Final Report - Figures

Short name of project	LEEToRB
Creation date:	26.01.2016
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Approving person:	Niklas Remer

Figure 1: Sealing concept with conventional silicone cords.

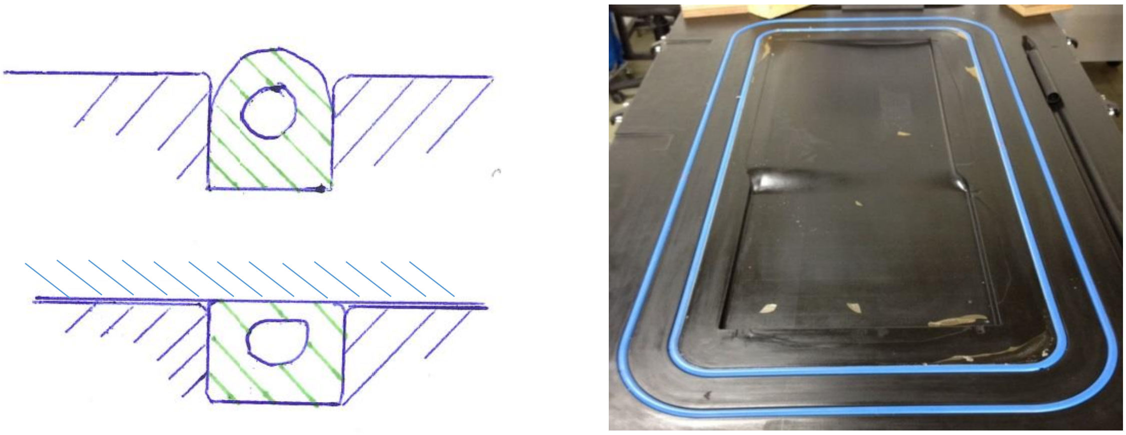


Figure 2: Sealing concept S1 with D-Section mold-sealing.

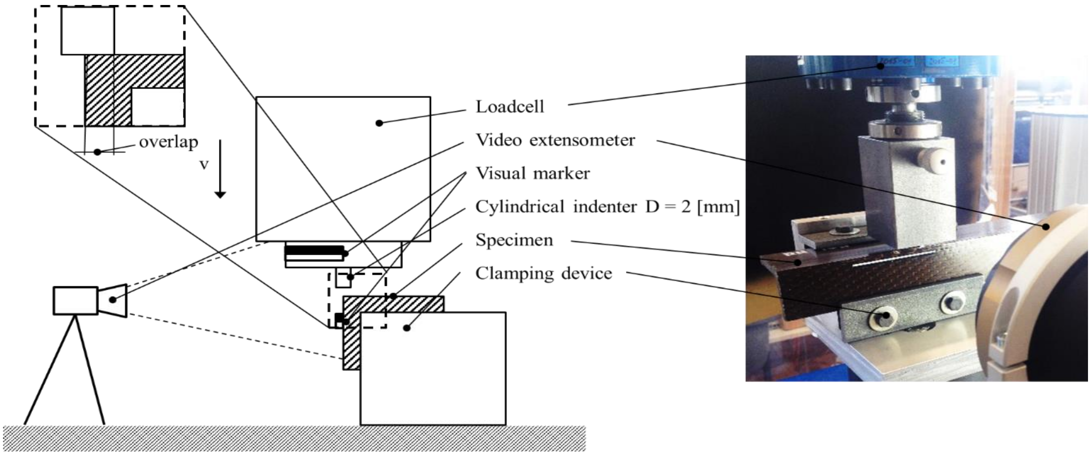
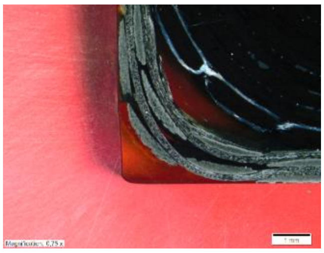
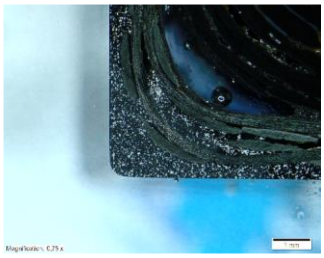


Figure 3: Test setup for quasi-static edge strength testing.

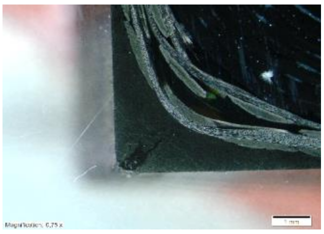
a)



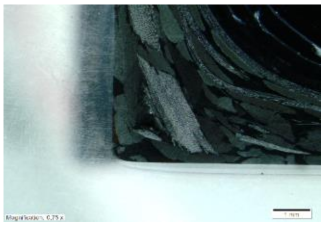
b)



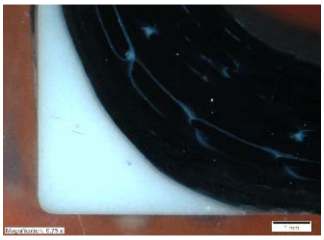
c)



d)



e)



f)

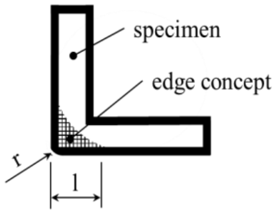
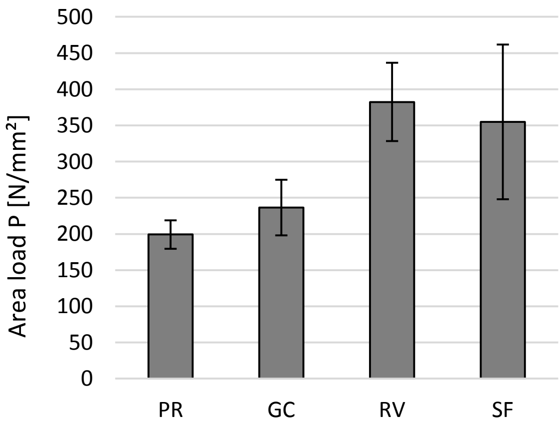


Figure 4: Micrographs of the specimen cross sections, magnification x 0.75: a) RH, b) GC, c) RV, d) SF, e) EE and f) illustrating the measured parameters (r: radius, l: leg length).

a)



b)

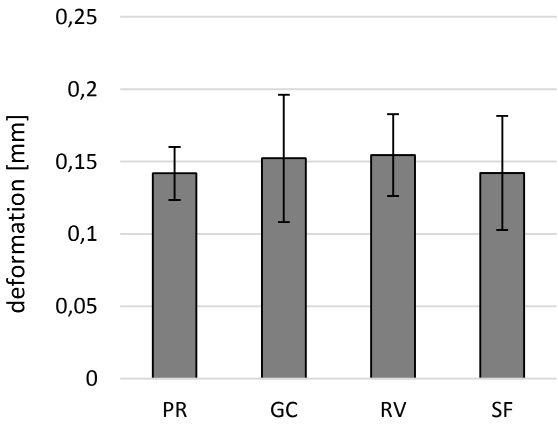


Figure 5: a) mean area load and b) mean deformation at first failure of the edge concepts.

Figure 6: CFRP-tools for long-term surface tests with different surfaces: a) Gelcoat, b) C-Paper and the test rig the mold were implemented.

