C/C-SiC Sandwich Structures for Lightweight TPS and Hot Structures

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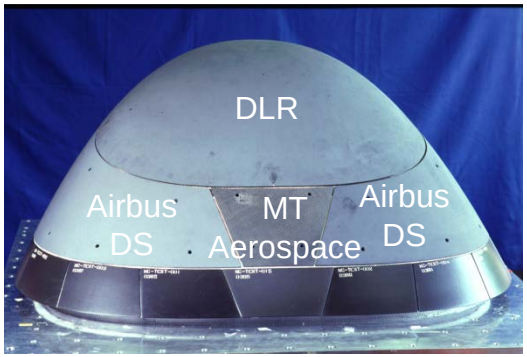
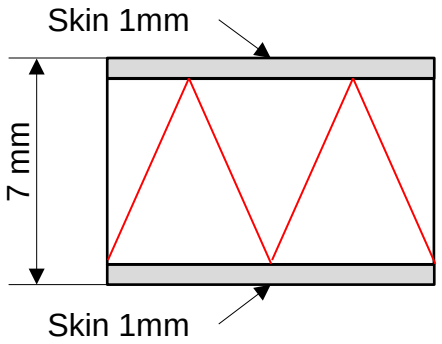
Outline

- Motivation
- Manufacture of C/C-SiC sandwich structures via LSI
- Test results
- Summary and outlook

Why Sandwich?





		Solid	Sandwich
Bending stiffness/b[1]	[Nm²/mm]	$E \cdot J$	$E_{Skin} \cdot J$
		1	
Panel thickness	[mm]	6	7
Panel weight[1]	[kg/m²]	11.4	4.4
Prepreg layers		24	8

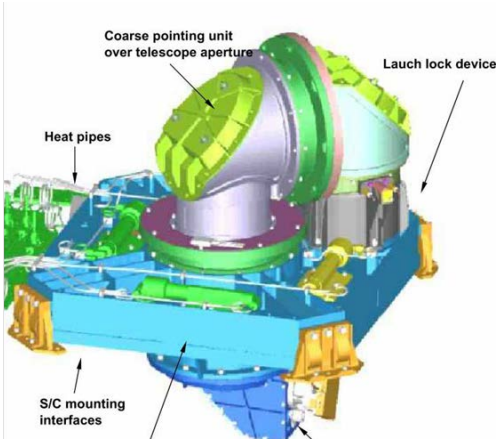
17% higher thickness

62 % less weight

[1] panel width = 1 mm

CMC Sandwich Application: Thermally Stable Structures

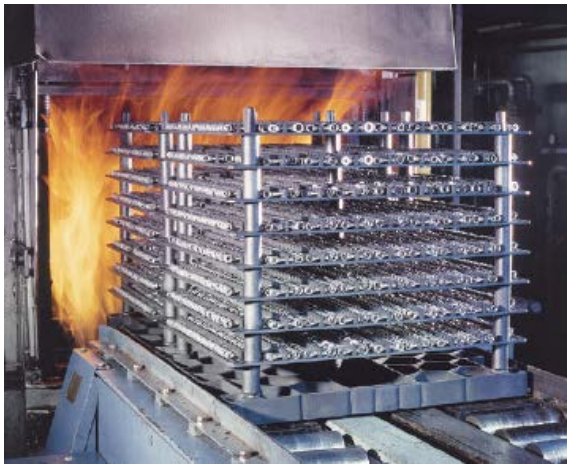
- Optical benches
- Telescope structures



R. Barho, M. Schmid, 2003

Others:

- Charging carriers for high temperature furnaces
- High temperature heat exchangers
- …



Schunk Kohlenstofftechnik

CMC Sandwich Application: Acreage TPS

- Current DLR concept proposes functional separation of insulation and load bearing CMC shell
- Self-standing CMC panels resting on dedicated CMC load introduction elements
- Design for stiffness according to pressure requirements
- SHEFEX design e.g. proposes un-stiffened plates with uniform thickness as panels
- Easy to manufacture but not effective → Increases mass and limits panel size
- Sandwich can be designed exactly to pressure requirement to optimise area mass and size of acreage TPS

Shefex II

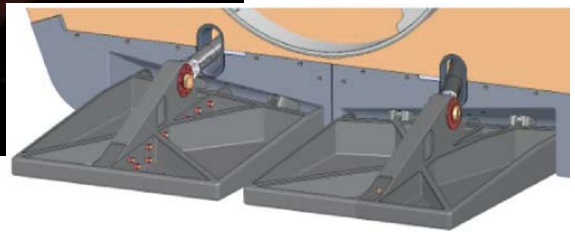
CMC Sandwich Application: Hot Control Surfaces

- Hot control surfaces essential for hypersonic cruise and entry vehicles
- High pressure loads, temperature gradients
- Stiffness required for shape stability
- Hot structures preferred (low temperature gradients and distortions, limited space)
- Low inertia required for fast-moving control systems
- Sandwich design can be tailored to structural / thermal requirements

