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EVo: Net Shape RTM Production Line

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Abstract: EVo research platform is operated by the Center for Lightweight-Production-Technology of the German Aerospace Center in Stade. Its objective is technology demonstration of a fully automated RTM (Resin Transfer Molding) production line for composite parts in large quantities. Process steps include cutting and ply handling, draping, stacking, hot-forming, preform-trimming to net shape, resin injection, curing and demolding.

1 Introduction

In order to increase fuel efficiency, the development of light and innovative structural components in the aerospace industry is at all times a fundamental aim which is pushed by the use of fiber reinforced plastics. The demand for a holistic approach in the fields of composites also drives the German Aerospace Center's (DLR) Institute of Composite Structures and Adaptive Systems. The institute closed the gap between basic research and industrial application by opening the Center for Lightweight Production Technology (ZLP) in Stade and Augsburg in the year 2010. Its thematic priority is the development of optimized, reliable, productive and, hence, also cost effective production processes.
The focus is not only on production of large scale part geometries, but also on technologies that allow large production rates for smaller parts, such as typical frames of aircraft fuselages or automotive parts. Project EVo (Endkonturnahe Volumenbauteile – net shaped parts in large quantities) addressed this approach and launched an automated production line for RTM-parts.

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2 EVo - plant concept

In order to achieve a fully automated production of complex composite parts in high rates, an RTM (Resin Transfer Molding) process most suitable with respect to cycle times and cost. Before the actual RTM-process – mainly consisting of resin injection into a closed mold and curing at high temperatures – can take place, the so called preform has to be produced. Preforms are consolidated stacks of carbon fabrics that already roughly have the 3D shape of the finished part. State of the art is production of oversized parts that get machined, inspected and edge sealed as post processes.
EVo's approach is to eliminate post processing such as edge sealing and instead perform net shape trimming and quality inspection in line. Trimming preforms to net shape before injection has some advantages compared to post processing. Tool abrasion can be minimized due to waiving the grinding of a cured composite part, micro-fractures can be avoided and a more robust injection is realized because the preform fits in the mold's cavity more precisely, thereby a pre running of the resin around the preform's edges can be avoided, having a lower risk of dry spots.
For a precise trimming, though, it must be ensured that the preforms geometry is very close to that of the cured part, because e.g. in case of a further compaction inside the RTM-mold, the preform's edges will no longer be net shaped, but somewhat distorted. To prevent that, both draping and hotforming have to be performed very accurate. Since the target part has a curved profile geometry, all layers must be draped one by one, because otherwise wrinkles and ondulations might occur at the inner layers. EVo's in-situ-NDI detects defects in fiber angle orientation by an eddy current measurement and analyses the preform's net shape by means of a laser scan. The degree of shear deformation during draping and hotforming can be examined by an "Argus" optical measurement.

