The Response of Hybrid Composite Structures to Low-Velocity Impact

Denise Niewerth, D. Stefaniak, C. Hühne
DLR - German Aerospace Centre

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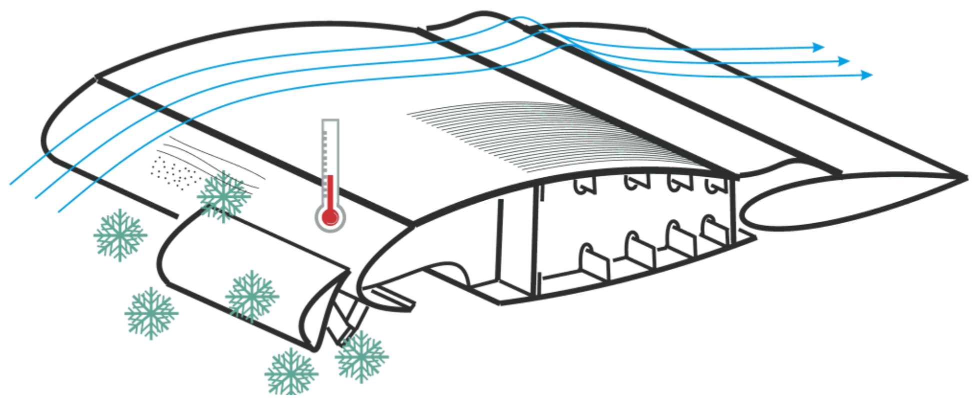
Overview

- Motivation
- Experimental
- Results
- Conclusion

Motivation

Objective for future generation of aircraft:

- Reduction of fuel-consumption and CO_2-emissions
  → Reduction of structural mass
  → Reduction of aerodynamic drag



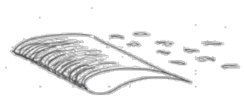
→ Wing with a laminar profile

Wing leading edge for a laminar wing:

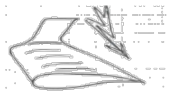
- Lightweight
- Laminar flow during cruise flight
  → Prevent surface roughening by erosion
  → Prevent ice-accretion (Wing Ice Protection System: WIPS)

→ Development of a laminar multi-material, multi-functional leading edge

Experimental – Materials



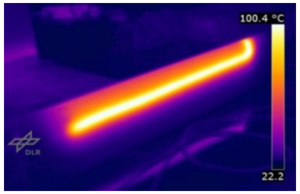
Erosion



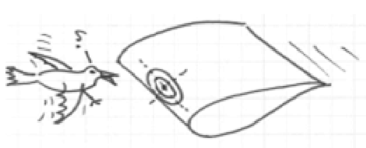
Lightning strike

Metallic erosion shielding

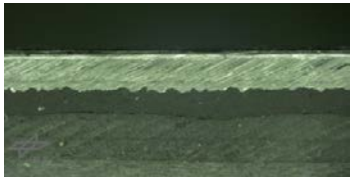
Wing Icing



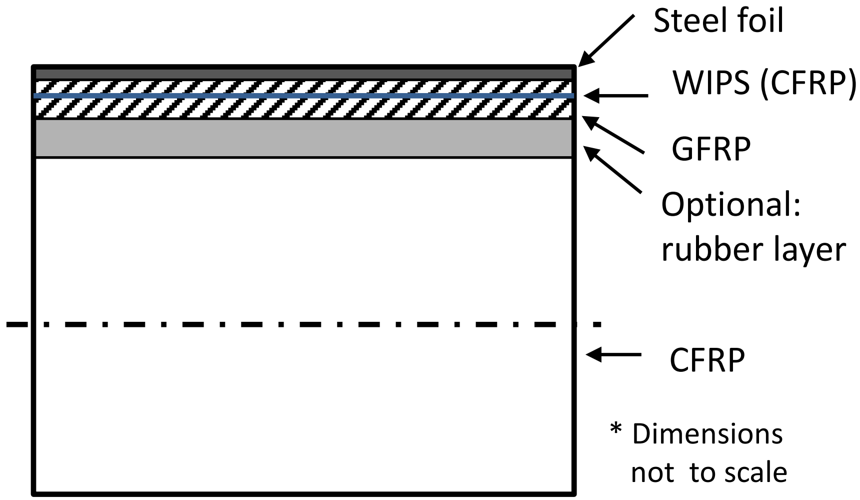
Electrical WIPS



Impact



Elastic layer



Questions:

- Does the addition of an elastic layer decrease the impact damage?
- Which is the ideal steel layer thickness to minimise impact damage?

