“Material Characterisation of Polyurethane-Based Paper Honeycomb Sandwich Structures”

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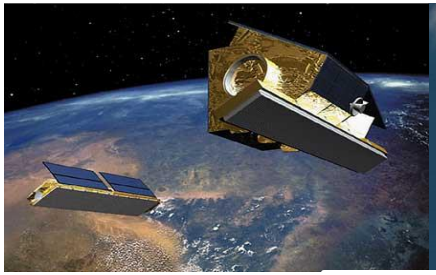
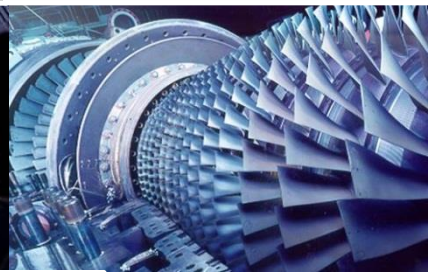
DLR

DLR - Overview

- 7.700 employee are working at 32 research institutes and facilities in
  - ■ 9 locations
  - ● 7 branch offices
- International Branch Offices in Brussels, Paris and Washington
- Partner of
  - ♦ European Transsonic Wind Tunnel (ETW)
  - ◆ German Dutch Wind Tunnels (DNW)

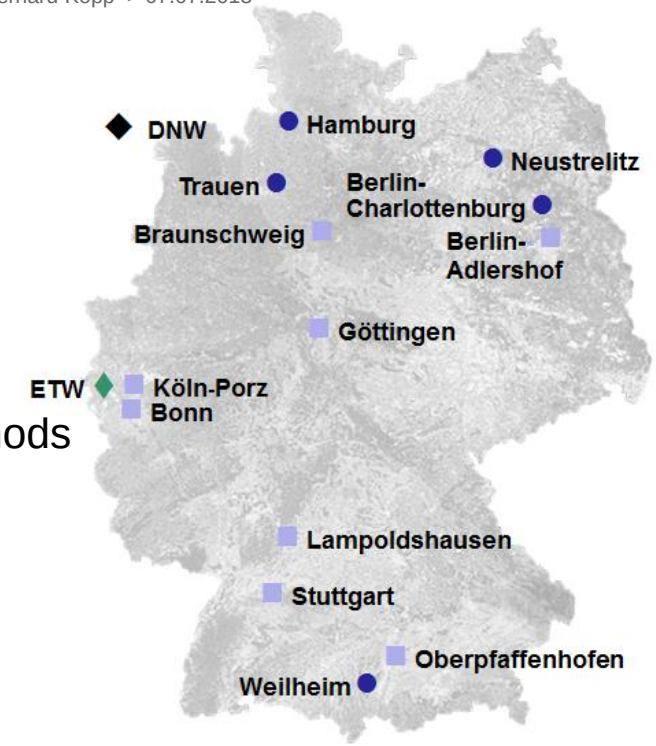
SPACE	AERONAUTICS	TRANSPORT	ENERGY



SECURITY

DLR - Overview



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Outline

- Introduction and motivation
- Sandwich characterization
    - Approach
    - Face sheet material
    - Core material
    - Sandwich configuration in bending
- Conclusion