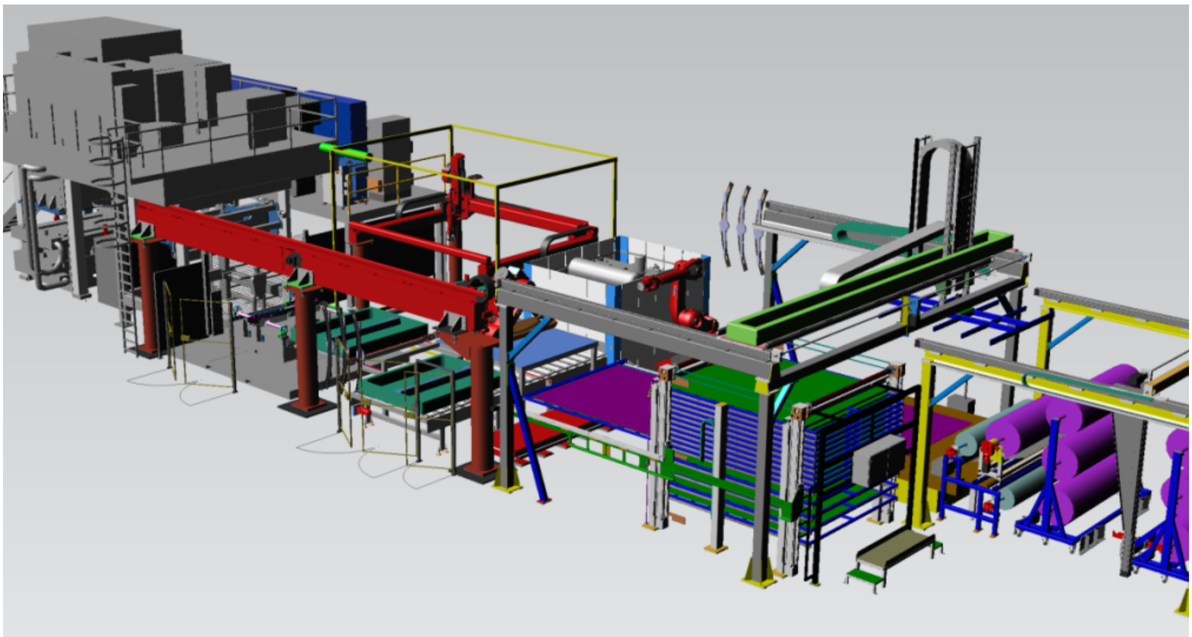

Figure 1: CAD-overview of EVo - research platform.

3 Sub processes

In the following the main sub processes and used machinery is described in main segments of ply preparation, preforming and RTM.

3.1 Ply preparation

NCF (non crimped fabrics) or woven carbon fabrics on rolls get inserted into the process line on magazine racks of 3 rolls each. Up to 6 different materials can be processed into one part. Material rolls get transferred towards an uncoiling unit and fed towards a cutter. All plies are cut out of the material and stored inside drawers. Thus it is not necessary to exchange rolls because of a part layup that contains different material in each layer. Individual plies then are picked out of the drawer-storage and placed on a transfer table.

Technical data:

- material storage with exchangeable magazines for 2x3 rolls of 100“ max. width
- automatic roll transfer to cutter
- Zünd-Cutter (3200mm x 2700mm) with variable tools for cutting, punching, grinding, plotting
- ply-storage with automated drawers, pick and place portal-robot

Figure 2: Cutter, storage and ply handling.

3.2 Preforming

EVo’s preforming segment contains the process steps draping, hot forming and trimming to net shape as well as preform handling and robotic quality inspection.

Figure 3: Preforming segment.

3.2.1 Pick and drape

Plies on the transfer table are detected by a camera that forwards the actual position on the table as an offset to the draping robots picking-program. The robot drapes the ply onto a vacuum assisted preforming-mold and stacks a sub preform. Once the sub preform stacking is completed, it is transferred to the consolidation-mold. A DLSR-camera linked to an "Argus"-optical measurement system evaluates the draping itself by analyzing the ply's deformation and is also mounted on the robots head. Single plies are locally fixed be electric binder activation.

Technical data draping robot:

- Reis- RV240-180 on linear axis
- VITRONIC - optical detection of ply positioning
- FASTcurve - offline programming
- flexible, active draping-gripper
- ARGUS - optical drape analysis
- local electric binder activation

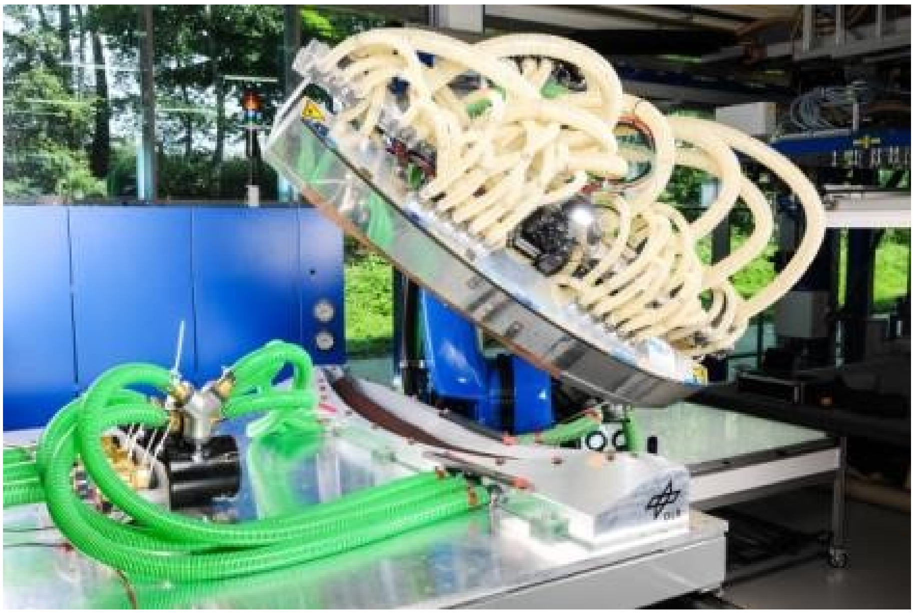

Figure 4: Robot with draping-gripper and mold.