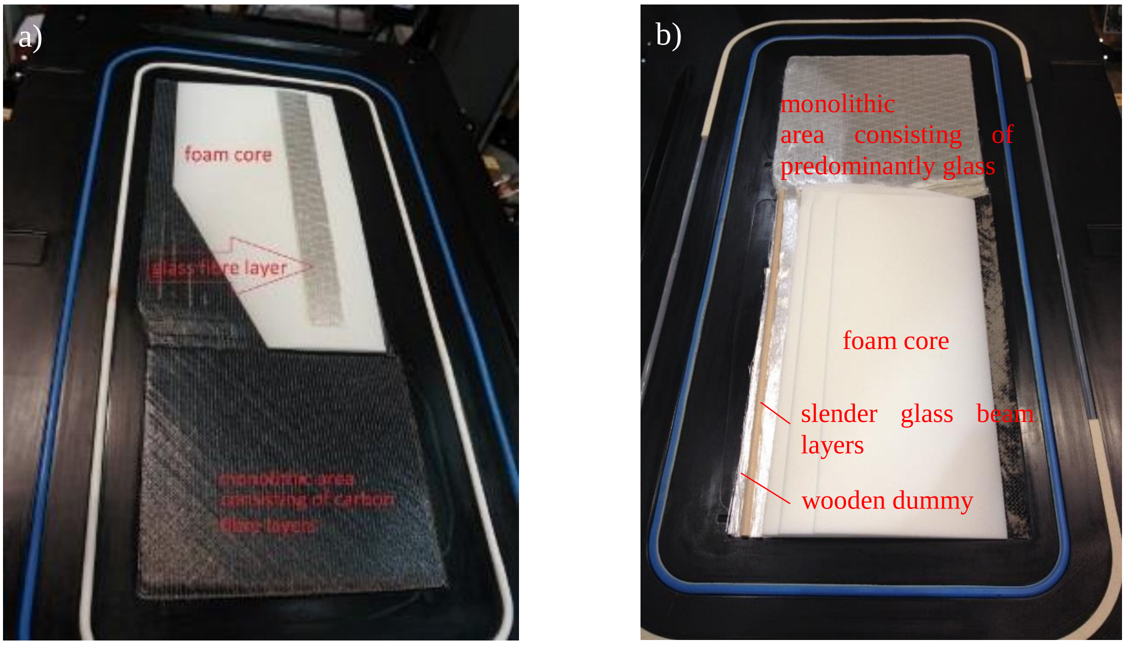


Figure 7: Preform integrated in the tool.

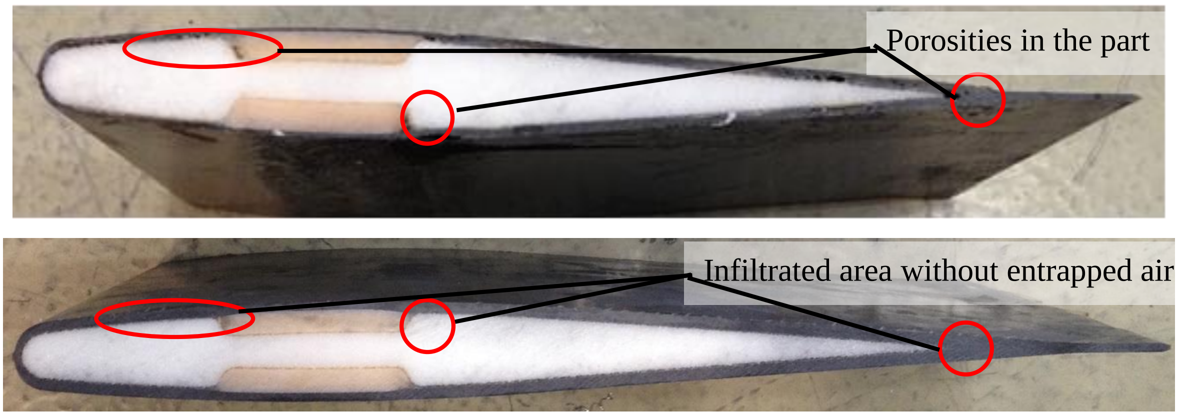


Figure 8: Comparison of cross sections of part 2 and part 3.

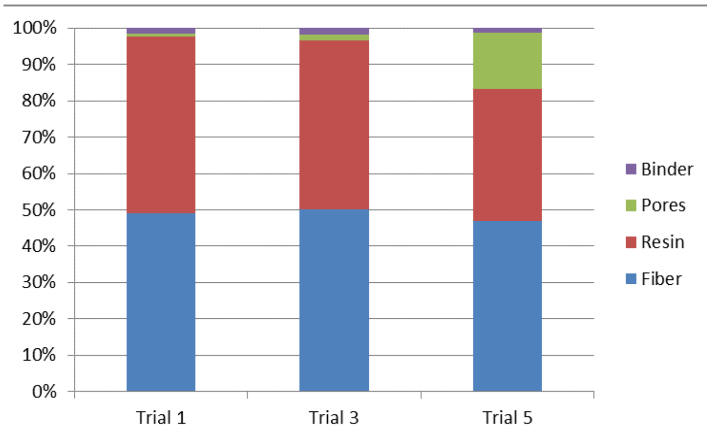


Figure 9: Analysis of the part quality by image processing.

Figure 10: Manufactured set of CFRP RTM tools with integrated heating.

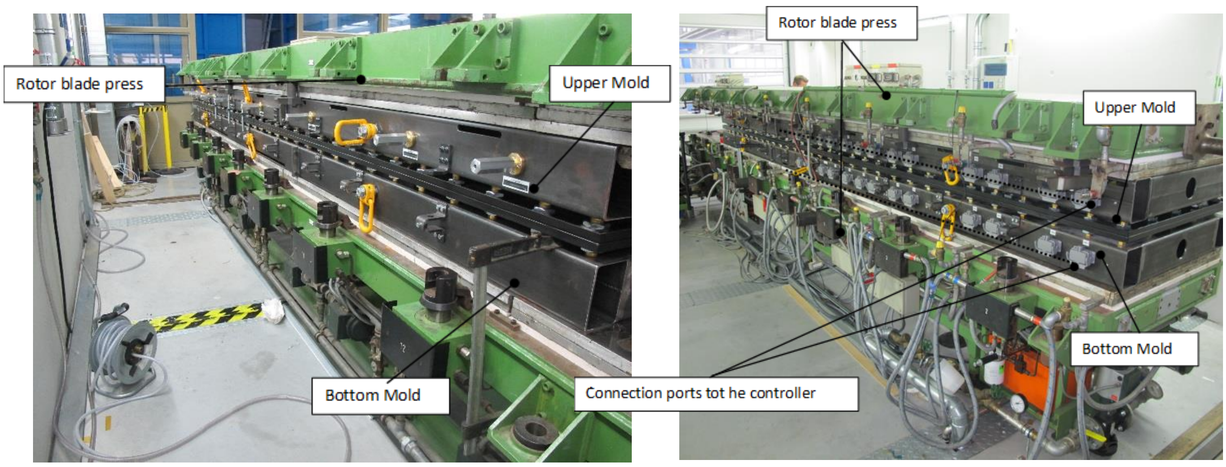


Figure 11: Tools integrated in the rotor blade press.