Introduction and motivation

Sandwich manufacturing processes

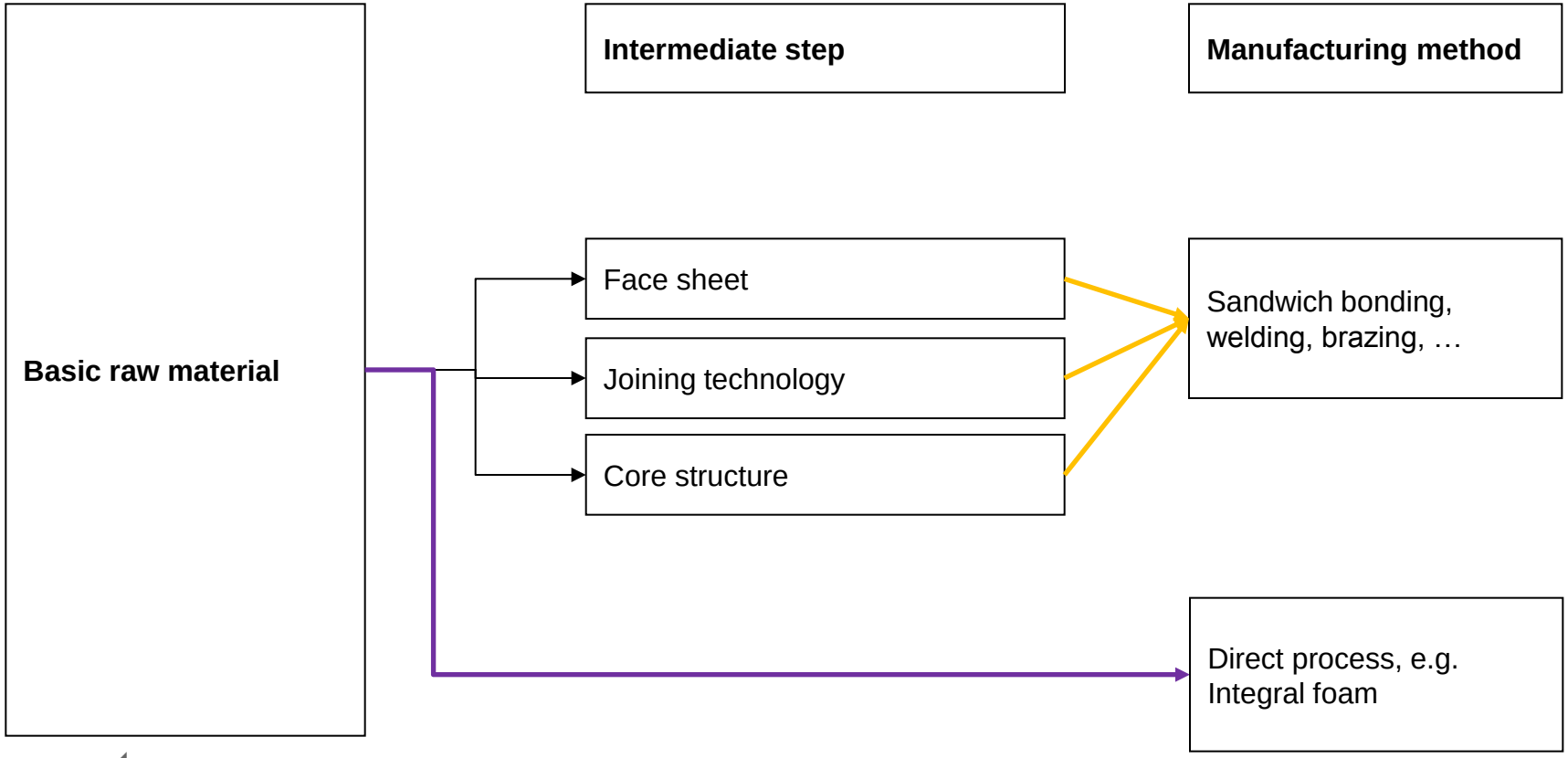
Introduction and motivation

Sandwich manufacturing processes

Basic raw material	Intermediate step	Manufacturing method
		Direct process, e.g. Integral foam