3.2.2 Hot forming

Sub preforms as well as the complete preform are consolidated during the hotforming process. A membrane applies vacuum and additional air pressure to the preform while IR-rays melt the textile's binder particles. The result is a stiff preform.

Technical data hotforming:

- Bürkle Membrane Press
- hotforming / consolidation of subpreforms
- IR- heating
- 2m x 2,5 m
- vacuum and additionally 4 bar air pressure
- automatic membrane feeding

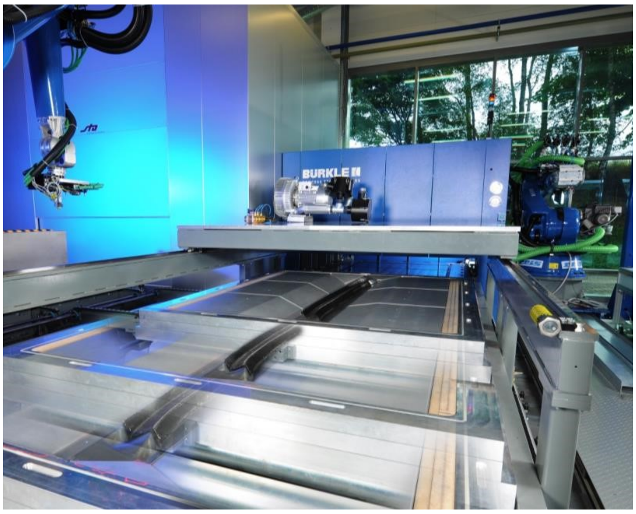

Figure 5: Hot forming.

3.2.3 Preform handling / NDI

As a quality gate, an eddy current measurement detects the local fiber angle orientation throughout 5-6 layers in depth. While measuring every sub preform after each hotforming step, the fiber orientation of every layer can be visualized. The preform afterwards is transferred to net shape trimming.

Technical Data Handling / NDI - Robot

- wall mounted Reis RVL130 on linear axis
- FASTcurve - offline programming
- Eddy-Cus - fibre angle measurement
- preforminsertion and partdemolding with vacuum grippers
- automatic cleaning and sealing of RTM-mold (coming soon)
- Schunk quick-change system

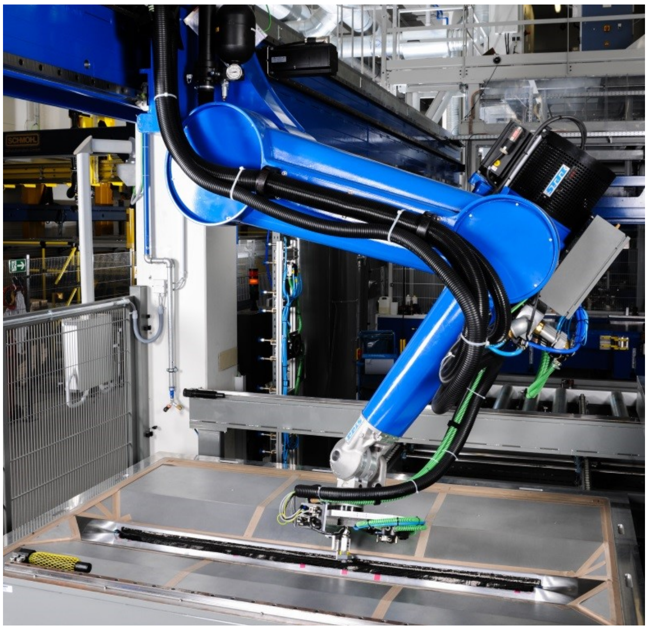

Figure 6: Eddy current measurement.