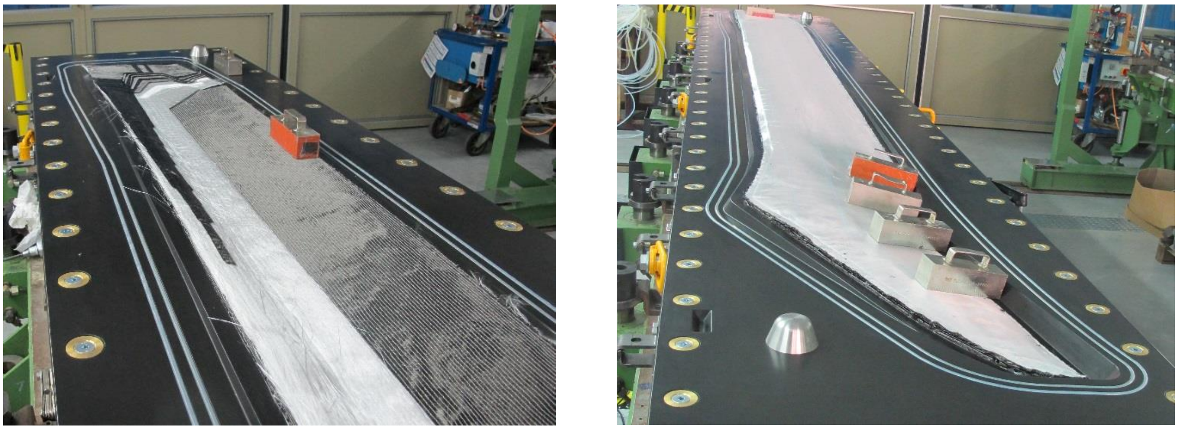


Figure 12: Layup of the full scale rotor blade.

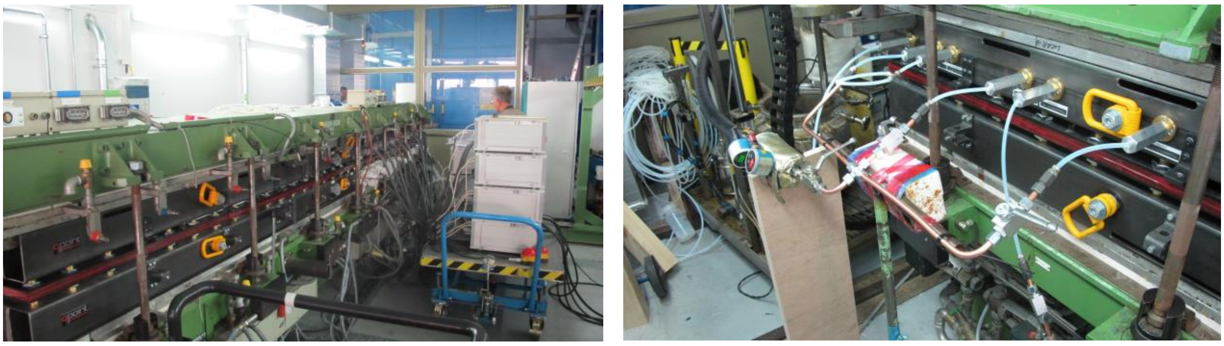


Figure 13 Closed mold with the controllers (left), resin inlet ports connected to the inject. device (right).

a) b)

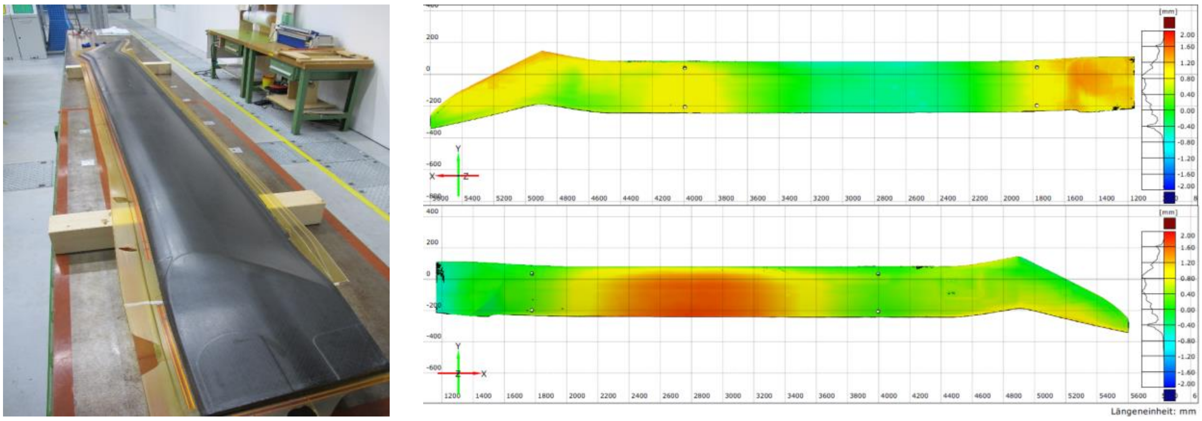


Figure 14: Manufactured rotor blade with resin film around the blade (a), results from optical measurement.

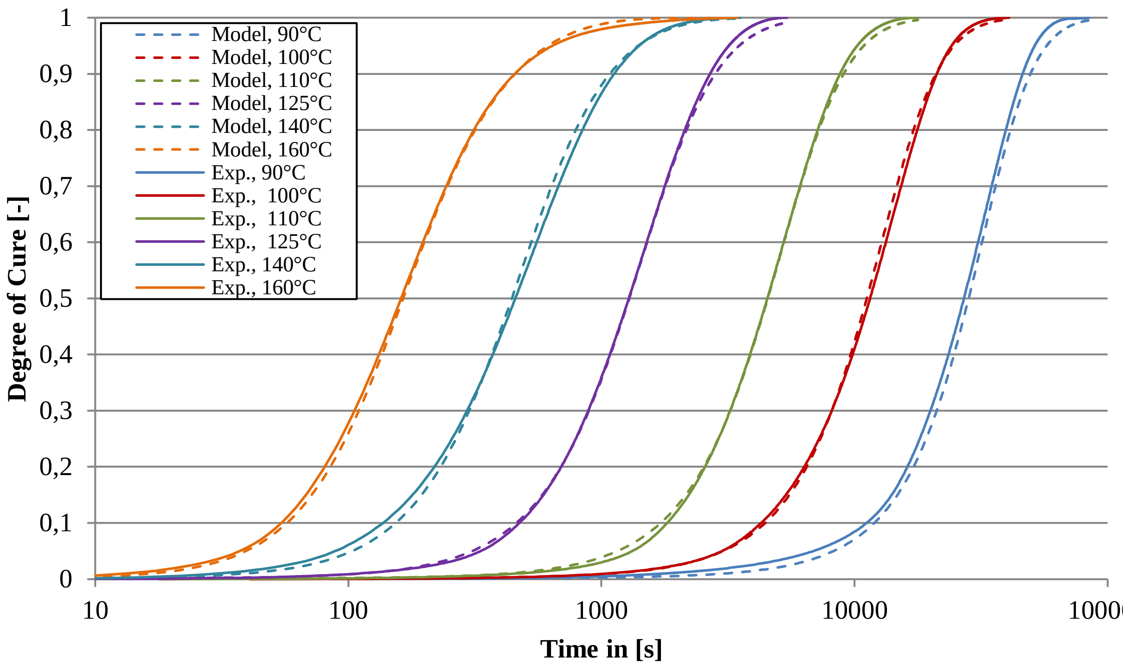


Figure 15: Evolution of the degree of cure at different temperatures[1].