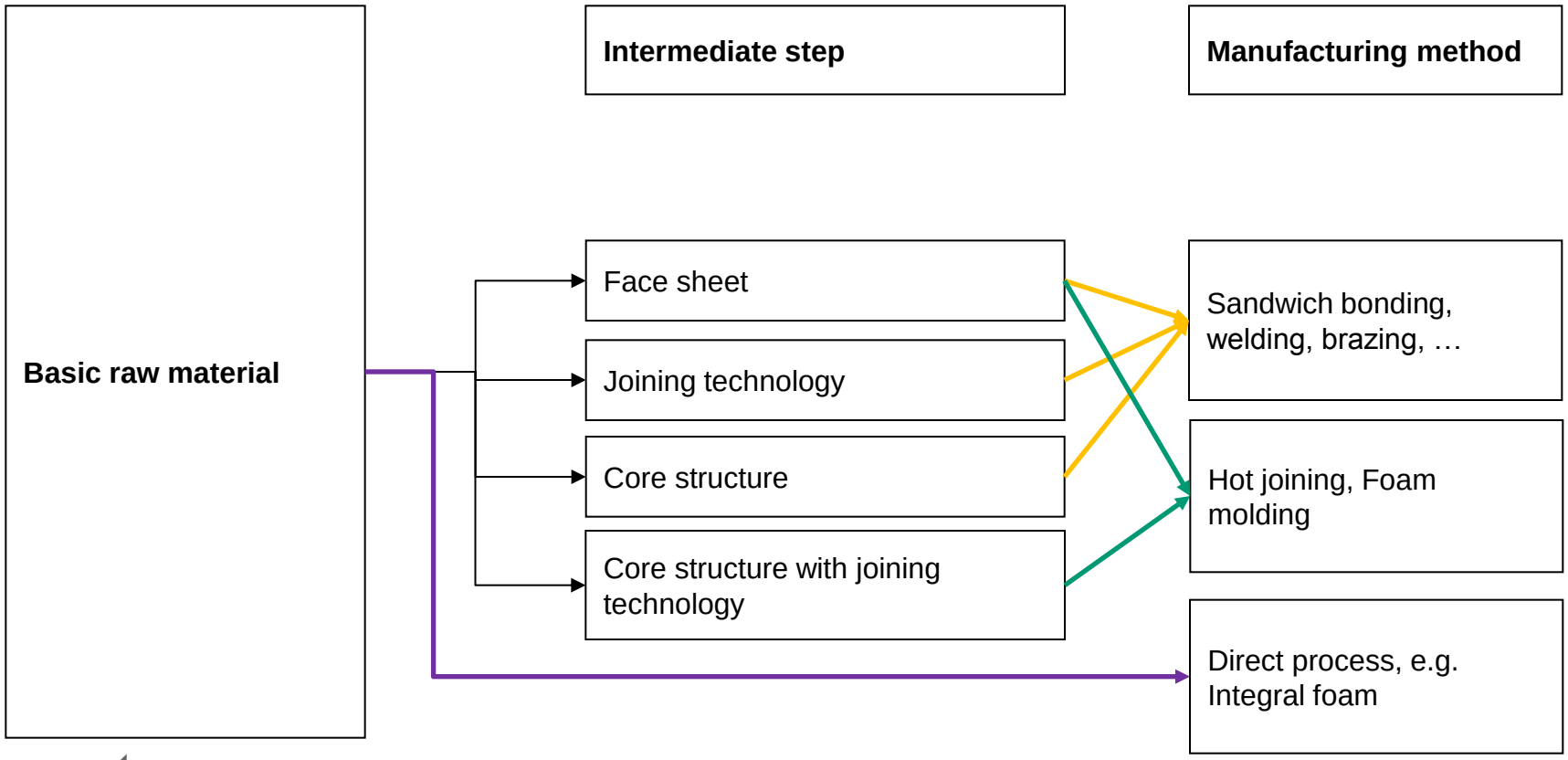
Introduction and motivation

Sandwich manufacturing processes



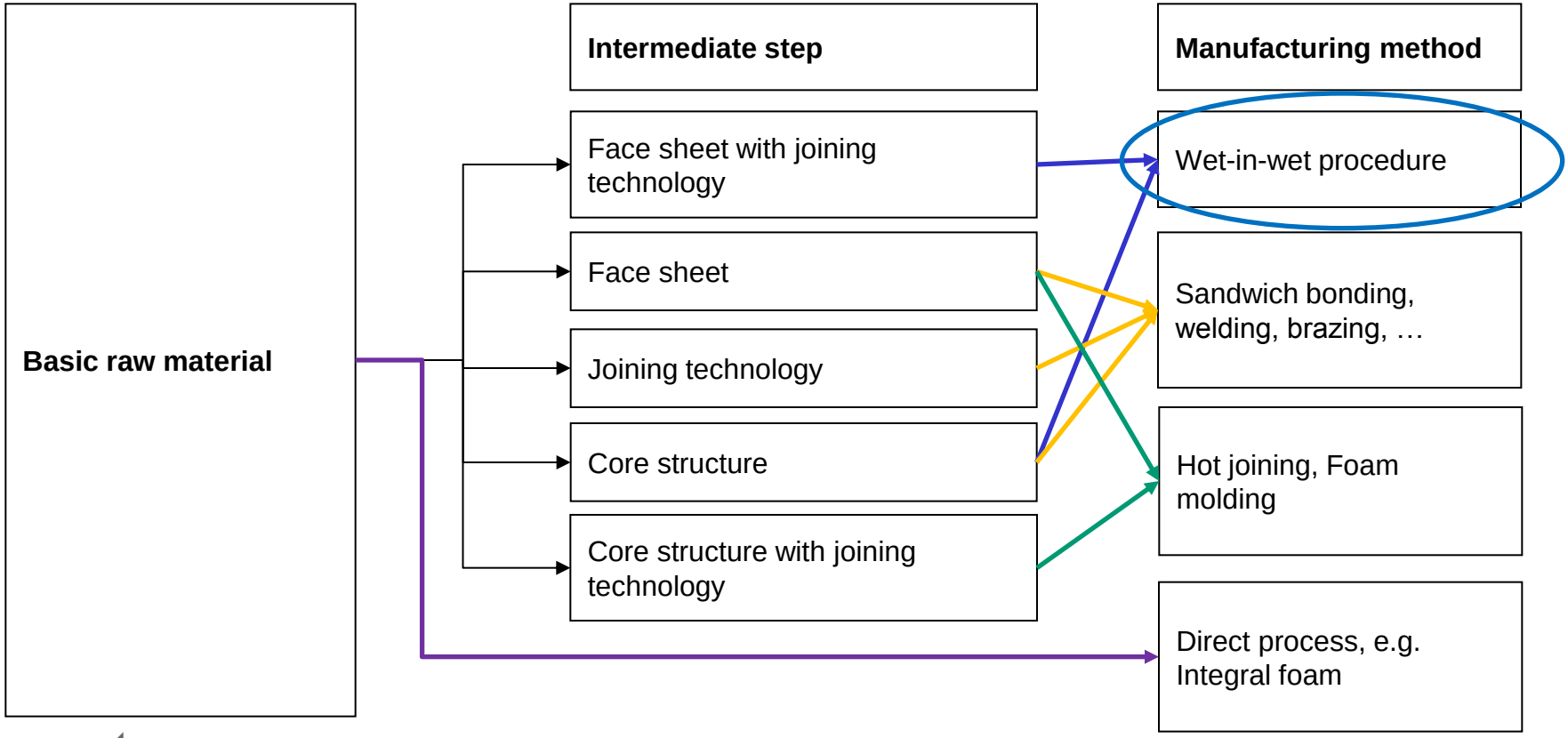
Introduction and motivation

Sandwich manufacturing processes



Introduction and motivation

Sandwich manufacturing processes



Introduction and motivation

Overview of the polyurethane fibre spraying process

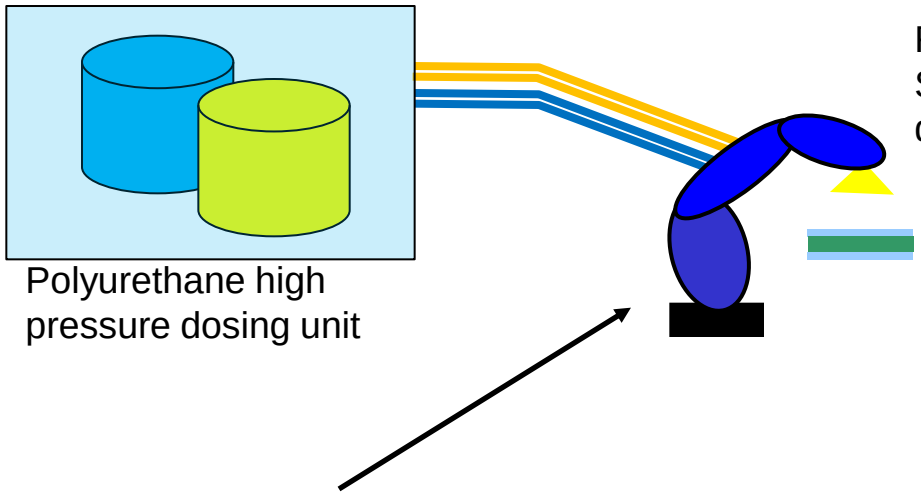
Sandwich configuration

Textile reinforcements and core structures

Source: [1]