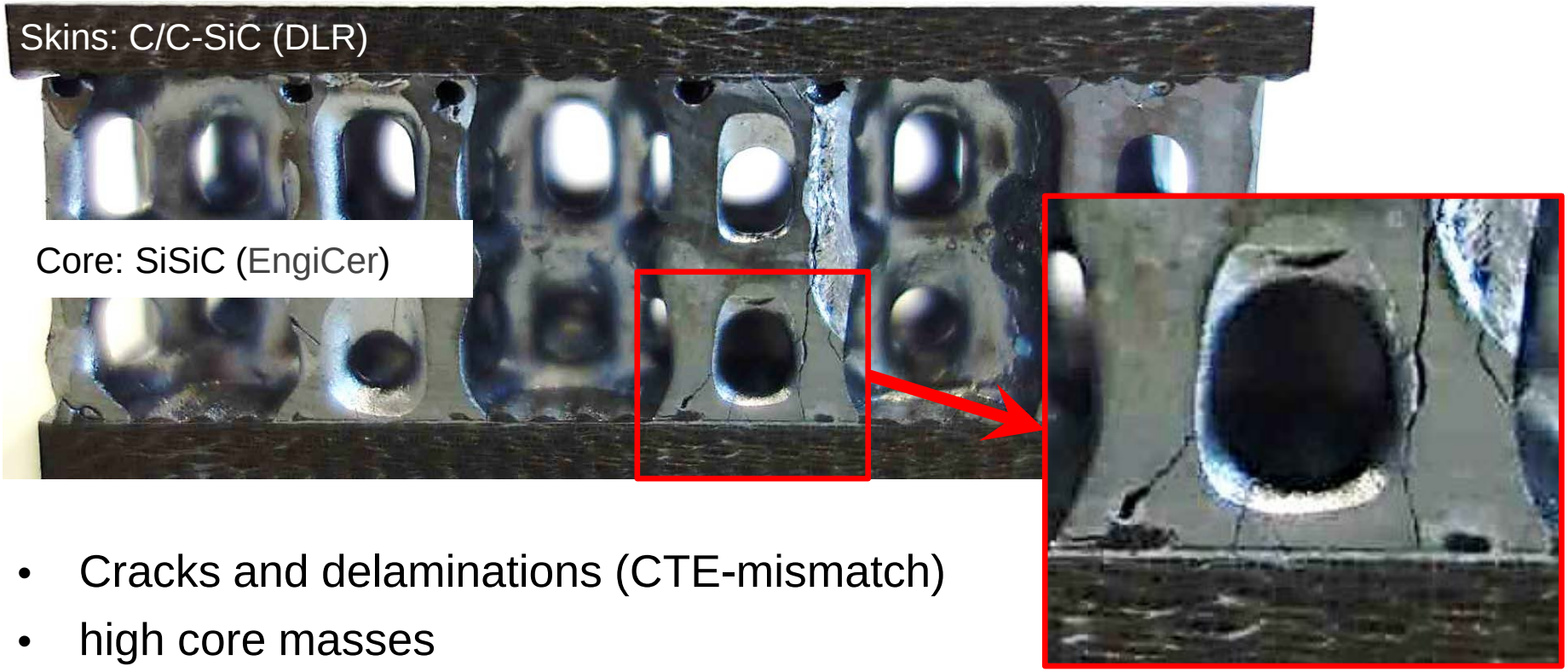
SpaceLiner concept, DLR

SHEFEX II, DLR

IXV
(ESA / MT Aerospace)



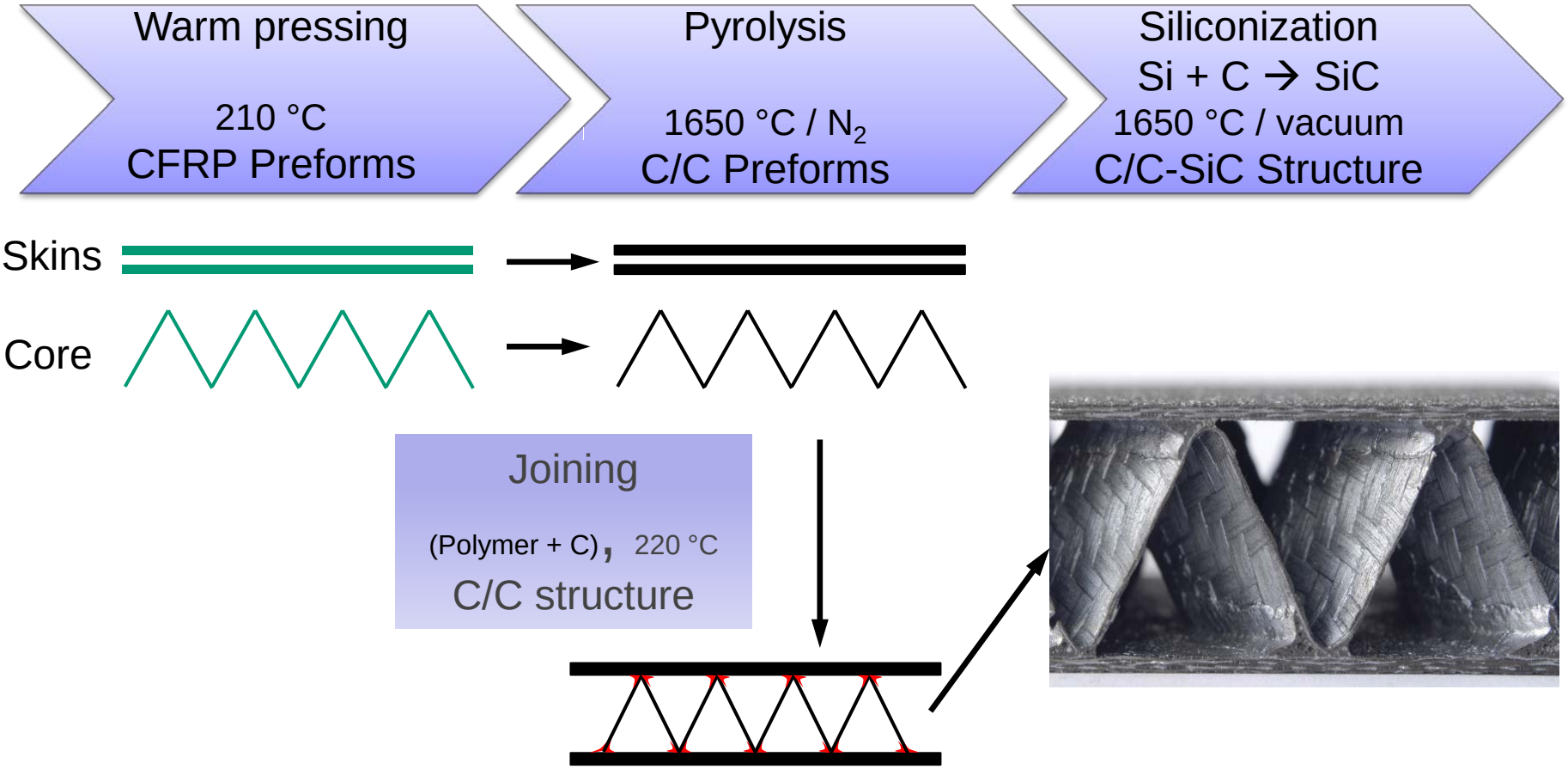
C/C-SiC / SiC Honeycomb



- Cracks and delaminations (CTE-mismatch)
- high core masses
- Brittle facture behaviour of core