Experimental – Test Methodology

Low-velocity impact tests according to AITM 1.0010

- Drop-weight test
- Steel indentor Ø = 20 mm
- Specimen-size: 100 mm x 150 mm
- Flat support with rectangular cut-out + 4 rubber clamps

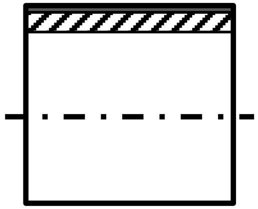
- Specimens for tests at certain impact energies
- Specimens for determination of impact energy causing 0.3 mm dent depth $E_{dent0.3}$

→ Assessment of the damage with special regard to surface damage

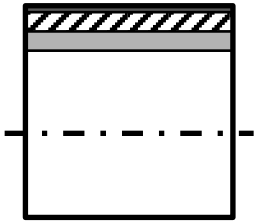
Results - Overview

1. Visual analysis
2. Damage area: projection of delaminated layers
3. Dent depth
4. Absorbed energy

St125-DB

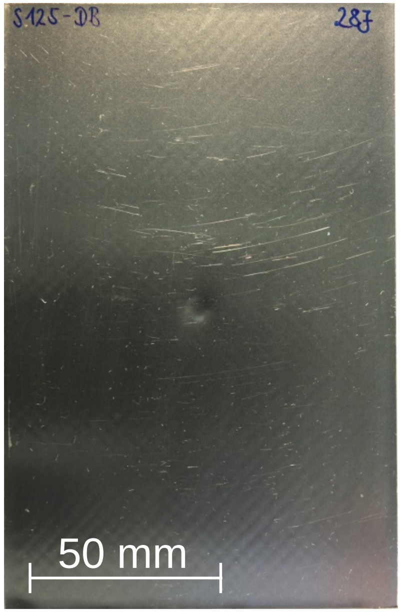


St125-EL

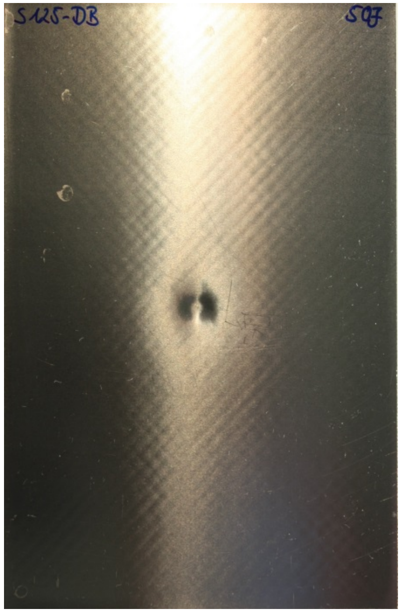


Results – Visual analysis

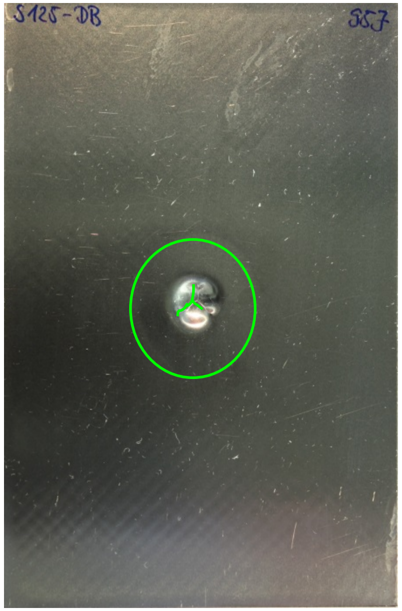
- Shape of the impact crater: hemispherical
- Front-side: damage barely visible until 50 J
- 95 J: Crack and detachment of steel foil