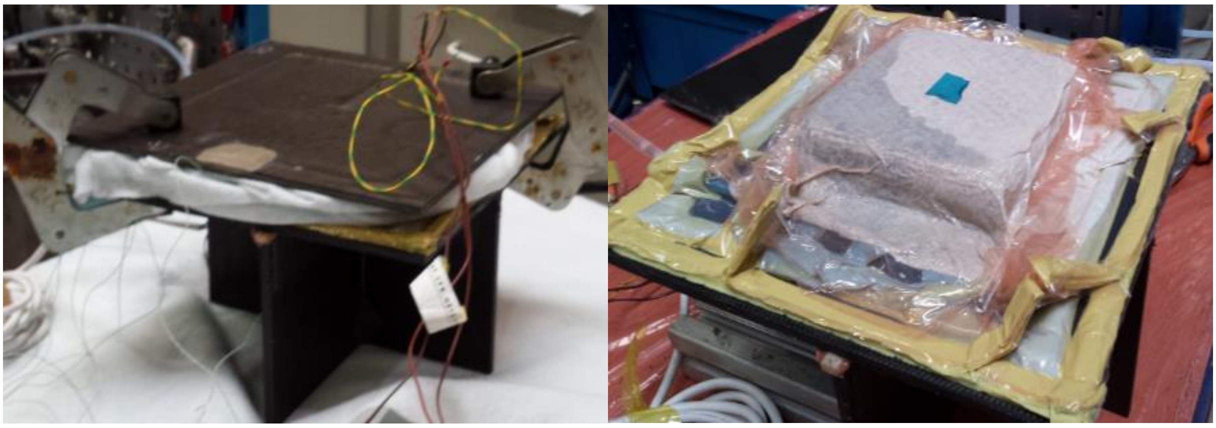


Figure 16: Experimental setup to validate the material models.

[1] Weiland, Hartmann, Hinterhölzl, Characterization and numerical investigation of an RTM cure process with CFRP molds and independent heat patches, Proceedings of the 20th ICCM, 2015

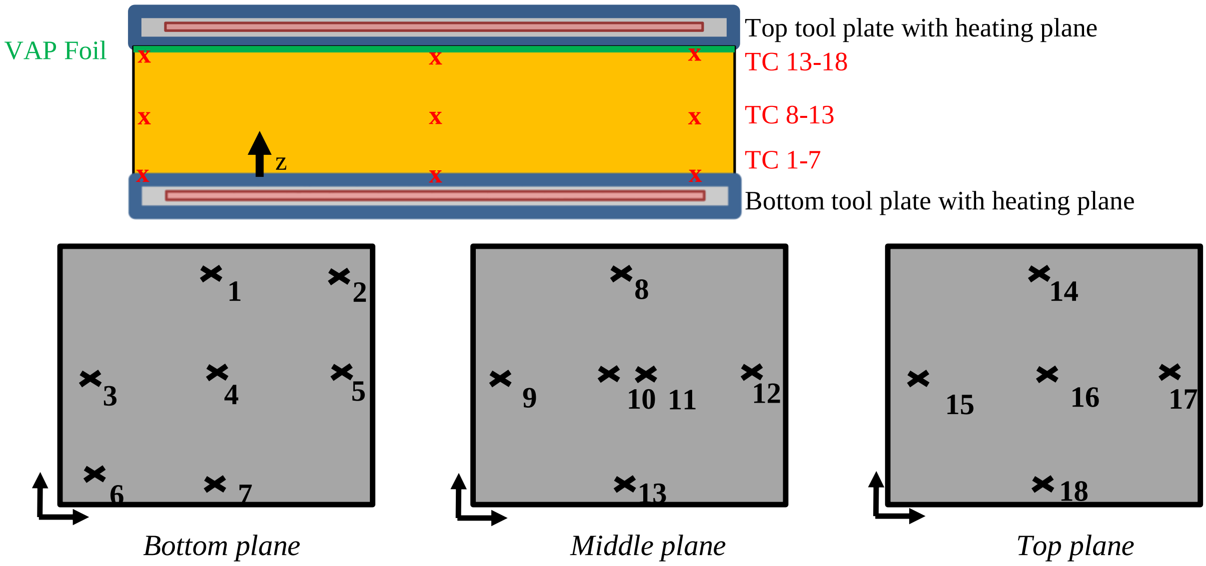


Figure 17: Positioning of the Thermocouples in the coupon test.

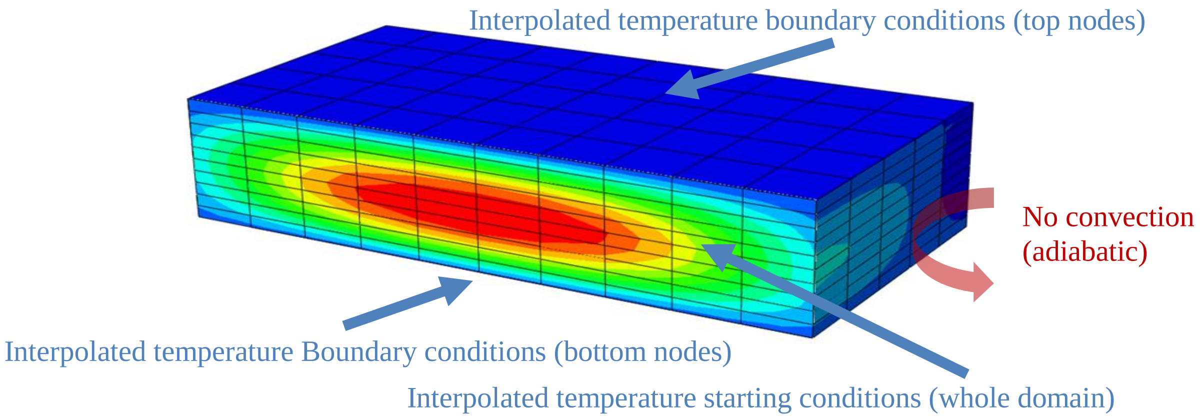


Figure 18: ABAQUS model of the coupon.

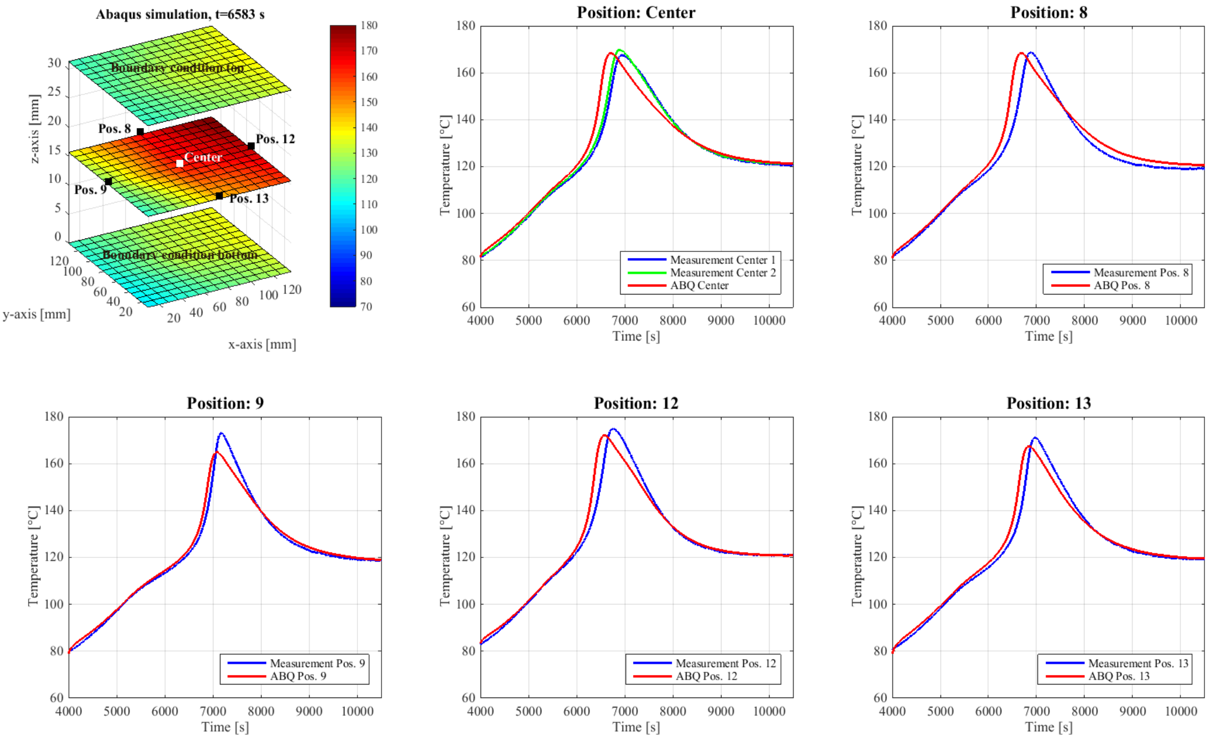


Figure 19: Material model validation[2].