Introduction and motivation

Overview of the polyurethane fibre spraying process



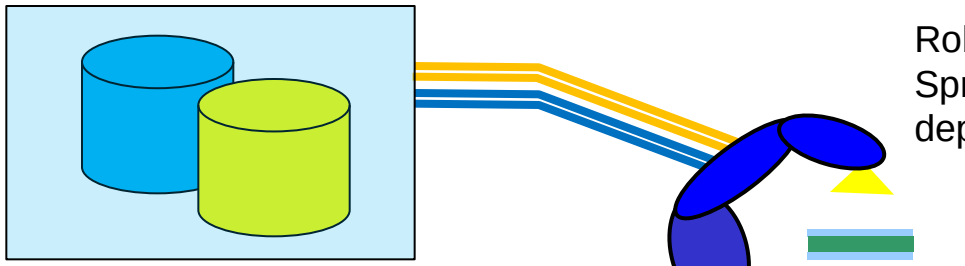
Sandwich
configuration

Textile reinforcements
and core structures

Source: [1]

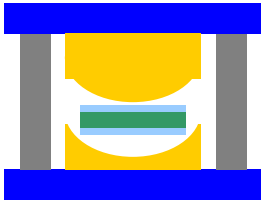
Introduction and motivation

Overview of the polyurethane fibre spraying process



Polyurethane high pressure dosing unit

Robot and Spraying deposition



Compression moulding

Sandwich structure

Sandwich configuration

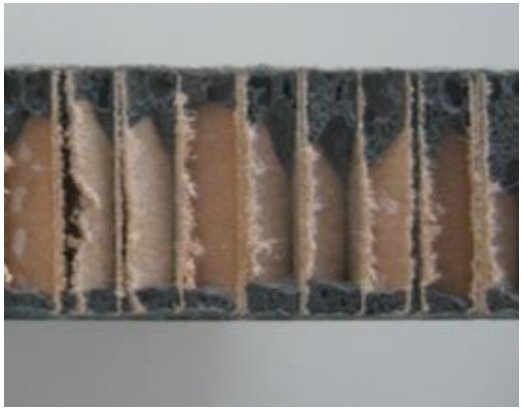
Textile reinforcements and core structures

Source: [1]

Introduction and motivation

Challenges for the future development and application of the process

- Detail analyze of the sandwich and material properties, depending of the manufacturing process
- Examination of the relevant mode of failure



Sandwich characterization

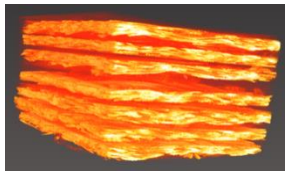
Approach

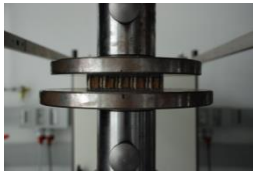
Approach in dependence on: [2] and [3]

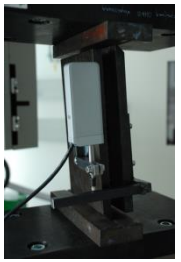
Sandwich characterization

Approach

Property characterisation of face sheet and core structure in tension, compression and shear







Source: Fraunhofer ICT

Approach in dependence on: [2] and [3]

Sandwich characterization

Approach

Property characterisation of face sheet and core structure in tension, compression and shear

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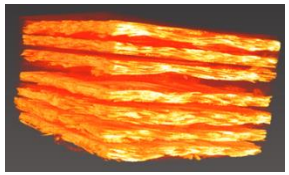
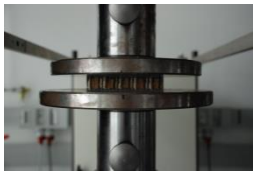
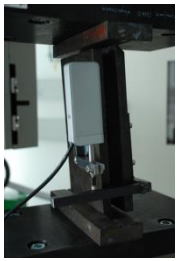
Derive correlations between the core densities and the core material properties

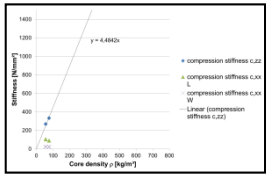






Source: Fraunhofer ICT

$$\frac{Prop_C}{Prop_S} = C \cdot \left(\frac{\rho_C}{\rho_S}\right)^n$$



Approach in dependence on: [2] and [3]

Sandwich characterization

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Property characterisation of face sheet and core structure in tension, compression and shear

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Derive correlations between the core densities and the core material properties