S125-DB-28 J



S125-DB-50 J



S125-DB-95 J

Results – Visual analysis

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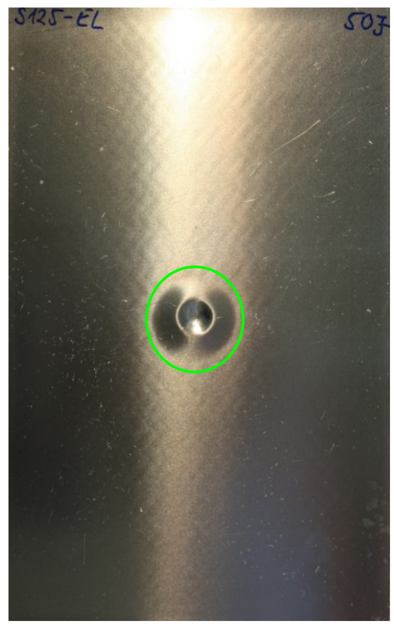
S125-EL-28 J



S125-EL-50 J

S125-EL-95 J

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Results – Visual analysis

- Shape of the impact crater: hemispherical
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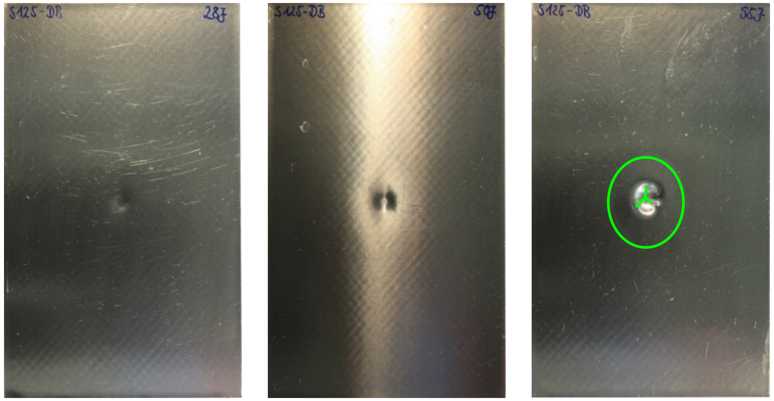
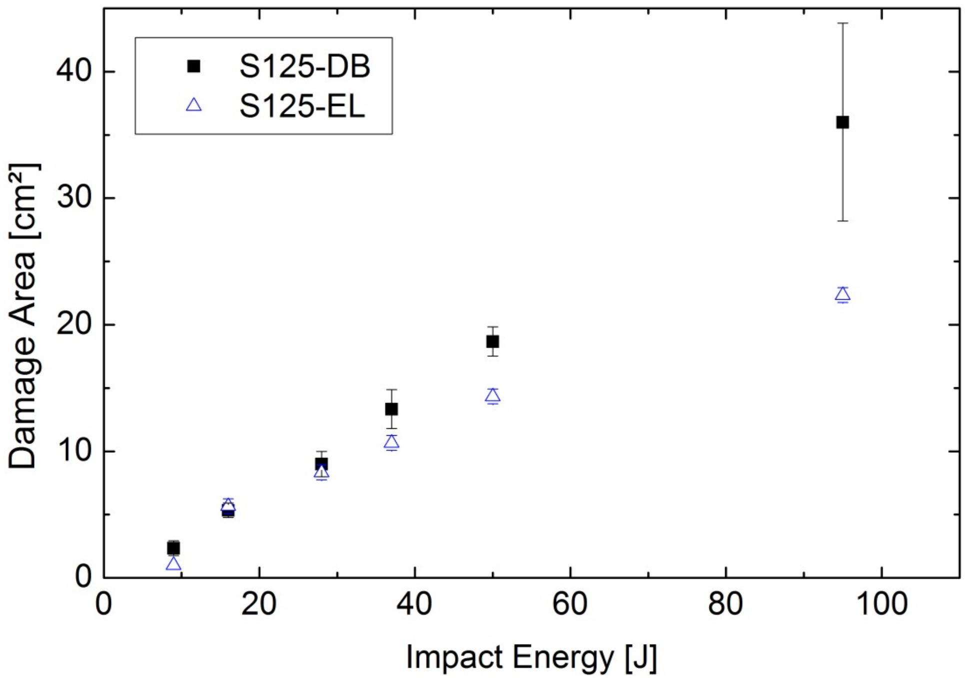