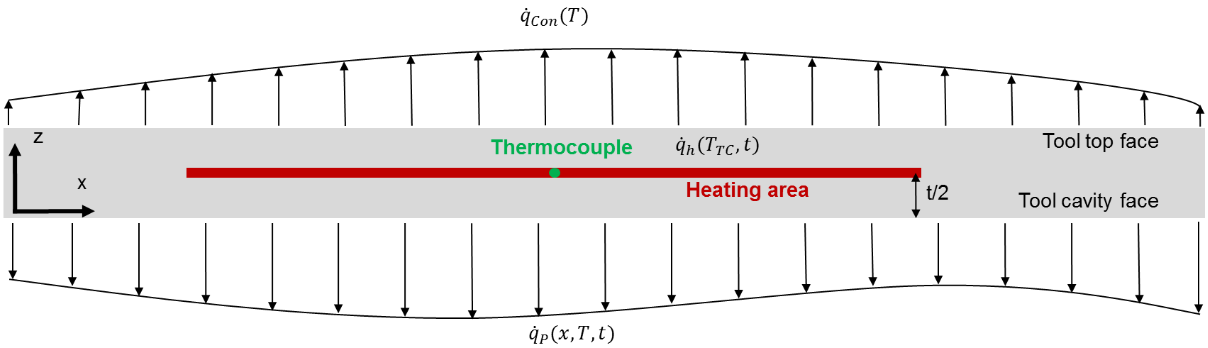


Figure 20: Sketch of the thermal tool behavior[3].

[2] Weiland, Hartmann, Hinterhölzl, Characterization and numerical investigation of an RTM cure process with CFRP molds and independent heat patches, Proceedings of the 20th ICCM, 2015
[3] Weiland JS, Hartmann MP, Hinterhölzl RM. Cure simulation with resistively in situ heated CFRP molds: Implementation and validation. Composites: Part A 2016;80:171-181.

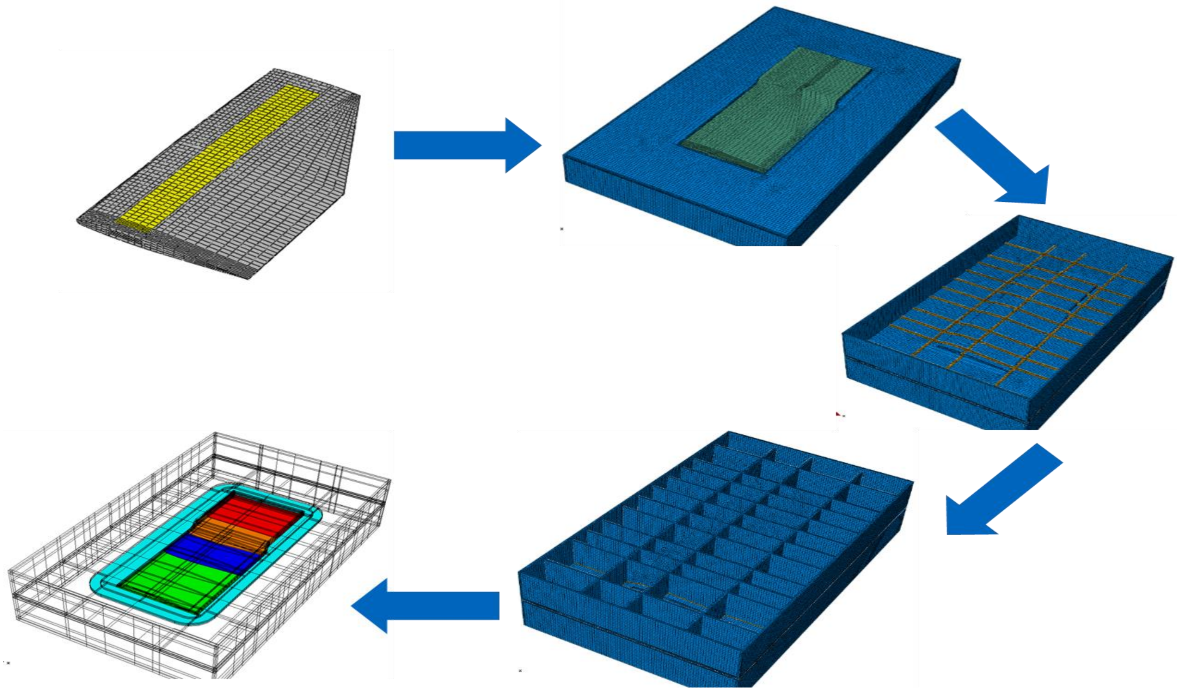


Figure 21: Finite element model development of the demonstrator part.