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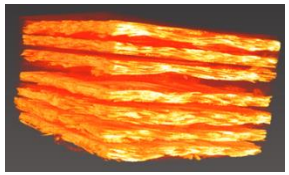
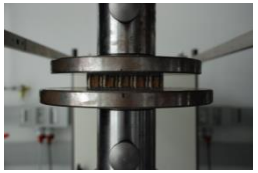
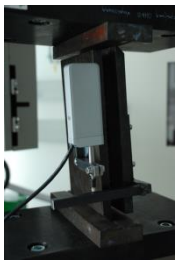
Derived failure mode maps with analytical formula and analyse the relevant modes of failure in bending







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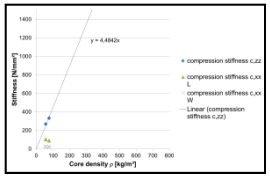
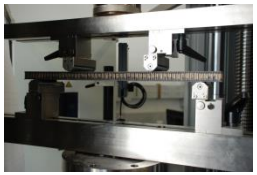
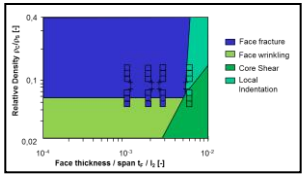




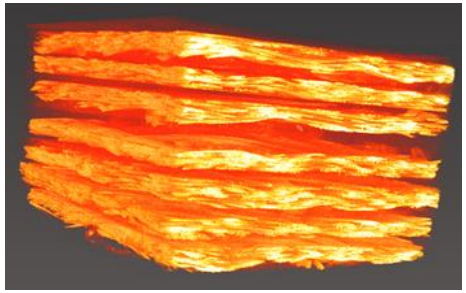


Approach in dependence on: [2] and [3]

Sandwich characterization

Face sheet material

- The face sheet thickness was measured with the computer tomograph (CT) also for different glass fiber mats
- In a wide range the material properties were independent of the mass of deposit polyurethane



Source: Fraunhofer ICT

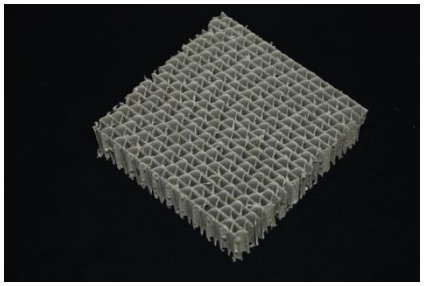
	300 g/m²	450 g/m²	600 g/m²	900 g/m²
Face sheet thickness [µm]	340	430	545	781
Standard deviation [µm]	31	26	32	38
Young modulus [N/mm²]	10300	12300	13200	13300
Standard deviation [N/mm²]	510	530	560	850
Tensile strength [N/mm²]	152	169	212	212
Standard deviation [N/mm²]	9,1	11,0	6,3	10,3

Source: Fraunhofer ICT

Sandwich characterization

Variations of the sandwich structure

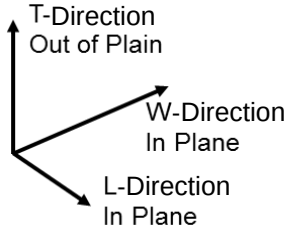
- Chopped glass strand mats with a mass per unit area of 600 g/m² in each cover as reinforcements for the faces
- Paper honeycomb core (A-wave, Testliner III, Density ca. 55 kg/m³ and A-wave, Testliner II, Density ca. 75 kg/m³)
- Polyurethane spraying deposition of 600 g/m² on the face sheets

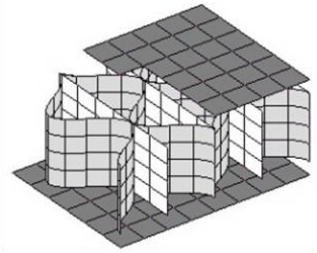


Sandwich characterization

Core material

- The core properties were measured in plane and out of plane
- Measurement based on DIN53291, DIN53292 and DIN53294





In Plane: σ_{xx}, σ_{yy}, τ_{xy}
Out of Plane: σ_{zz}, τ_{xz}, τ_{yz}

Sandwich characterization

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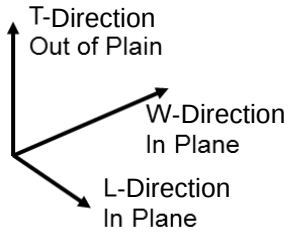

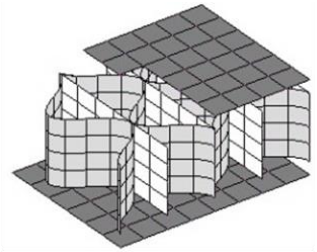

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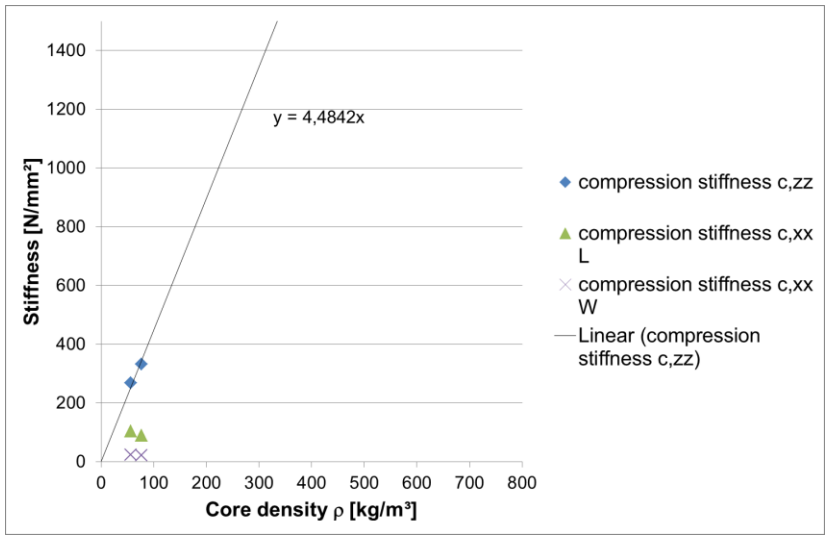