M. Kütemeyer (DLR), M. Kuhn (DLR), A. Ortona (SUPSI), Gianella (EngiCer), 2015

Manufacture of All C/C-SiC Sandwich Structures

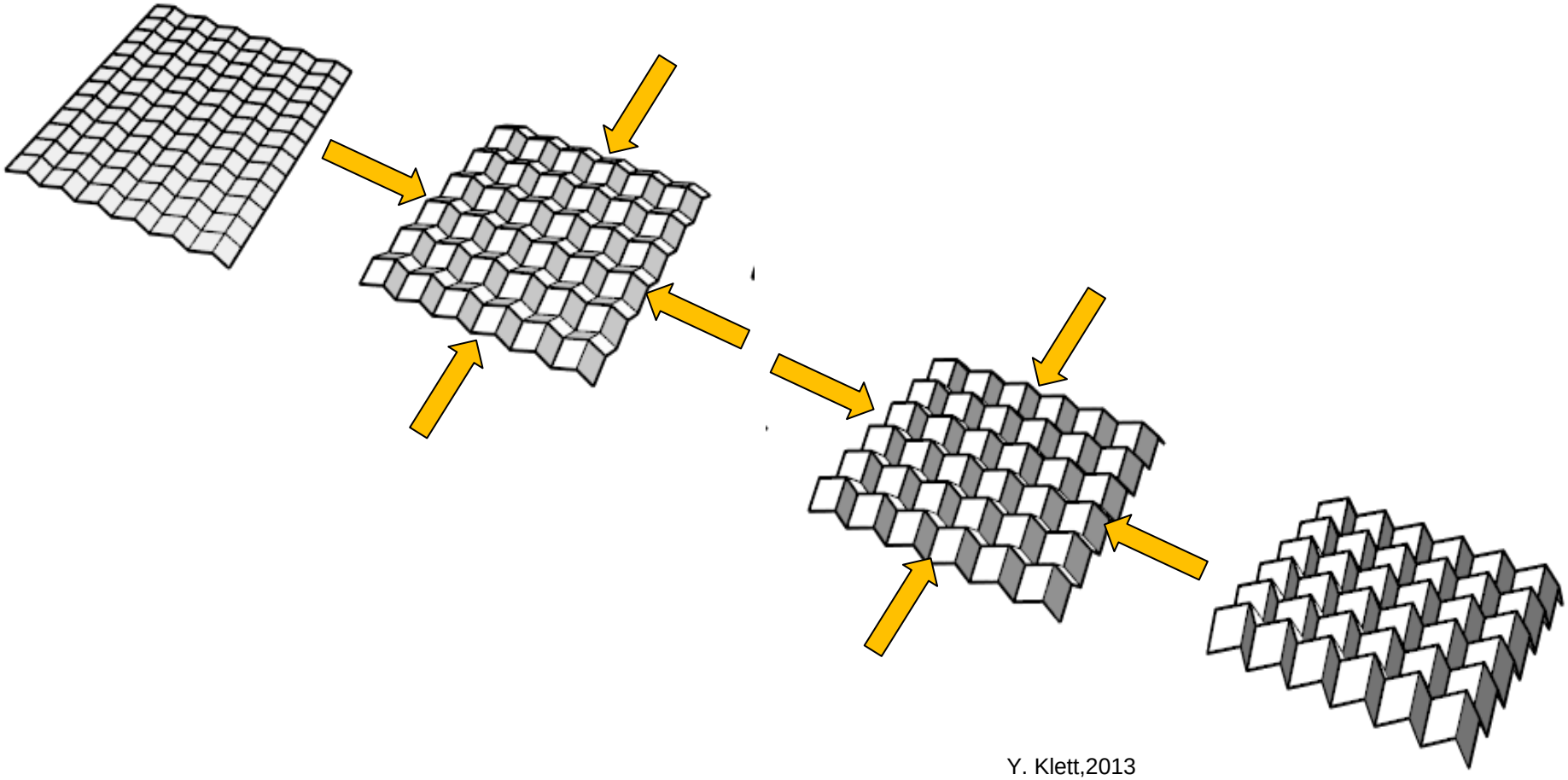


CFRP Preform Manufacture

	Core	Skin Panel
Raw Material	Prepreg: C fibre fabric (245 g/m²) + Phenol-Resol	
Lay up	1 layer 0°/90° and ±45°	3 layers 0°/90°
CFRP preform manufacture	Folding + Warm pressing	Warm pressing
p_{max} [kPa]	5.8	3.9
T_{max} [°C]	210	220

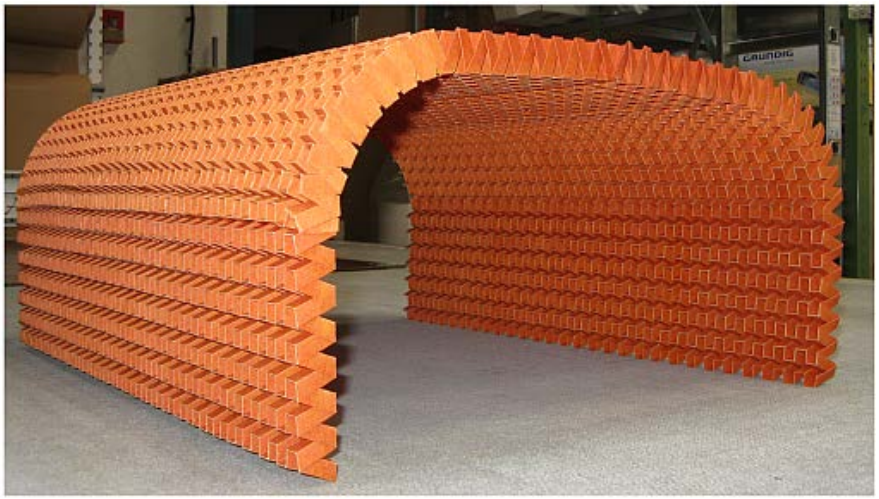
Folded Core Technology

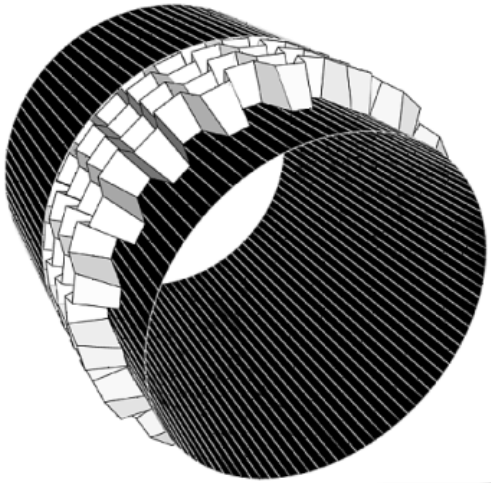
University of Stuttgart, Institute of Aircraft Design