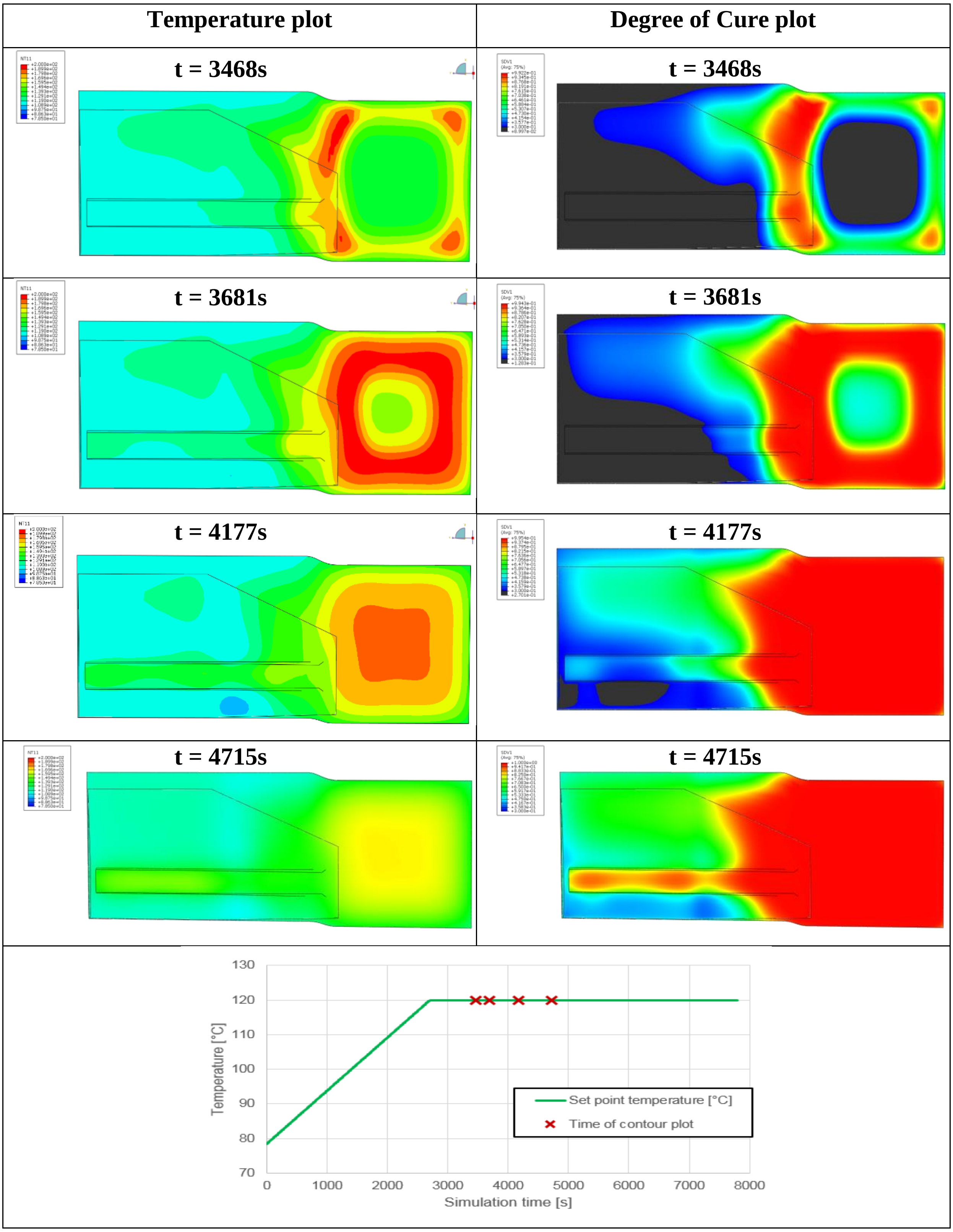


Figure 22: Temperature and degree of cure contour plots with standard cure cycle.

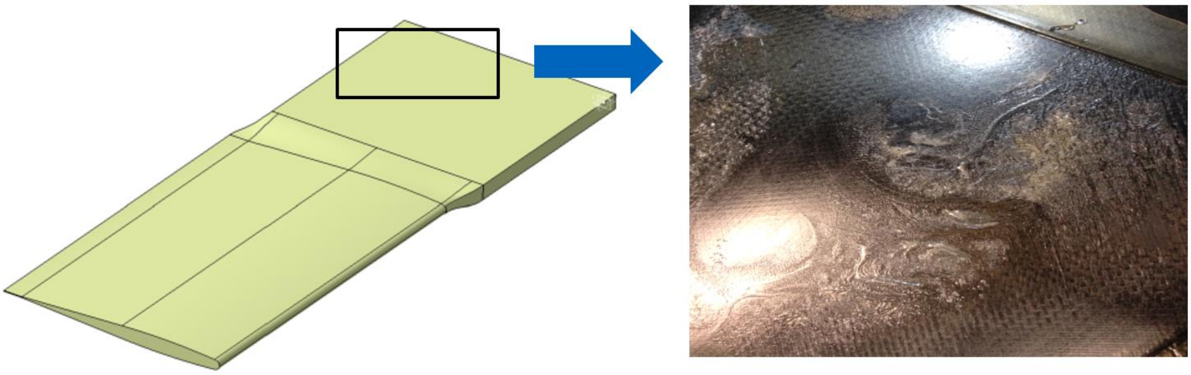


Figure 23: Flow marks on the monolithic section of the scaled rotor blade.

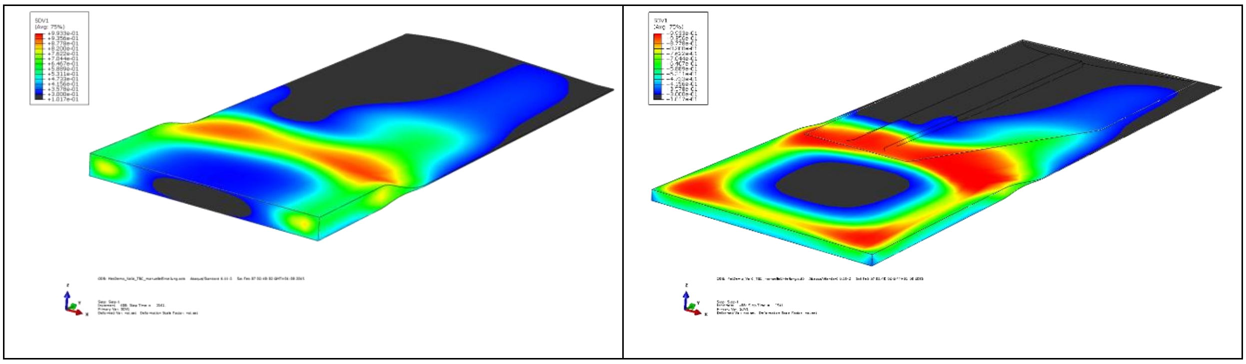


Figure 24: Contour plot of the scaled rotor blade at the simulation time t=3541s, left side: cut through the monolithic section in the xz-plane, right side: cut through the center in the xy-plane.

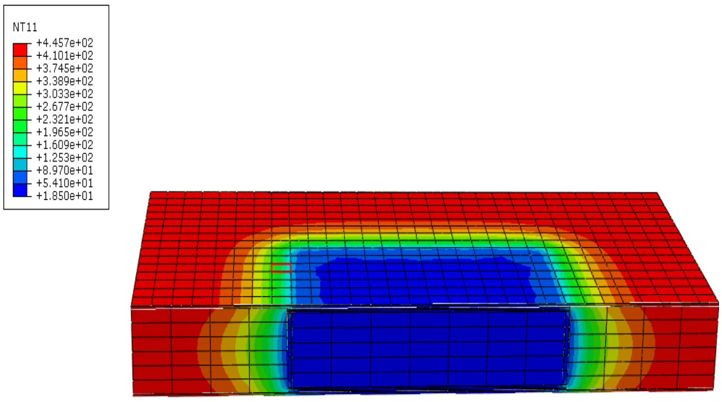


Figure 25: Insert study for the full-scale blade.

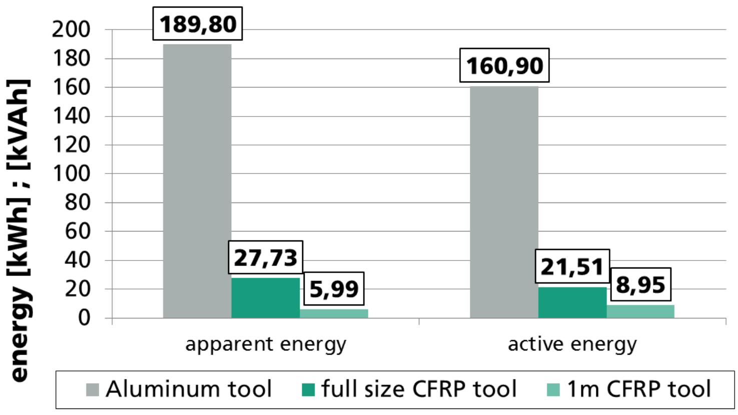


Figure 26: Measured apparent and active energy consumption of all tools for one use-phase cycle in comparison.

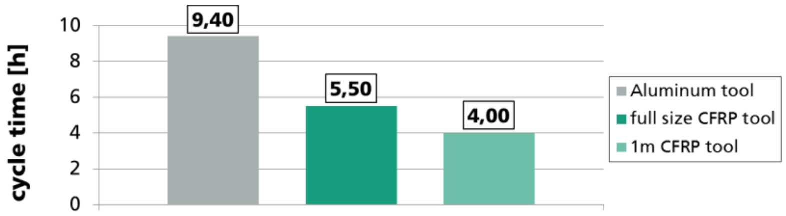


Figure 27: Total curing cycle duration of all tools for one use-phase cycle in comparison.

