Manufacturing process simulation for autoclave tooling optimization

The design of autoclave molds is even today mainly based on the experience of the tooling designer. After the mold has been produced and tested the options for possibly required optimization are significantly reduced compared to those that could have been done during an early design phase. Thus the Tooling Evolution & Improvement Team of Airbus Helicopters Deutschland GmbH introduces manufacturing process simulation (MPS) into the tooling design process.

If an autoclave mold cannot provide the desired part quality. Costly tooling re-work, higher rejection rates, or a delay in serial production are possible consequences, since mold testing and optimization cannot be carried out before the mold is actually produced.

Early action

The Tooling Evolution & Improvement Team of Airbus Helicopters Deutschland GmbH is aiming at overcoming those adversities by introducing manufacturing process simulation (MPS) into the tooling design process (Fig. 1). This MPS mainly aims at providing an estimation of the manufacturing outcome for different mold designs and at showing the influence of the mold on the parts' quality. Areas of principal interest are heat-up and curing characteristics, final part thickness, and fiber volume fraction as well as out-of-plane fiber wrinkling caused by the compaction of the material during autoclave processing.

The simulation applied is a sequential thermo-mechanical finite element analysis that predicts changes in resin properties during cure as well as tool-part-interaction, mismatch in coefficients of thermal expansion, resin flow during compaction, and interlaminar friction. User defined material models for ABAQUS™ were developed and verified to provide adequate accuracy. The primary advantage of this simulation methodology is the focus on tool-part-interaction and interlaminar friction providing the capability to fully predict the molds' influence on part quality.

Taking maths on board

The use of MPS replaces the design from experience with a design based on the understanding of the physical phenomena and the evaluation of different tooling concepts by means of simulation. Although there is still a need for more effort towards up-scaling for industrial application, the first thermal simulations nevertheless show the large potential of MPS for tooling optimization. Even for complex molds the simulation is capable of providing adequate accuracy and it enables fast parameter studies and sensitivity analysis (Fig. 2).

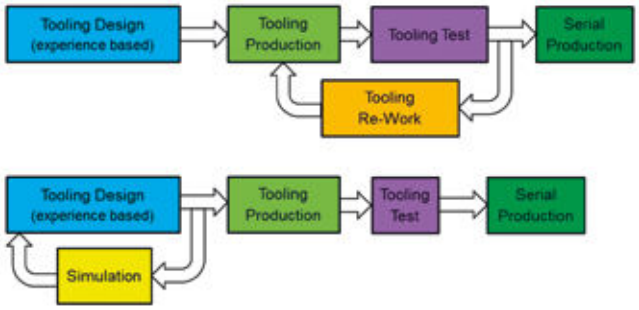

Fig. 1: Tooling design process (top: original approach without simulation; bottom: new approach including MPS)

By means of the MPS different mold concepts can be evaluated within the virtual design phase leading to an optimized tooling design that requires only minimal testing and re-work and therefore provides a much faster and less cost-intensive entry into serial production.

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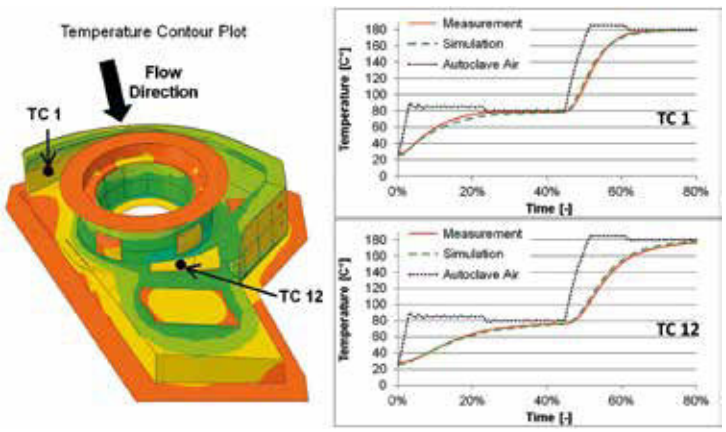

Fig. 2: H145 Fenestron™ shroud tooling thermal simulation: Comparison of the thermal simulation developed by Airbus Helicopters Deutschland GmbH with experimental measurement of the temperature distribution on the mold surface during a standard autoclave cycle.