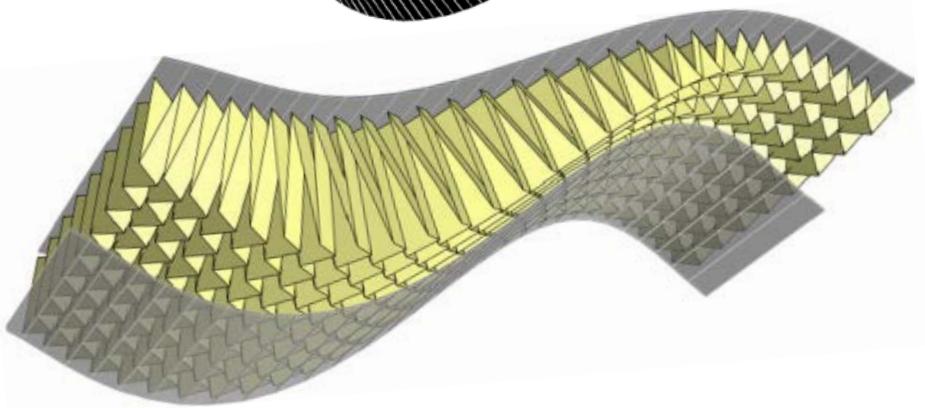


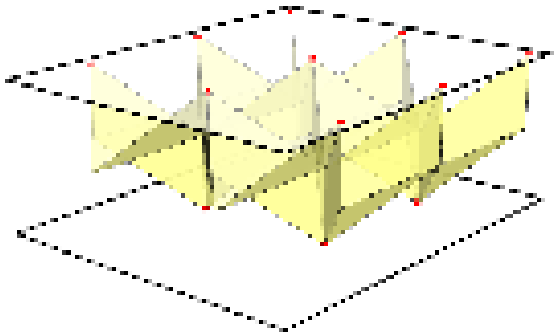
Y. Klett,2013

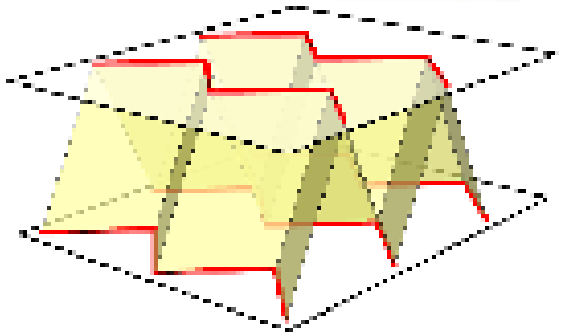
Variety of Folded Cores

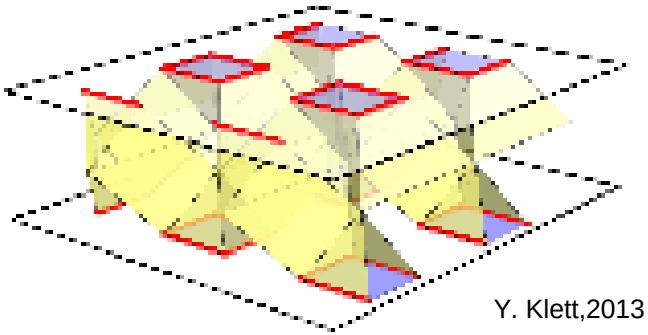






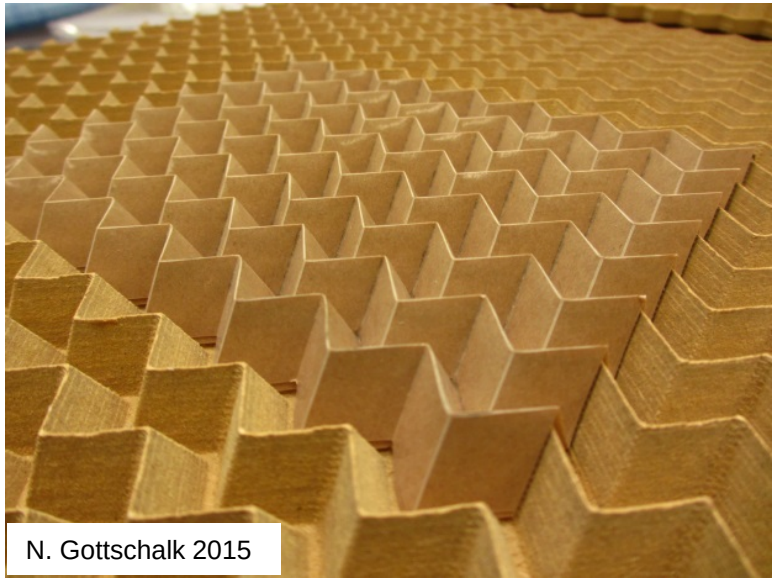


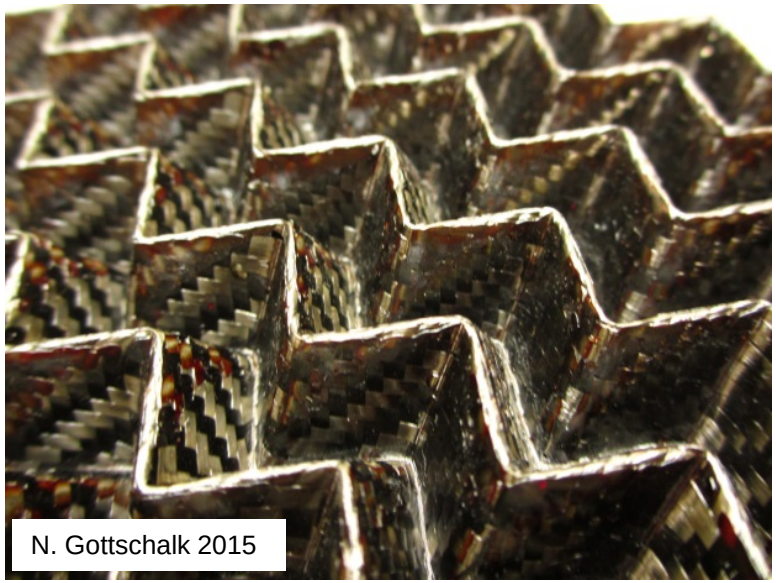




Y. Klett,2013

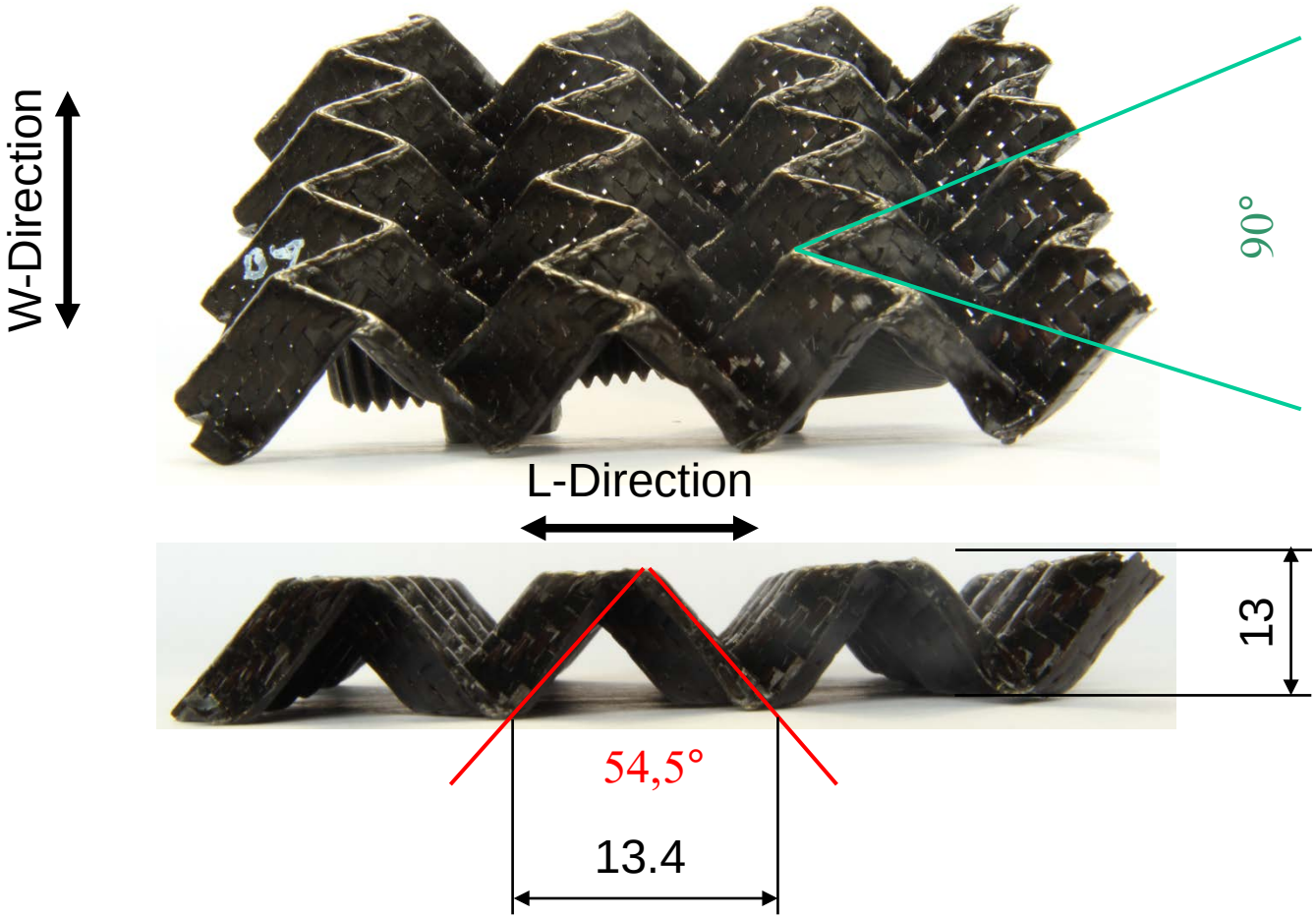
Manufacture of CFRP Cores via Folding Technology