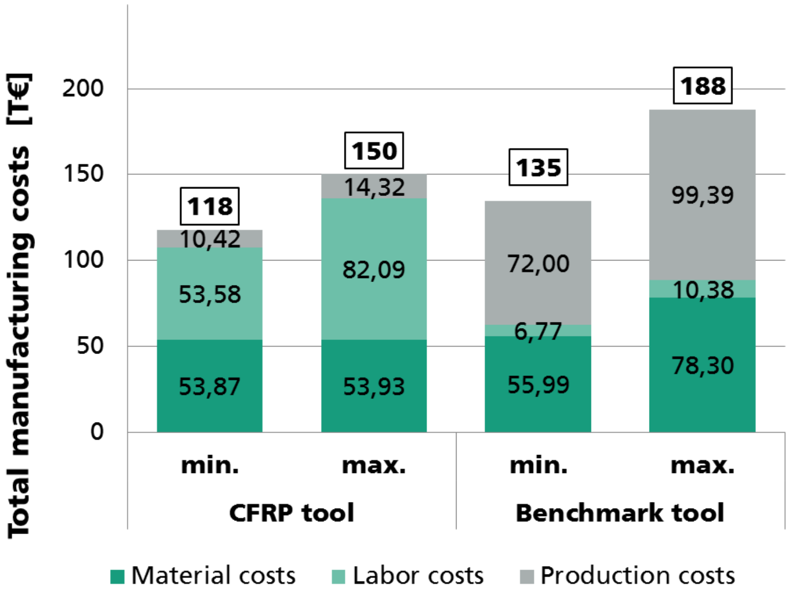


Figure 28: Total manufacturing costs of the CFRP tool and the benchmark tool in comparison, each separated into the minimum and maximum scenario.

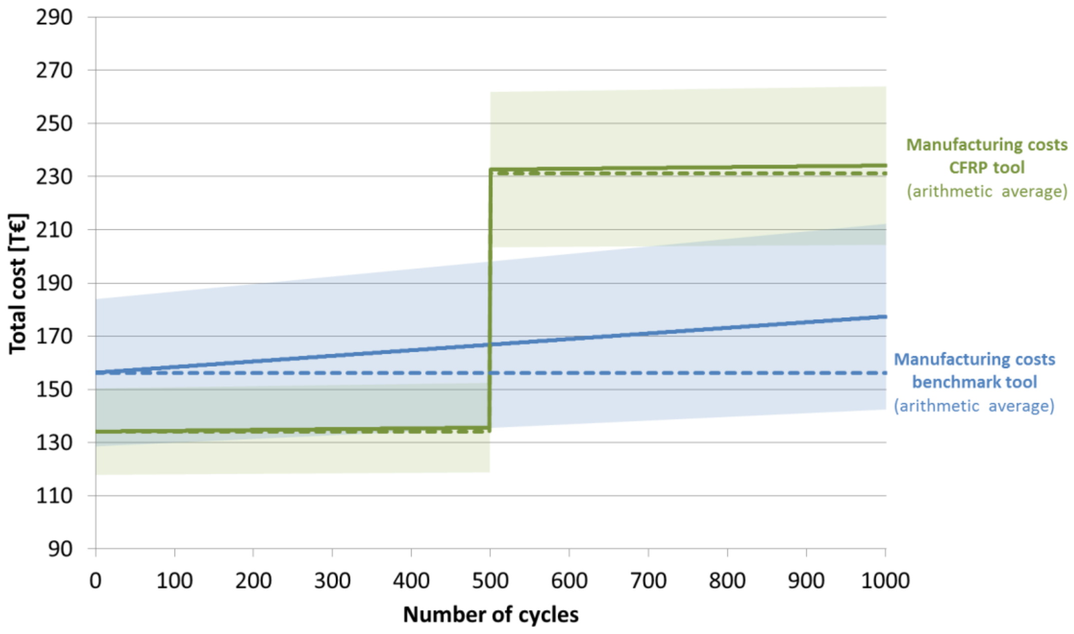


Figure 29: Break-even point analysis – total costs during the use-phase for 1000 cycles for the aluminum tool and 500 cycles for the CFRP tool.

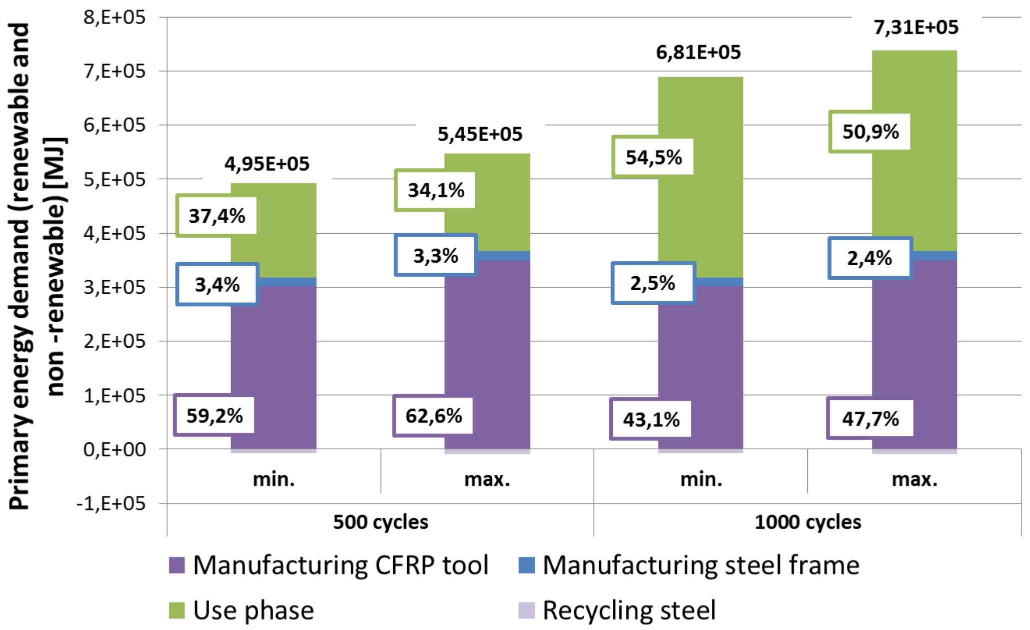


Figure 30: PED for minimum and maximum scenario of each life cycle phase – CFRP tool.

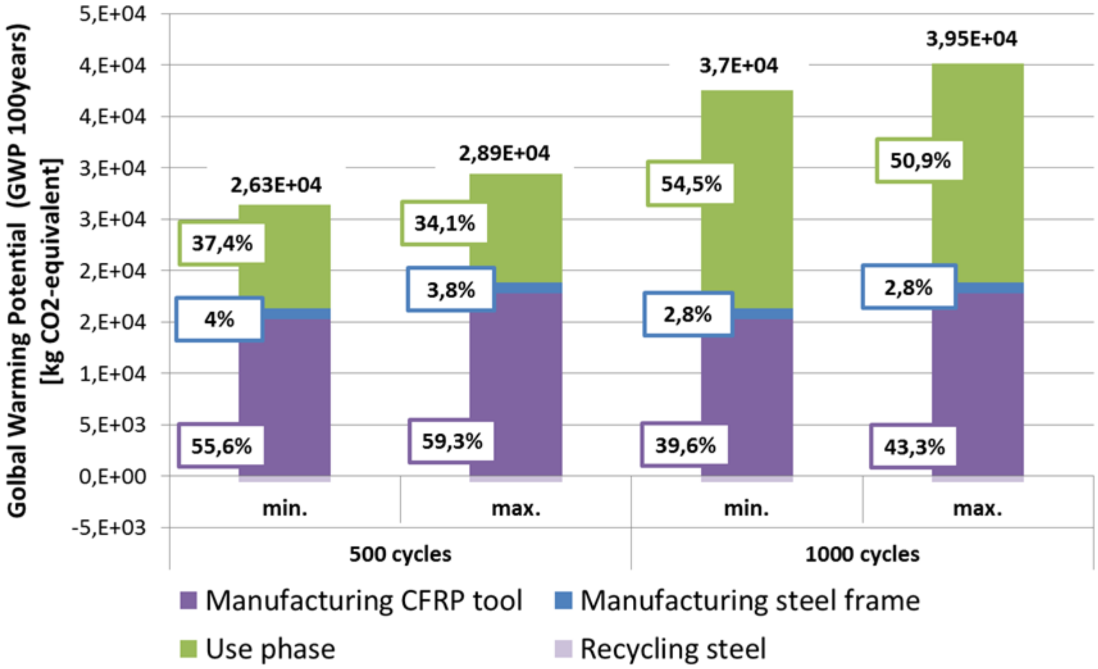


Figure 31: GWP for minimum and maximum scenario of each life cycle phase – CFRP tool.