- Bump around impact crater E ≥ 50 J
- Maybe also detachment of steel foil
- Cracks in steel foil longer

→ Overall, surface damage of EL-samples more severe → Disturbing laminarity

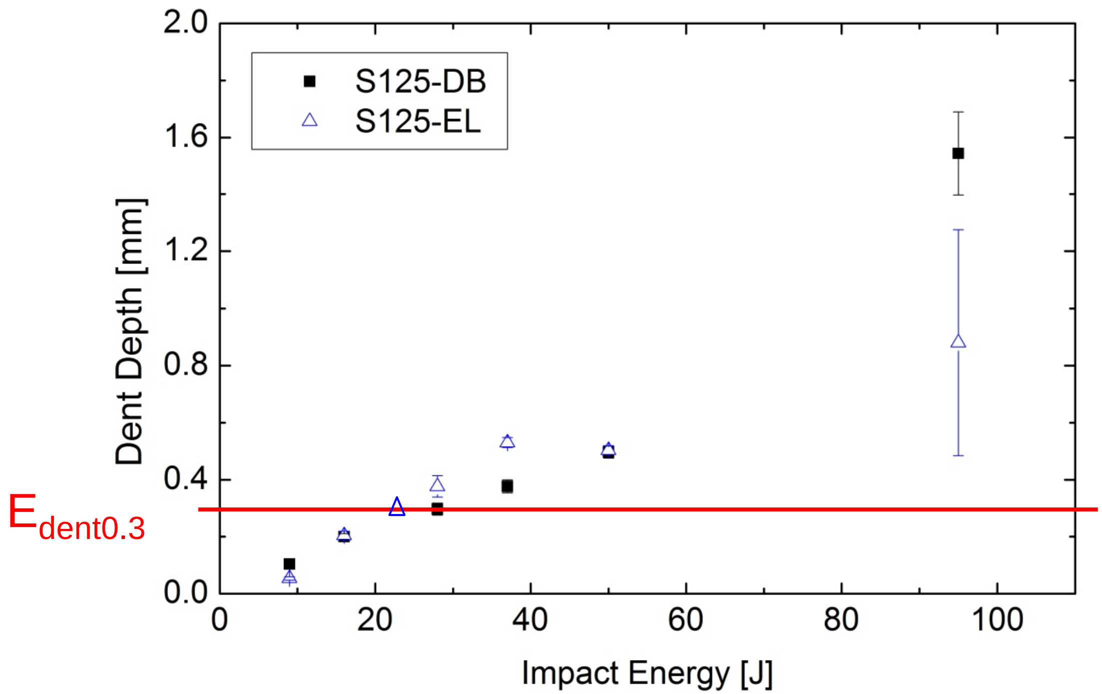
Results – Extend of Damage – Damage area



- E = 9 J: addition of elastic layer decreases damage area by 50 %
- 9 J < E < 37 J: damage areas approximately equal
- E ≥ 37 J: rubber decreases damage area by up to 36 %