- Prepreg with release tapes
- Folding and forming in wooden mould (380 x 400 mm²)
- Curing + Postcuring at T = 130°C/3h + 210 °C/4.5h
- CFRP fold core (360 x 330 x 13 mm³)

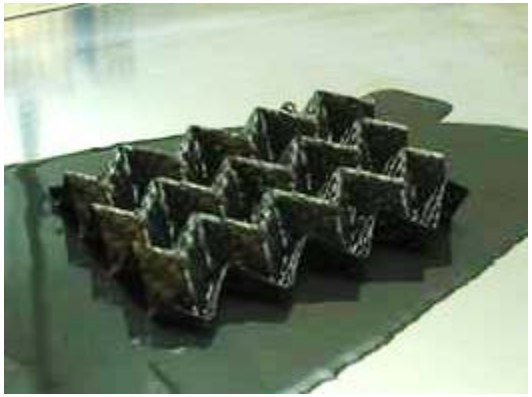
Folded Core - Geometry

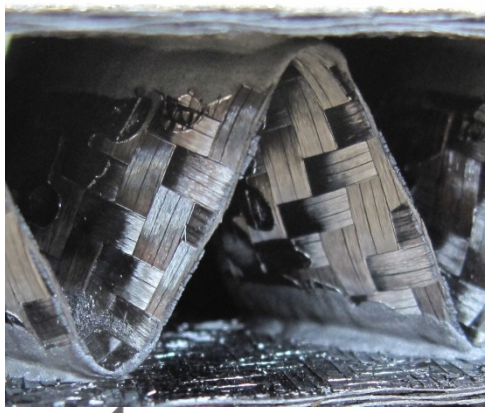


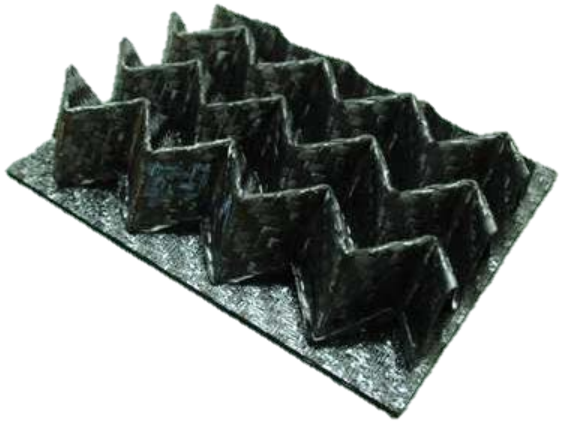
Joining

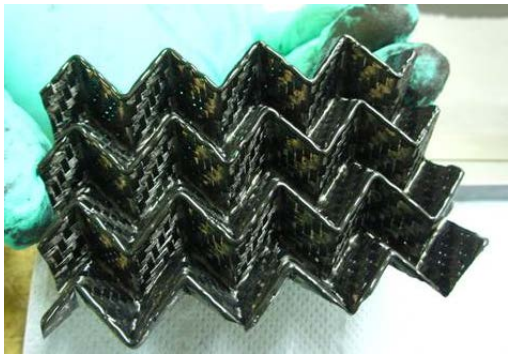
- Joining paste: Phenolic resin (JK 60) + C particles (PC 40; < 45 µm)
- C/C-core preform dipped in joining paste with constant film thickness (3 mm)
- Curing of joining paste (220 °C / 4h)
- Joining of second skin

→ C/C sandwich preform (360 x 330 x 15 mm³)



