Sandwich structures bearing resorcinol-formaldehyde aerogel honeycomb cores

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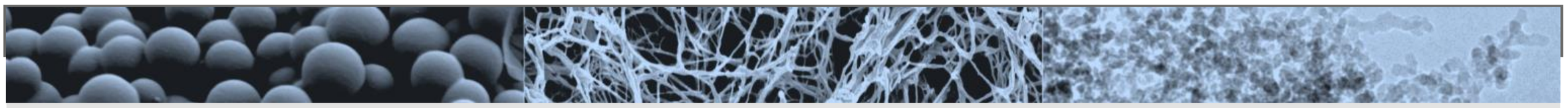


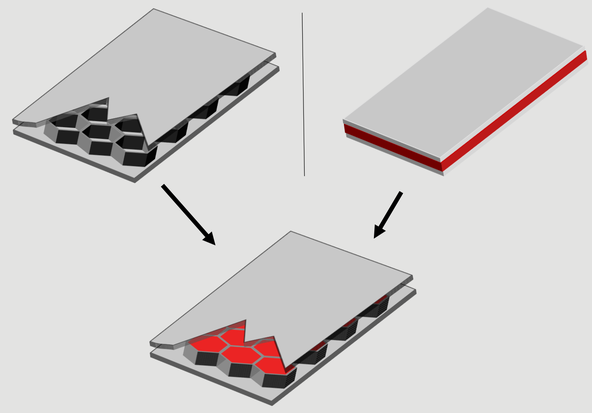
Motivation

Light-weight materials bearing additional functionality may contribute in future towards saving energy within the transport sector. Due to their high compressive strength and capacity to absorb energy upon impact, honeycombs have long been used as core constituent of sandwich structures [1].

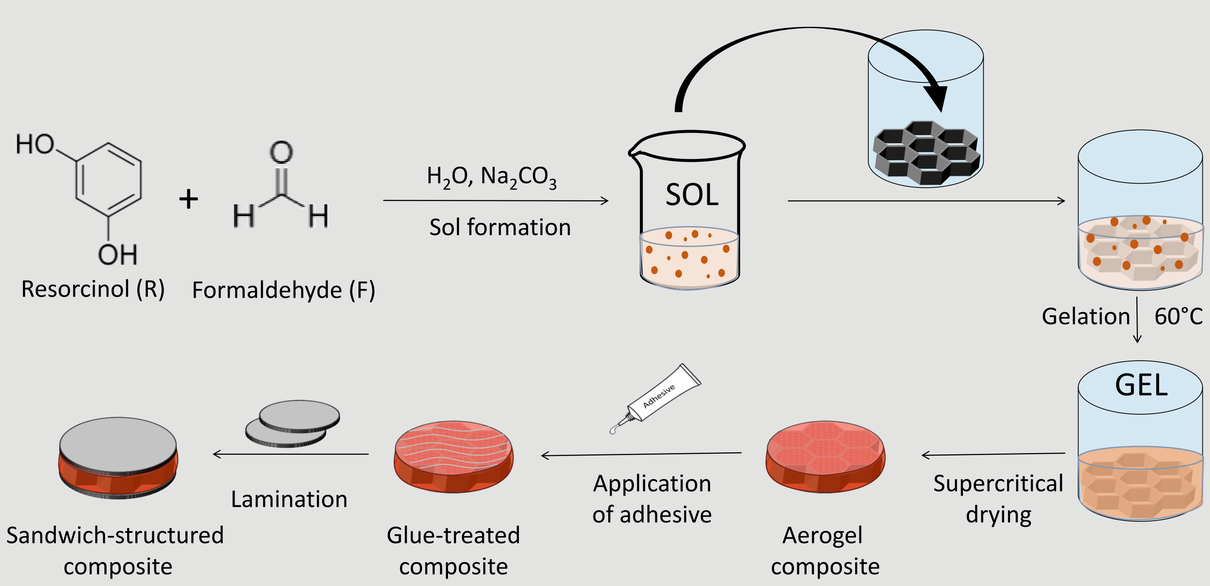
However, despite their favorable mechanical properties, such sandwich structures do not generally act as thermal insulators, as the honeycombs are typically filled with air, thus contributing to convective heat transfer. One concept for reducing the heat transfer of honeycomb sandwich structures is based on filling the honeycombs with aerogel materials. Aerogels are nanoporous lightweight materials with super-insulating properties [2,3].