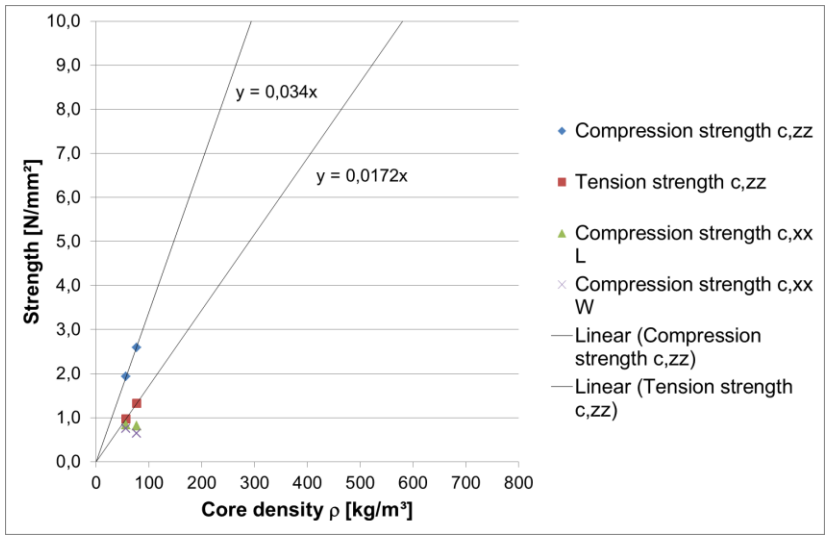

Sandwich characterization

Core material

- The core properties were measured in plane and out of plane
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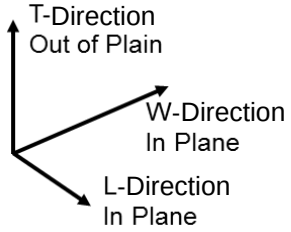
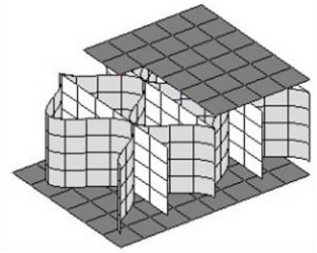
- Examples:





In Plane: σ_{xx}, σ_{yy}, τ_{xy}
Out of Plane: σ_{zz}, τ_{xz}, τ_{yz}

Material properties	Correlation in tension and compression
Tension strenght out of plane	$\frac{\sigma_{C,tension,zz}}{\sigma_S} = \left(\frac{\rho_C}{\rho_S}\right)$
Strenght in compression out of plane	$\frac{\sigma_{C,Pressure,zz}}{\sigma_S} = \left(\frac{\rho_C}{\rho_S}\right)$

Material properties	Correlation in shear
Shear strenght out of plane L-direction	$\frac{\tau_{C,xz,L}}{\tau_S} = 1{,}348 \cdot \left(\frac{\rho_C}{\rho_S}\right)$
Shear stiffness out of plane L-direction	$\frac{G_{C,xz,L}}{G_S} = 0{,}763 \cdot \left(\frac{\rho_C}{\rho_S}\right)$