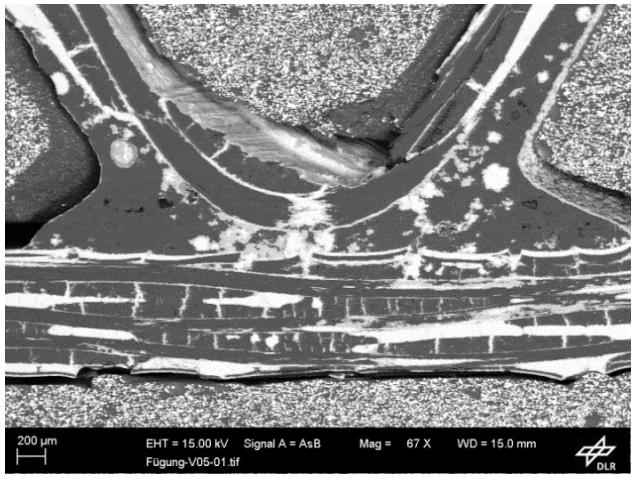


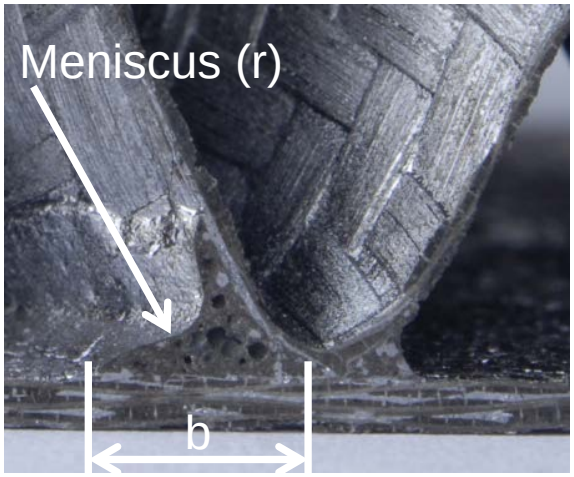


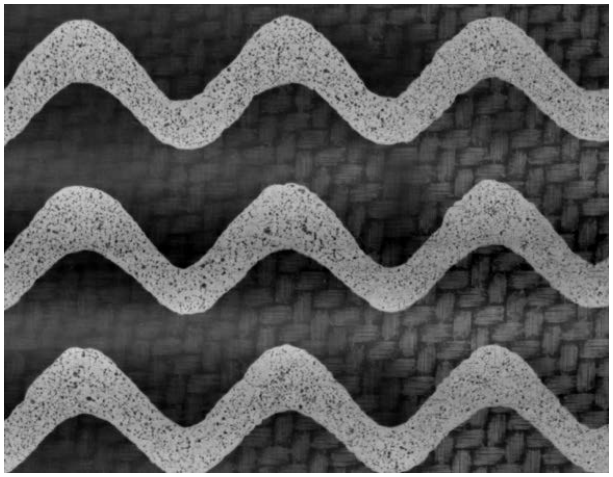


N. Gottschalk 2015

Core Structure and Joining after Siliconication



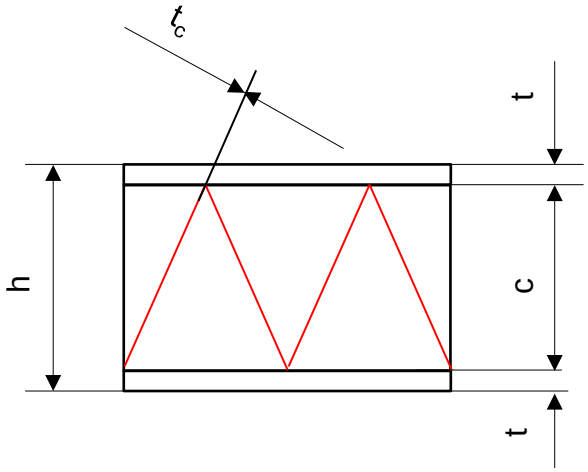




- Single layer core material with characteristic C/C-SiC microstructure
- C-rich joining after siliconization (71% C;18% SiC; 11% Si)
- Homogeneously joined contact lines
- C/C-SiC core density ≈ 100 kg /m³

DLR

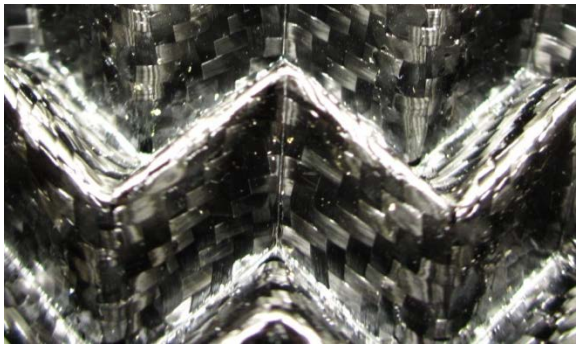
C/C-SiC Sandwich Geometry



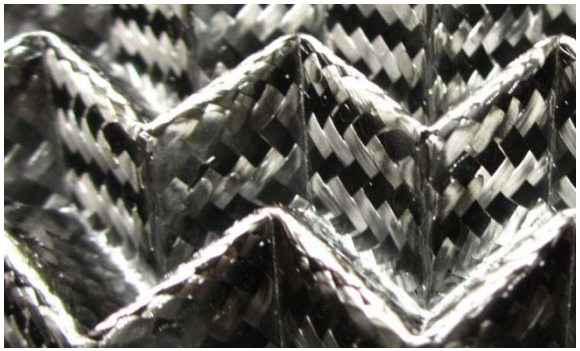
		[mm]
Total thickness	h	15
Skin thickness (0°/90°)	t	1
Core height	c	13
Core wall thickness (0°/90° and ± 45°) 45°)	t_c	0.3

Fibre orientation in core

0°/90°



±45°



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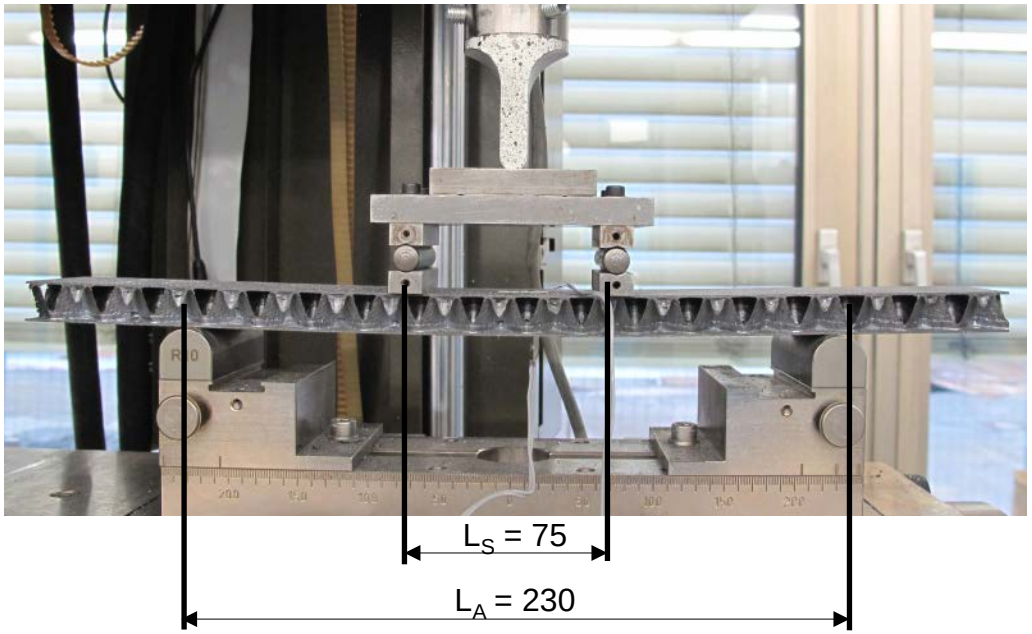
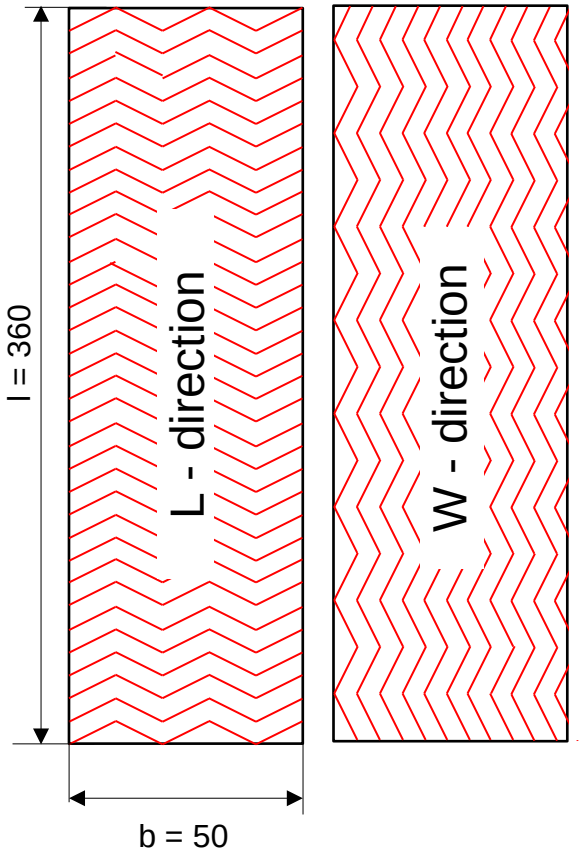
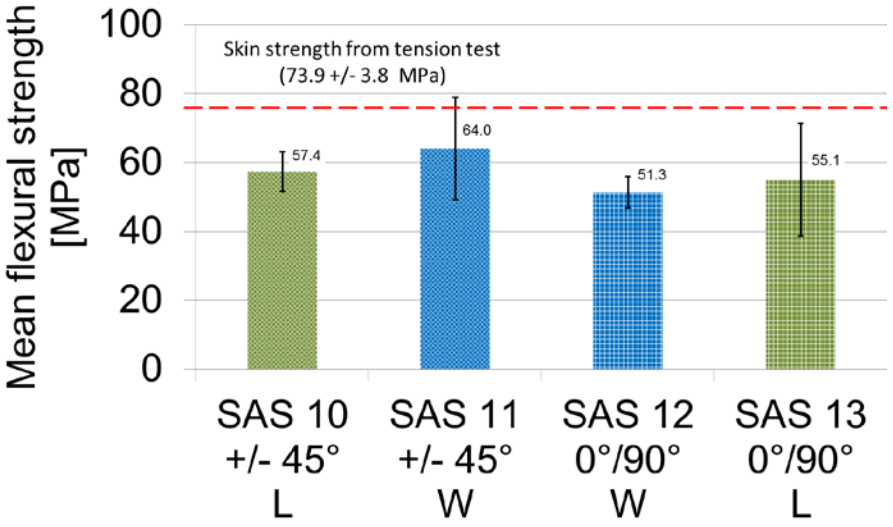
Coupon Geometry and Test Set Up