→ Smaller damage area at higher and low impact energies through elastic layer

Results – Extend of Damage – Dent depth

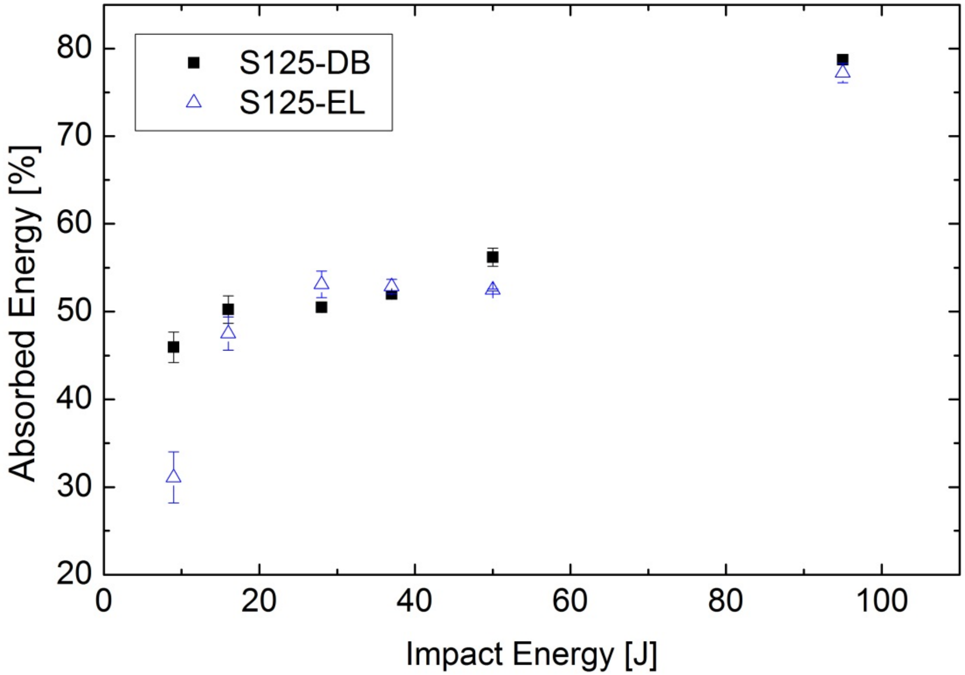


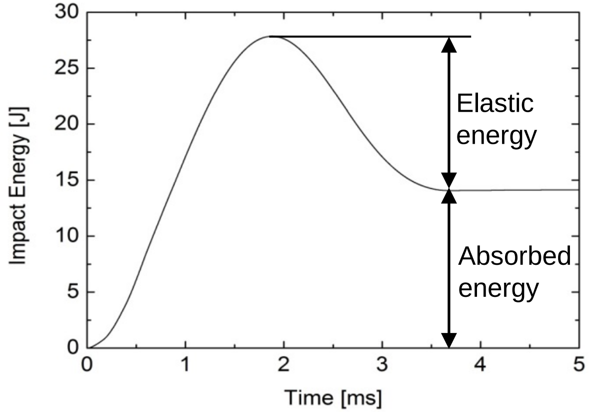
$E_{dent0.3}$(S125-DB) = 28 J
$E_{dent0.3}$(S125-EL) = 23 J

- E = 9 J: elastic layer decreases dent depth by 50 %
- 16 J ≤ E < 50 J: deeper dent with elastic layer
- E > 50 J: elastic layer may decrease dent depth (but large deviation)

→ Elastomer increases dent depth at moderate impact energies (50 J > E > 16 J)

Results – Absorbed Energy





E_{abs}(S125-DB) = 46 - 79%
E_{abs}(S125-EL) = 31 - 77%

- No linear dependence of absorbed energy and impact energy
- E < 16 J: Elastic layer decreases absorbed energy significantly
- E > 16 J: absorbed energy more or less equal in both configurations

→ Question for further investigation: why is the absorbed energy with elastic layer about the same as without it but the damage is less severe?

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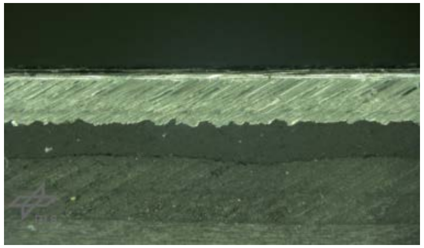
Conclusion – Additional elastic layer



Question: Does the addition of an elastic layer decrease the impact damage?

- Low energy: laminates with elastic layer absorb less energy → less damage
- E > 16 J: absorbed energy approximately equal

→ Elastic layer absorbs impact energy partially→ Deeper impact craters

→ Reduction of damaged area

→ In the tested combination the elastic layer is not suitable for our purpose

→ Possible applications should be investigated

→ Damage mechanisms have to be investigated

→ Developing an appropriate testing method

Thank you!

Denise Niewerth, M.Sc.

Research Engineer

German Aerospace Centre
Institute of Composite Structures
and Adaptive Systems

Lilienthalplatz 7
38108 Braunschweig
Germany

Phone: +49 531 295 3186
Email: denise.niewerth@dlr.de

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