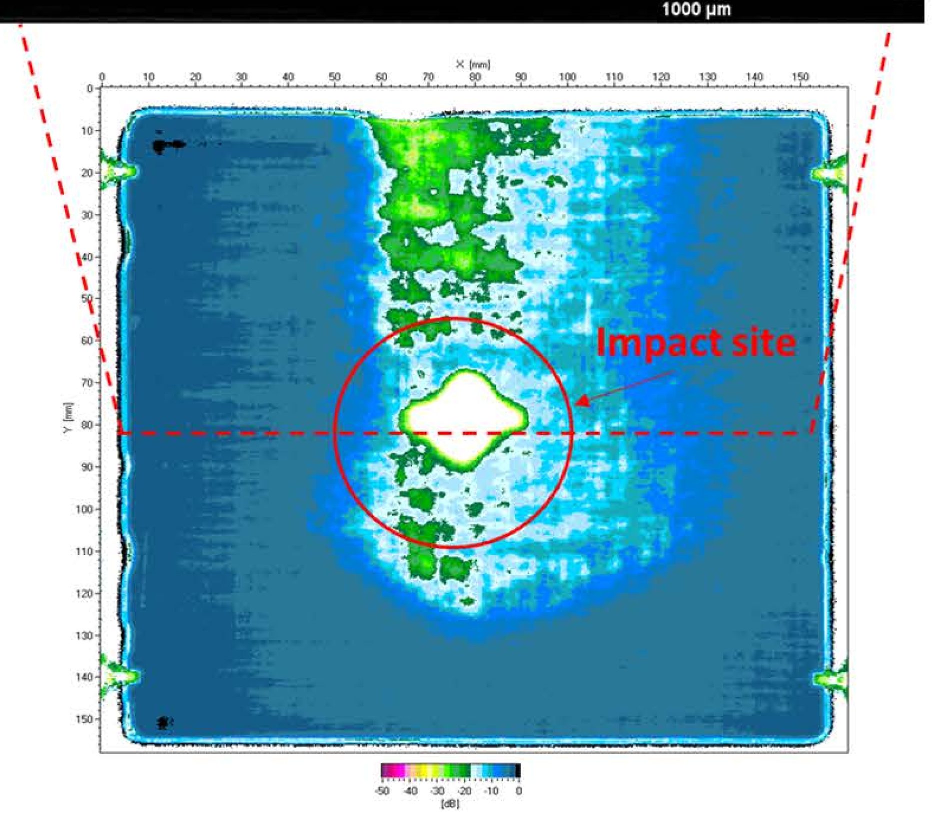




Ultrasonic C-scan of Glare 3-3/2 impacted at 15J

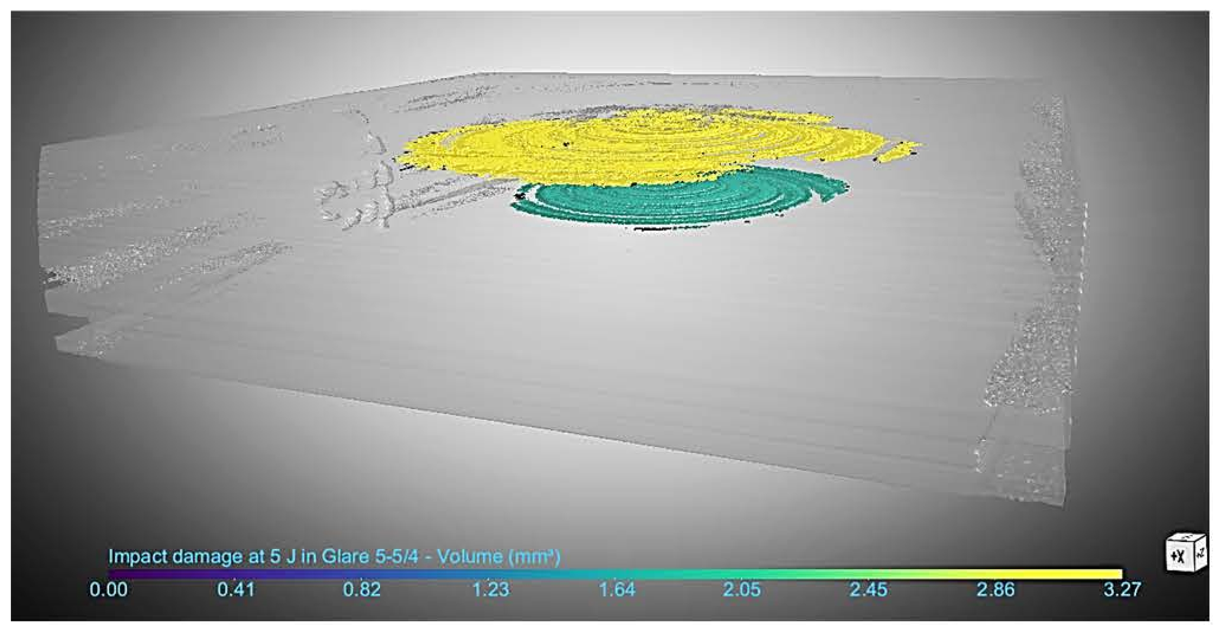
Cross-sectional view of Glare 5-3/2 impacted at different impact energies



