Final Report - Figures

Short name of project: LEEToRB
Creation date: 26.01.2016
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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)

![Image a) RH, b) GC](image1)

![Image c) RV, d) SF, e) EE and f) illustrating the measured parameters](image2)

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)

![Graph a) mean area load and b) mean deformation at first failure of the edge concepts](graph1)

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).

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 temperatures¹.

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 validation².

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Figure 20: Sketch of the thermal tool behavior³.

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
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.