Our approach: Development of lightweight materials with thermal insulation

→ Benefit for aerospace, aviation, and the transport sector



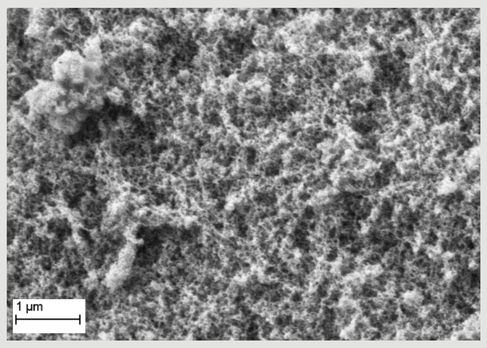
Experimental

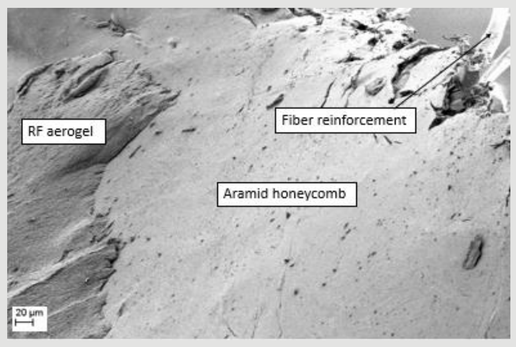


- Previous studies on several adhesives (silicone, silane-modified, polyester, polyurethane, epoxy resins) revealed that, according to criteria such as applicability, curing behavior, sample penetration - and price, the silicone adhesive performed best.
- The silicone adhesive was applied to the aerogel honeycomb composites and laminated with aluminum sheets of different thicknesses (0.3 mm; 0.5 mm).

Honeycomb type	Honeycomb material	Cell size [mm]	Height [mm]	Film thickness [µm]	Density [g·cm⁻³]
AL-6.4	Aluminum	6.4	15	60	0.060
AL-12.7	Aluminum	12.7	15	80	0.042
AR-3.2	Aramid	3.2	20	40	0.029
AR-6.4	Aramid	6.4	20	50	0.024

Structural properties:



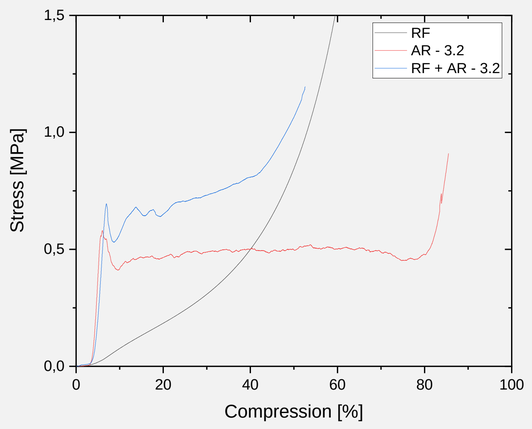


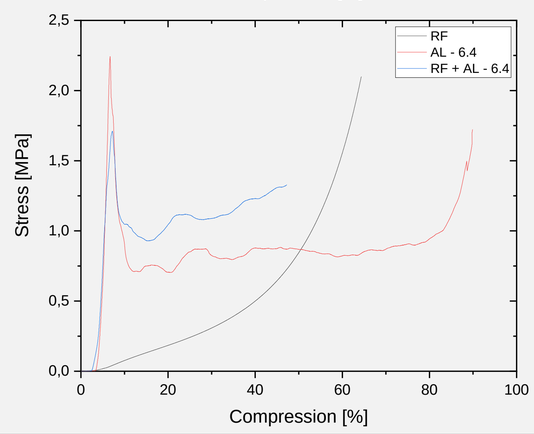
Material	Envelope density [g·cm⁻³]	Skeletal density [g·cm⁻³]	Porosity [%]
RF	0.1383	1.5693	91.2