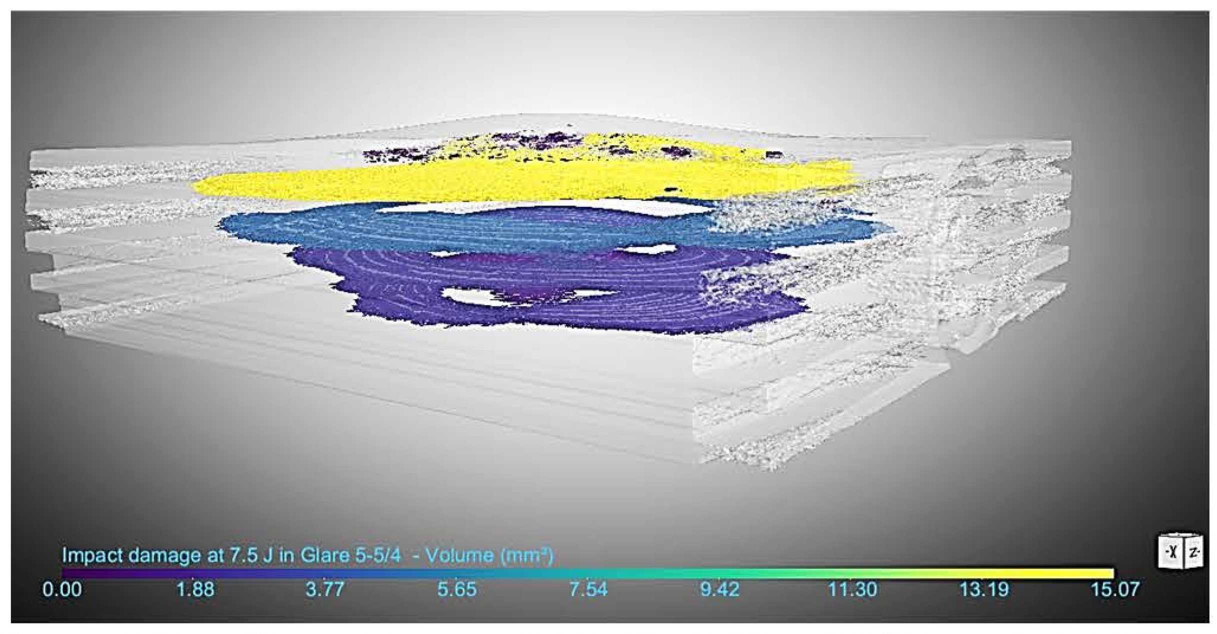


Ultrasonic C-scan of Glare 5-3/2 impacted at 15J

Quantitative image analysis using Dragonfly



Segmentation of impact damage distribution in Glare 5-5/4 impacted at 5 J.



Segmentation of impact damage distribution in Glare 5-5/4 impacted at 7.5 J.

Discussion

- Global damage detection benefits from ultrasonic C-scans, while local damage assessment is achievable via X-ray Computer Tomography (XRCT).
- XRCT reveals delamination areas in planar view, consistent with C-scan findings. However, detecting all sub-surface failure patterns and damage distribution through C-scans poses challenges.
- The presence of distinct intralaminar matrix cracking is detected in XRCT which is not evident in C-scans. These can be best viewed in the cross-sectional XRCT images.
- XRCT indicates a larger damage extent than C-scan results due to distributed damage throughout the thickness.
- Damage accumulation increases on the non-impacted side with rising impact energy.
- In Glare 5, the height of the regions with interfacial debonding decreases, alongside reductions in global flexure and dent depth, indicating enhanced perforation resistance.
- Fibers on the non-impacted side are prone to tensile failure.
- Matrix cracking initiates from damaged edges, rather than directly beneath the impacted area.
- Layer failure occurs in shear at a 45° angle to the impactor's direction.

Universität Siegen
LMW Lehrstuhl für Materialkunde und Werkstoffprüfung
DLR
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Contact:
Chirag Shah
Tel: +49 271 740 2812
Email: chirag.shah@uni-siegen.de