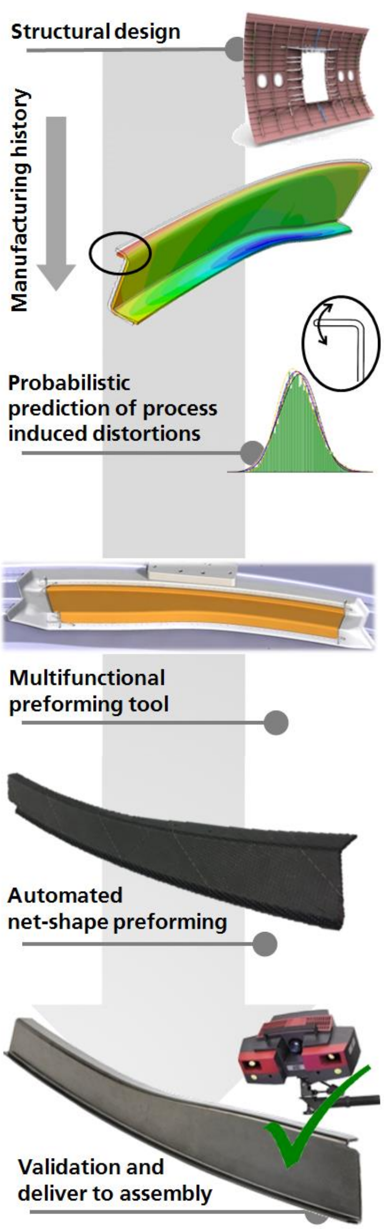
Automated, net-shape preforming and isothermal injection process of spring-in compensated frames



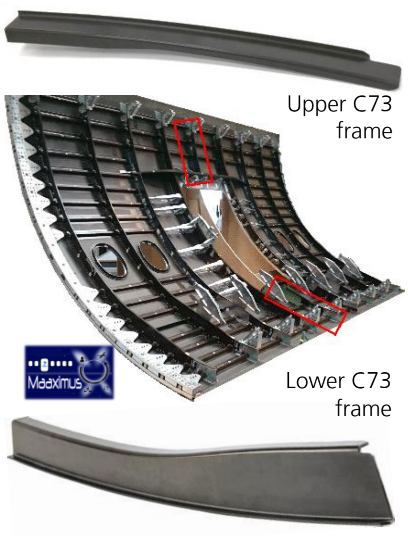
The European FP7 project MAAXIMUS (More Affordable Aircraft through eXtended, Integrated and Mature nUmerical Sizing) dealt inter alia with the manufacturing and testing of an aircraft side shell structure while its ambitious cost-saving goals have been conscientiously pursued. A time reduced manufacturing processes of two typical frames made of carbon fiber reinforced plastic (CFRP) was a subgoal to this. In order to enable efficient assembly of the overall MAAXIMUS side shell tight part tolerances were achieved taking into account process induced distortions during tooling design based on numerical simulations.

Connection of multiple disciplines to an automated manufacturing strategy

A manufacturing strategy that connects multiple working steps was developed for RTM-processing of CFRP frames. The automation of the preforming steps, including ply preparation, draping, consolidation and net-shape trimming allows a high time and cost efficiency. The net-shape approach decreases the total manufacturing time further.

Process verification and correlation of predicted part tolerances

The manufacturing of multiple frame parts allowed improvements of each discipline for outstanding part quality. In order to ensure tolerances of the final part geometry probabilistic simulations of process induced distortions were conducted and tooling design was adapted accordingly. Optical shape measurement and process evaluation were performed to validate the feasibility of the used methods and working steps. The resulting frames were assembled to the overall MAAXIMUS door surround structure which was mechanically tested to prove the operational capabilities.

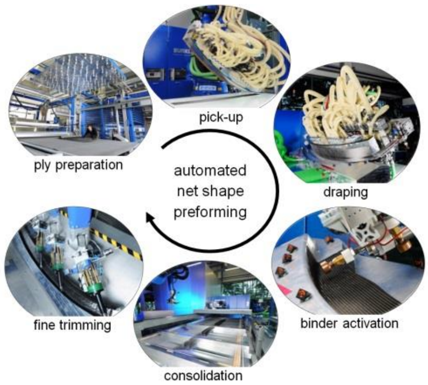


MAAXIMUS door surround structure and manufactured C73 frames

Achievements:

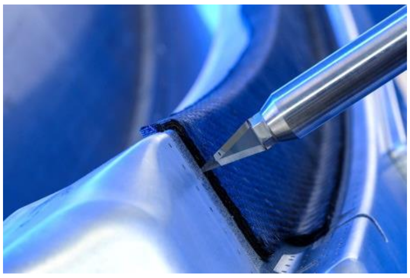
- *Successful demonstration of a simultaneous production of two different frame geometries with one automated production line*
- *Fully automated net-shape preforming of 9 frame pairs, each have a length of about 1m*
- *Development of multifunctional preforming tools and a new binder activation method*
- *Successful net-shape manufacturing with high and reproducible preform quality*
- *Successful statistical prediction of process induced distortions to achievement of required part tolerances*
- *Tool design taking into account process induced distortions*
- *Successful correlation of part geometry and manufacturing simulation*

EVo facility – fully automated RTM production line



Automated net-shape preforming process

Preform processing: ply, oversized preform, net-shape preform, cured part



Preform trimming to net-shape geometry by ultrasonic knife

Fully automated net-shape preforming process

The automated process consists of the sub-processes ply preparation, robotic action of picking and draping of plies, local binder activation, consolidation and preform trimming to net-shape.

Fully automated preforming

Individual plies of woven carbon fabrics get trimmed on a cutter and handled by an array of vacuum grippers. The position of plies on a transition table is detected by digital image correlation. After preparation, the cut ply is forwarded towards the draping robot. The segmented draping gripper collects the ply from the table by airflow and drapes it into its three dimensional shape over a vacuum assisted multifunctional tool. After some plies are draped they will be locally fixed to each other by activating the binder through electrical resistance heating. After draping of the final ply, an infrared heated membrane press will activate the binder globally and consolidate the preform into a stiffer state.

Net-shape preforming

The DLR approach is to eliminate post processing such as edge sealing and milling effort through net-shape trimming of the preform. Tool abrasion can be minimized due to waiving the grinding of a cured composite part, microfractures can be avoided and a more robust injection can be realized because the preform fits in the mold cavity more precisely. Additionally, a pre running of the resin around the preform edges can be avoided, having a lower risk of dry spots.

Probabilistic manufacturing process simulation

After manufacturing of CFRP parts, their final geometries vary from their design shapes, even in case of adapted tool designs. Such behavior is considered within numerical process simulations with respect to statistical uncertainties.

Consideration of uncertainties

The inherent scatter of composite material properties and uncertainties such as ordinary process variations are considered. The associated computational effort of numerical simulation is minimized by an efficient design of experiments. As a result numerical manufacturing process analyses provide part distortions due to exemplarily variances of temperature, thermal expansion coefficients or fibre volume ratio. This leads to design and manufacturing guidelines and provides the basis for an advanced online correction strategy within manufacturing.

Probabilistic tolerance prediction

Based on the distortion results, surrogate models are provided capturing uncertainties and variances of input parameters. The surrogate models allow efficient probabilistic investigation, taking into account distribution functions of relevant parameters. As a follow-up to the statistical prediction, an enhanced tooling design was derived to decrease rejects and rework.

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