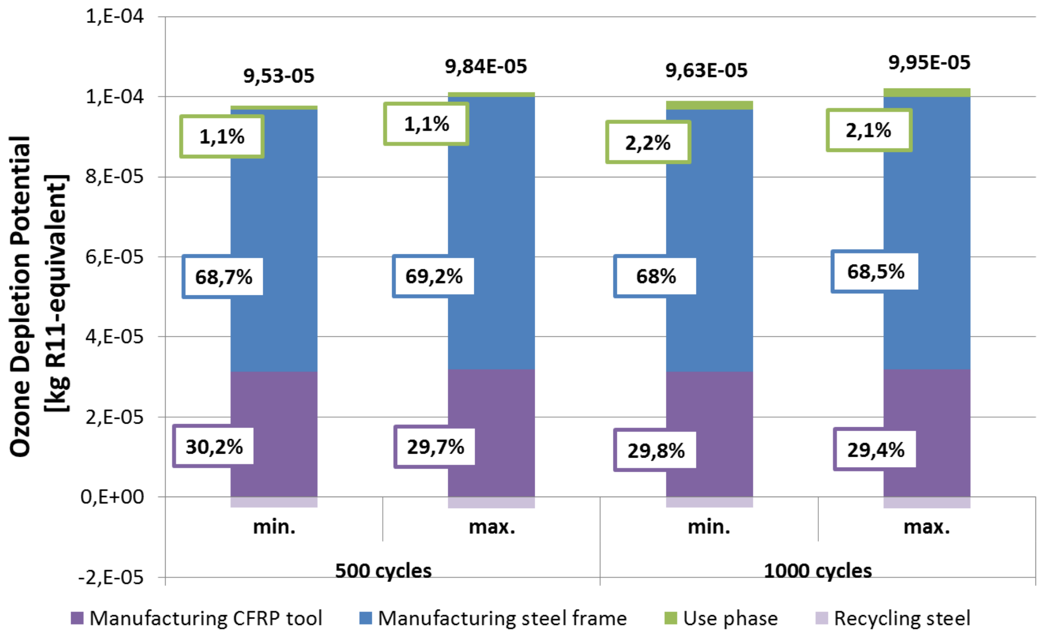


Figure 32: ODP for minimum and maximum scenario of each life cycle phase – CFRP tool.

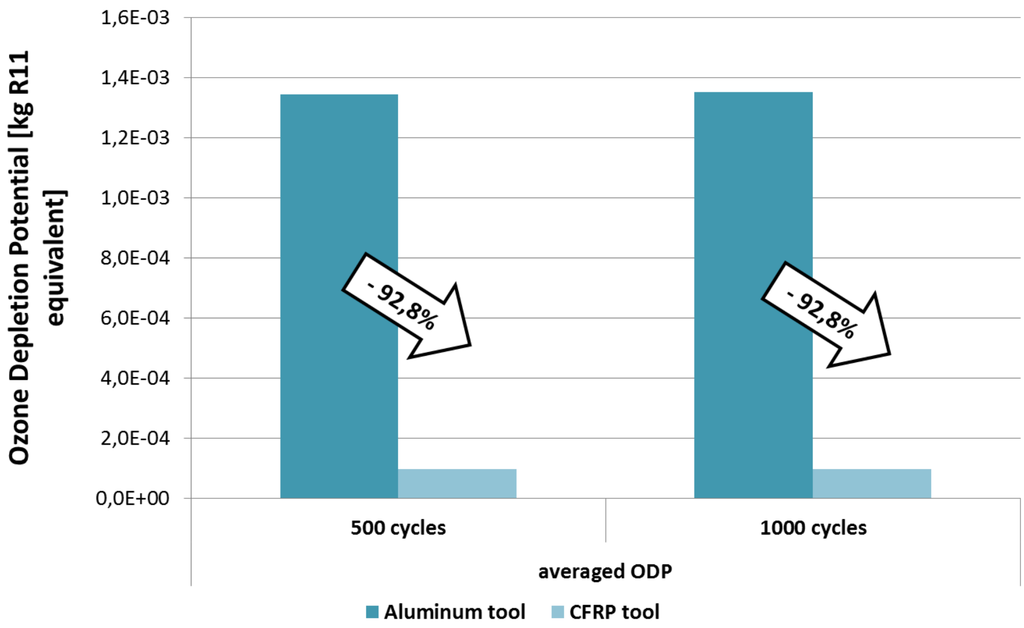


Figure 33: Comparison of the tools - total averaged ODP for the 500 and 1000 curing cycles.

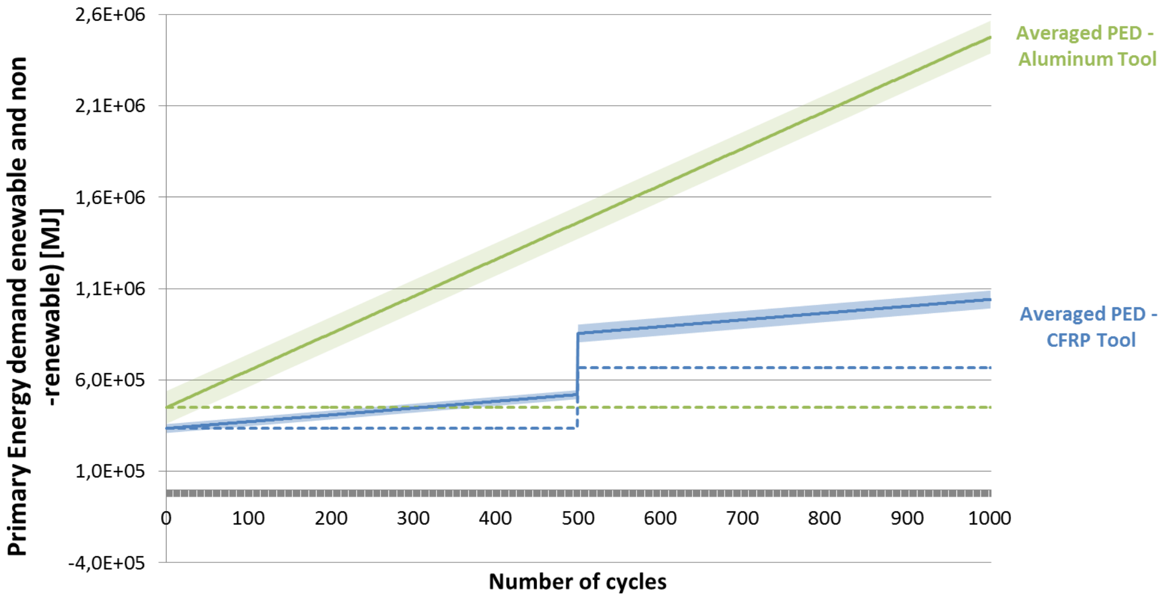


Figure 34: PED - Break-even point analysis of the PED for the whole life cycle of both tools.