Characterization & Results

Compression behavior

Material	Stiffness [MPa]	Compressive strength [MPa]
RF	1.09 ± 0.03	-
AR-3.2	34.6 ± 2.33	0.69 ± 0.02
AL-6.4	92.1 ± 3.25	2.70 ± 0.03
RF + AR-3.2	25.9 ± 5.50	0.75 ± 0.04
RF + AL-6.4	108 ± 4.92	2.27 ± 0.25
RF + AR-3.2 + 0.3 mm plate	16.4 ± 2.76	0.63 ± 0.04
RF + AR-3.2 + 0.5 mm plate	12.5 ± 3.64	0.76 ± 0.05
RF + AL-6.4 + 0.3 mm plate	107 ± 24.3	2.18 ± 0.17
RF + AL-6.4 + 0.5 mm plate	104 ± 16.8	2.30 ± 0.09



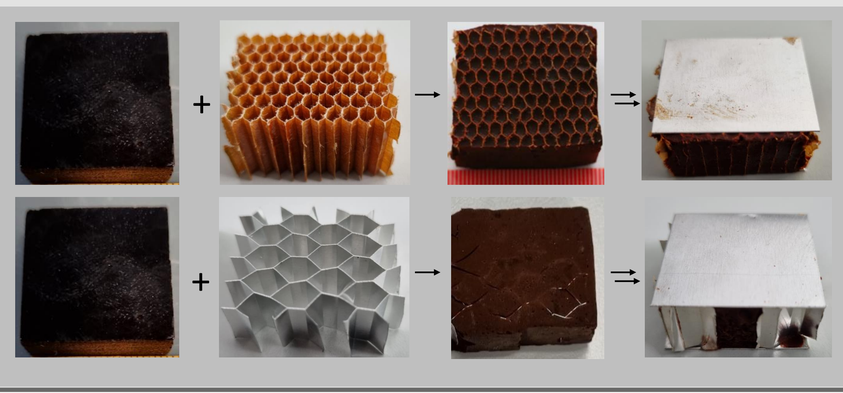


Thermal conductivity

Sample	Adhesive	Thickness Al cover [mm]	Density [g·cm⁻³]	Thermal Conductivity [W·m⁻¹·K⁻¹]
RF	-	-	0.131	0.017
AR-3.2	-	-	0.029	0.058
AR-6.4	-	-	0.024	0.055
AL-6.4	-	-	0.060	0.290
AL-12.7	-	-	0.042	0.246
RF + AR-3.2	-	-	0.154	0.025
RF + AR-6.4	-	-	0.127	0.024
RF + AL-6.4	-	-	0.168	0.165
RF + AL-12.7	-	-	0.136	0.099
RF + AR-3.2	Silicone	0.3	0.225	0.036
RF + AR-3.2	Silicone	0.5	0.288	0.036
RF + AL-6.4	Silicone	0.3	0.258	0.184
RF + AL-6.4	Silicone	0.5	0.316	0.153

Conclusion

- Successful production of a variety of sandwich structures bearing RF aerogel honeycomb cores
- Aerogel aramid honeycomb **composite AR-3.2 is 25 times stiffer** than **pure aerogel,** aerogel aluminum honeycomb **composite AL-6.4** approx. **100 times stiffer**
- **RF honeycomb composite** exhibits **40-60% improved insulating properties compared** to the **pure honeycomb** material



Acknowledgement

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References

[1] T. N. Bitzer, *Honeycomb Technology: Materials, Design, Manufacturing, Applications and Testing*, Springer Netherlands, 2012.
[2] H. D. Gesser, P. C. Goswami, *Chem. Rev. (Washington, DC, U. S.)* 1989, *89*, 765-788.
[3] X. Lu, M. C. Arduini-Schuster, J. Kuhn, O. Nilsson, J. Fricke, R. W. Pekala, *Science* 1992, *255*, 971-972.

FFAE Fokusanwendungen Fahrzeugstruktur Antriebsstrang Energiemanagement

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