3.2.4 Trimming to net shape

A high accuracy portal robot equipped with an ultrasonic knife trims the preform's edges into net shape. After the residue is collected by a needle gripper, a laser scans the preform's topology to determine its thickness

Technical data trimming robot

- Reis portal robot RLP16
- FASTcurve – offline programming
- EM-Systeme – ultrasonic knife
- Renishaw – referencing system
- laser – topology scan
- laserready safety housing
- vacuum assisted mold

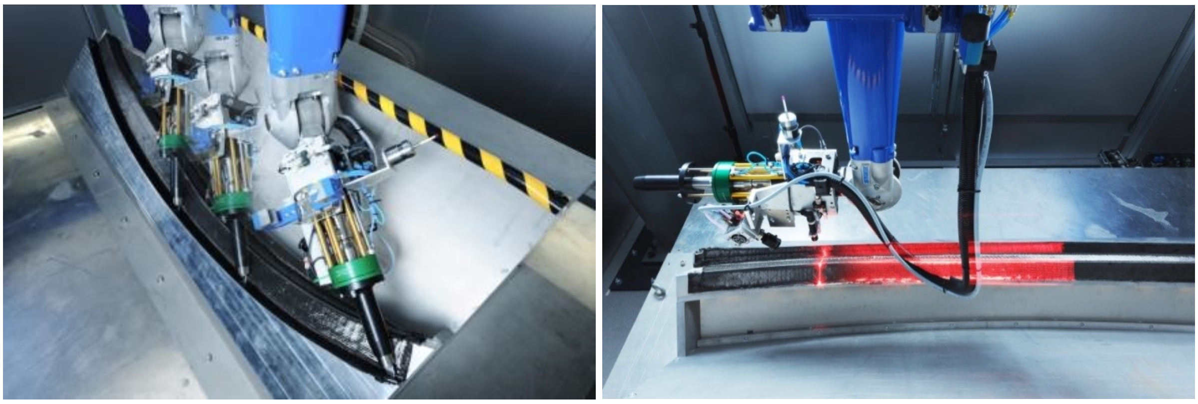

Figure 7: Net shape trimming (left) and laser scan (right).

3.3 RTM

RTM processes for aerospace applications usually mean cycle times of 4 hours and more. The mold must be prepared with seals and release agent, the preform has to be positioned, the mold is closed and heated up with a pre-defined ramp, then held for a given time before and during injection. After injection the mold is heated up to curing temperature and hours later cooled down under defined conditions. Both, heating times and curing time are the major bottlenecks for the achievable cycle times in an RTM-process. In order to cut these times to a minimum, EVo's RTM-section uses transportable core molds and fixed shell molds that contain heating circuits. Using transportable molds, an isothermal process can be realized. Outside the press, in a lifting station, the hot mold is opened and a robot prepares the mold and inserts the preform. It is then transferred into the press for injection. Once the resin has reached a certain degree of cure, the still closed mold is transported to a curing oven. Thus, the press occupancy time can be reduced from 4-5 hours to only 30-40 minutes.

Technical data RTM unit

- injection Unit (1K / 2K, 60 bar max. auto coupling)
- press (500t, 2m x 2,5m press table)
- water-based mold heating (200°C max)
- RTM mold (fixed shell-mold, movable core-mold)
- ultrasonic sensors for curing
- curing oven (pyrometer controlled, camera, 2 mold-slots)

Figure 8: RTM-section containing transport system, opening station, press and cure oven (f.l.t.r.).

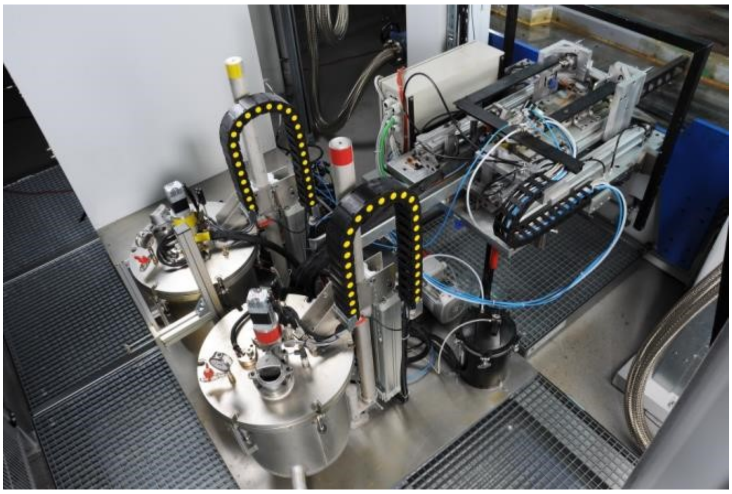

Figure 9: Two-component injection unit with automated docking system.

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