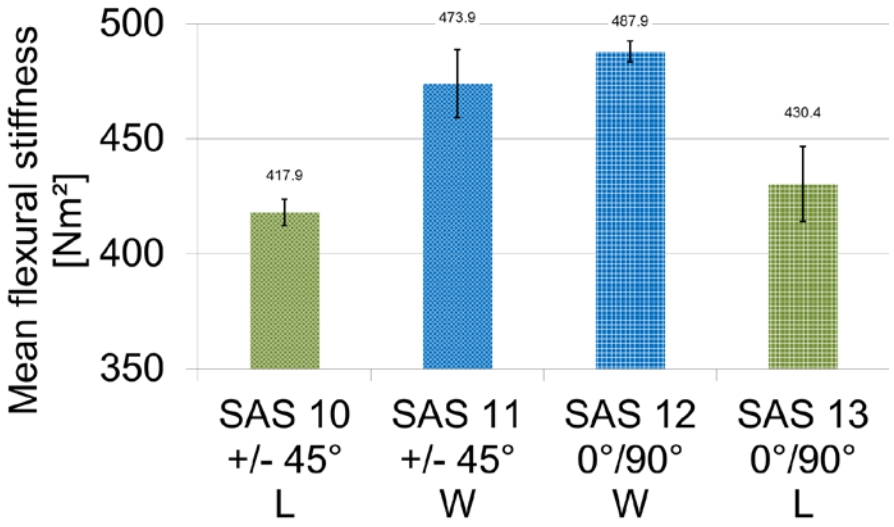
4 Pt. Bending according to DIN 53239





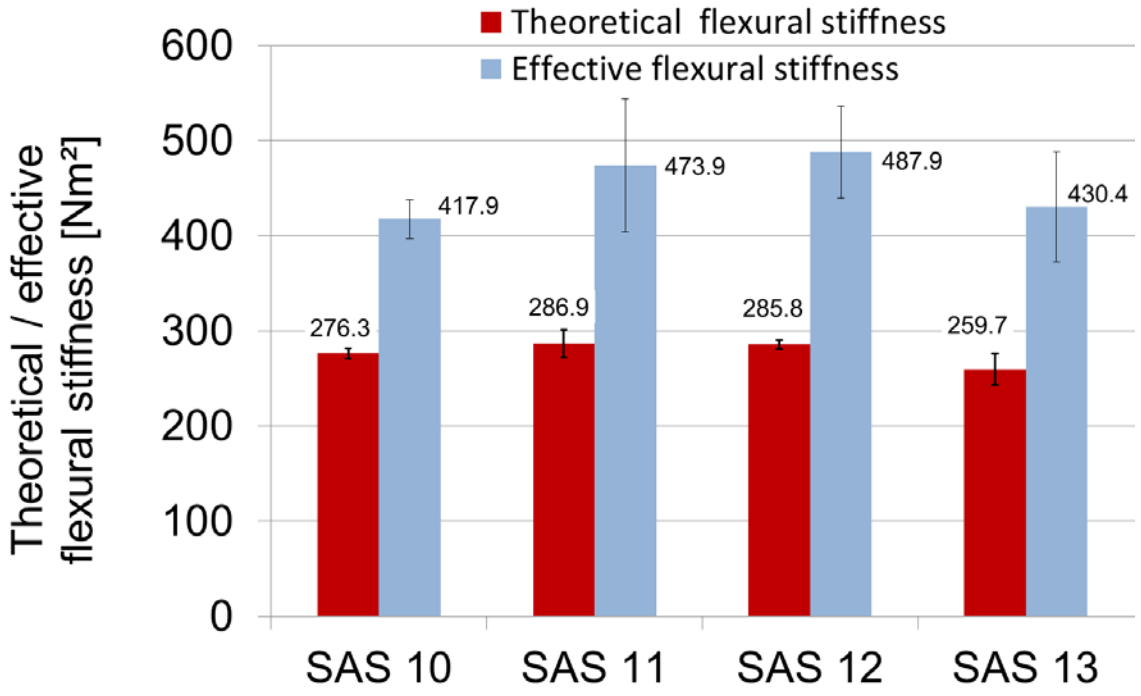
Results-Bending of Sandwich Structures





- Failure by tension fracture of lower skin
  (2 coupons out of 20 show shear failure of core)
- Load factor for the skins > 70 %
- Highest Stiffness in W-direction (joining lines II to sample length)