Sandwich characterization

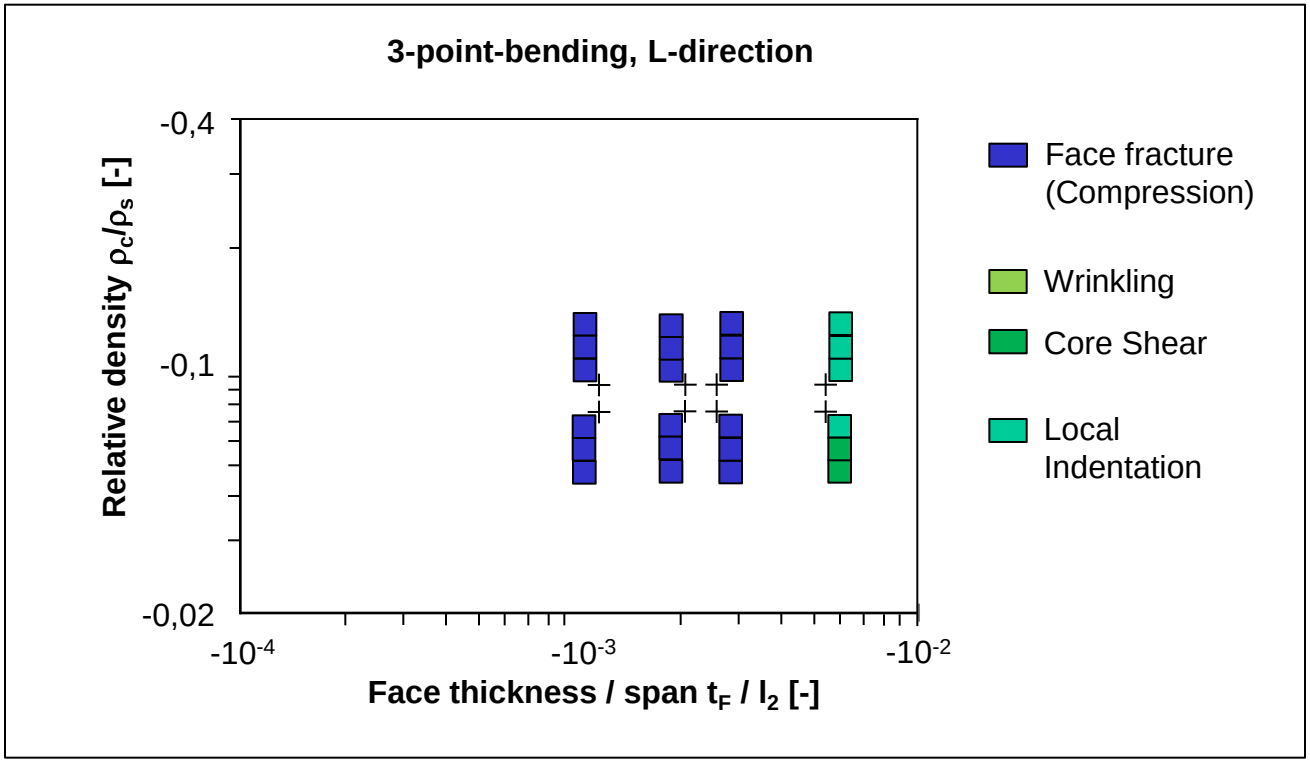
Sandwich configuration in bending

- Relevant mode of failure:
  - Face sheet failure
  - Core shear failure
  - Locale indentation

Sandwich characterization

Sandwich configuration in bending

- Failure mode maps



Sandwich characterization

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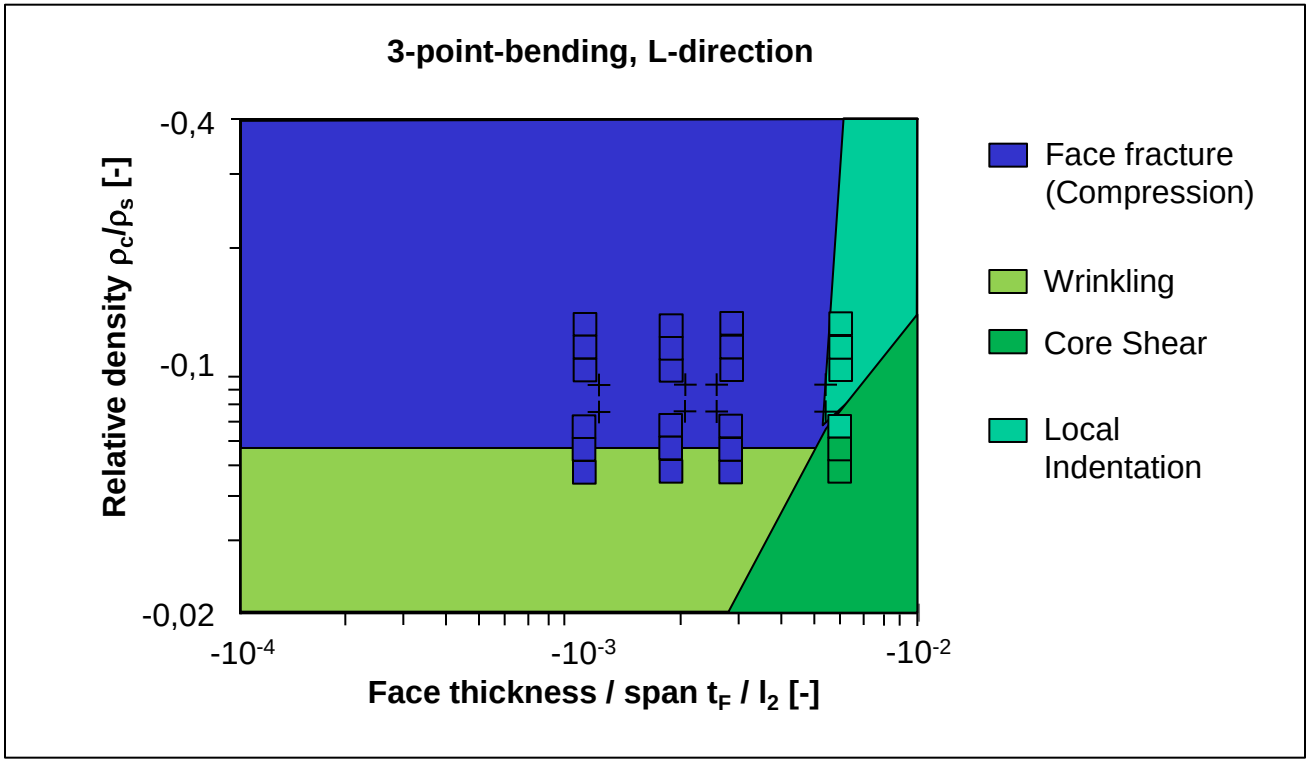