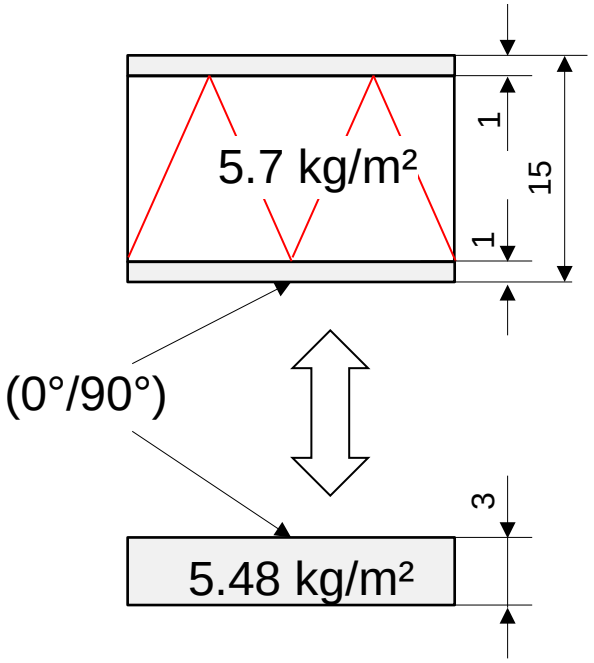
Sandwich Effectivity

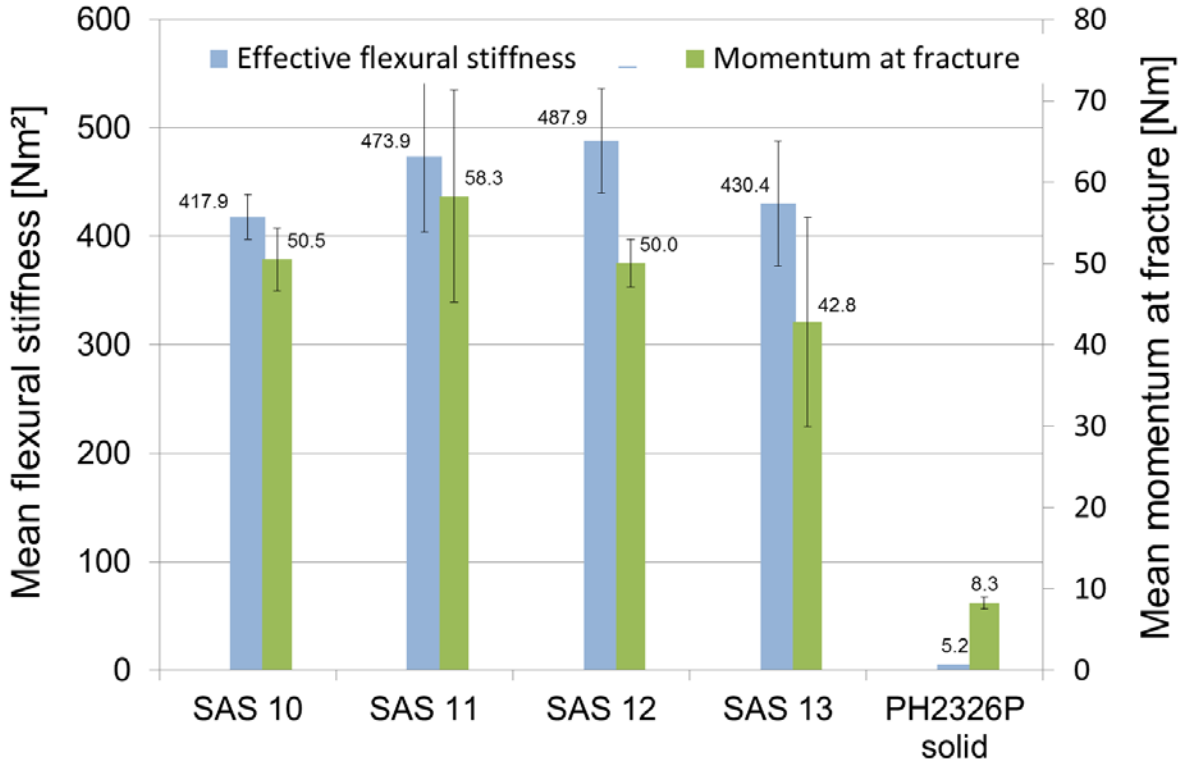


Effective / measured stiffness > theoretical stiffness (+ 63 %)

- Core is increasing stiffness of sandwich structure
- Lighter core possible?

Comparison Sandwich Structure – Solid Panel





Sandwich panel offers:

- 80 times higher flexural stiffness
- 6 times higher load at fracture

Solid panel of same stiffness → t_{solid} = 11 mm; m_{solid} = 4 x $m_{sandwich}$

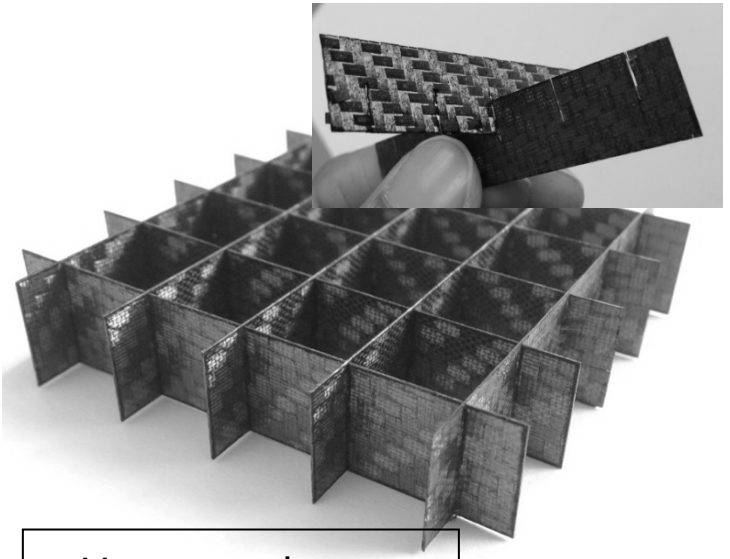
Summary

- Sandwich structures entirely made of C/C-SiC realized via LSI.
- Lightweight cores based on single layer C/C-SiC and LSI are possible (similar microstructure compared to multilayer C/C-SiC).
- C/C-SiC Sandwich design based on folded cores offer highly stiff and lightweight C/C-SiC structures.

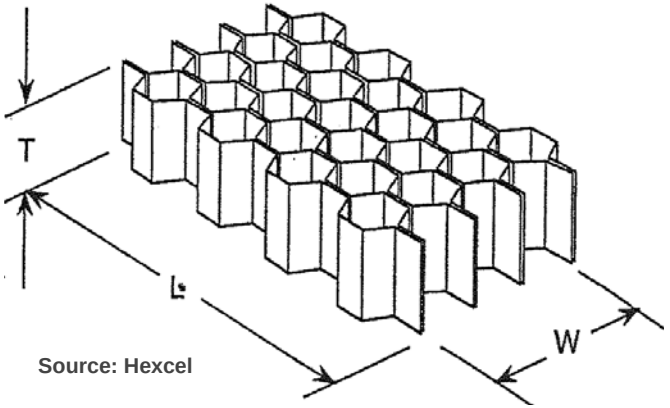
Outlook

- Use of high performance skin materials.
- Lighter core materials by using lighter fabrics (245 → 80 g/m²).
- Grid / honeycomb core types with wall structures perpendicular to skins.
- Upscaling to praxis relevant sandwich structure (ca. 500 x 500 x 70 mm²).
- Demonstrator.

Grid core



Honeycomb core



Source: Hexcel