Sandwich characterization

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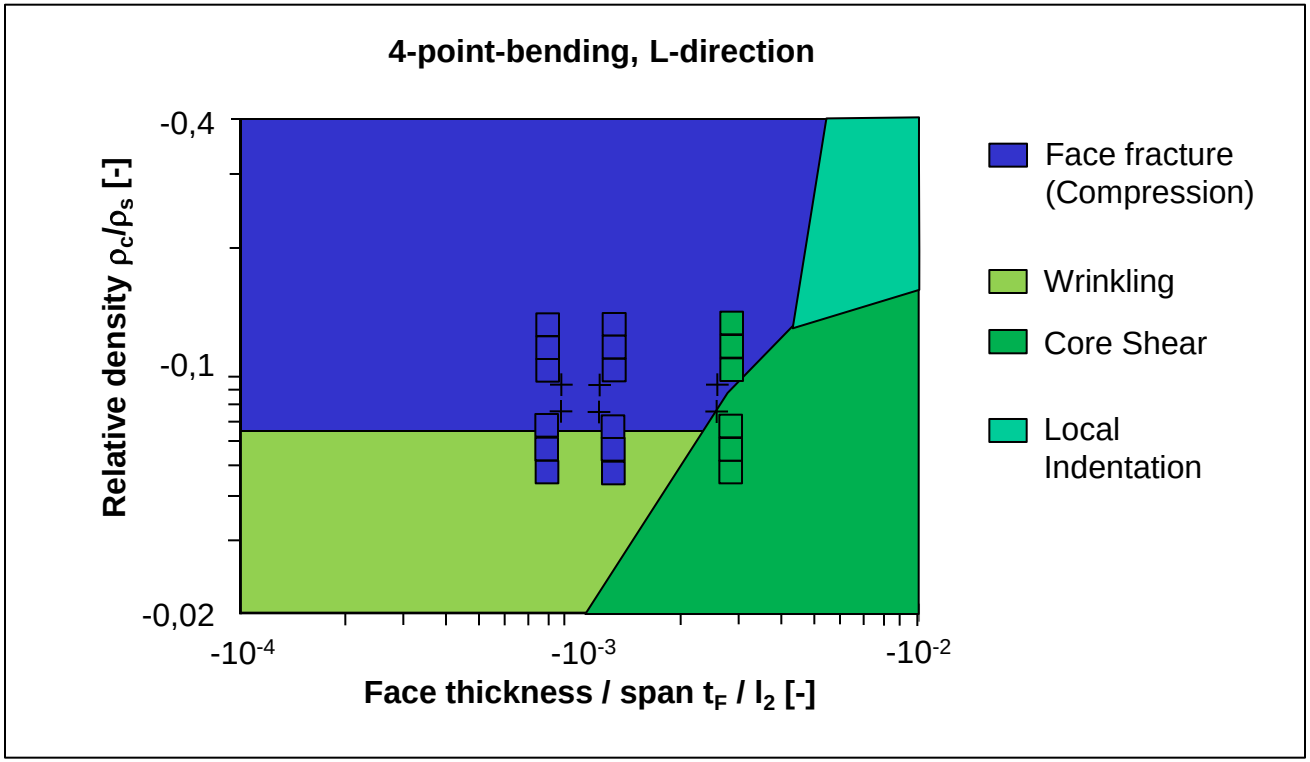
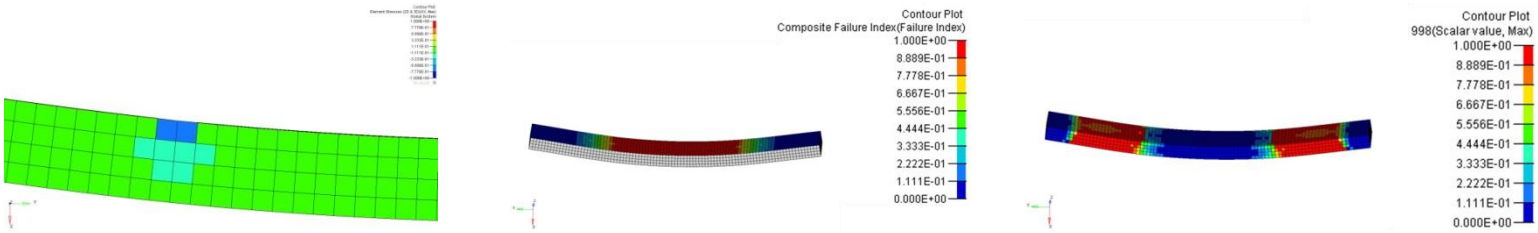


Conclusion

Material Characterisation of Polyurethane-Based Paper Honeycomb Sandwich Structures

- Basic material parameters were determined from sandwich structures produced using the polyurethane fibre spraying process
- Furthermore, the critical failure modes were determined using bending tests
- These results were used to design and simulate such sandwich components with FEM



Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Thank you very much for your attention.

Contact:
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Dipl.-Ing. Gerhard Kopp
Gerhard.Kopp@dlr.de

DLR

Source

[1] - Cageao, R.A.; Lorenzo, J.M.; Franken, K.: Studies of Composites made with Baypreg F: Component Selection of Optimal Mechanical Properties, in: Polyurethanes, 2004

[2] - Triantafillou, T.; Gibson, L.: Failure Mode Maps for Foam Core Sandwich Beams, in: Materials Science and Engineering, Vol. 98, 1987, p. 37 - 53

[3] Petras, A.; Sutcliffe, M.: Failure mode maps for honeycomb sandwich panels, in: Composite Structures, Vol 44, 1999, p. 237 - 252