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BALU: Largest autoclave research facility in the world

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Abstract: Among the large-scale facilities operated at the Center for Lightweight-Production-Technology of the German Aerospace Center in Stade BALU is the world's largest research autoclave. With a loading length of 20m and a loading diameter of 5.8 m the main objective of the facility is the optimization of the curing process operated by components made of carbon fiber on an industrial scale. For this reason, a novel dynamic autoclaving control has been developed that is characterized by peripheral devices to expend the performance of the facility for differential applications, by sensing systems to detect the component state throughout the curing process and by a feedback system, which is capable to intervene into the running autoclave process.

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1 Introduction

For the manufacturing of advanced and large scale composites autoclave devices are preferable or even imperative to assure achieving the high demands of quality especially in the aviation industry. It is for this reason, the autoclave process is in urgent need of higher productivity, flexibility, low part costs and low scrap rate.
The current research deals with a new concept for autoclave process control which is currently developed. The concept is based on sensors obtaining quality relevant process parameters and a real time process simulation able to predict multiple scenarios of different control strategies. The so called MASTERBOX is the center piece of this new process control concept. It serves as interface between sensors including data acquisition, the process simulation and the real autoclave and takes decisions for the process control based on sensor data, simulation results and data bases. This intelligent process control will be able to react to process and product deviations leading to an enormous reduction of scrap parts. Also as the process is controlled directly in function of the product's quality development, the process time can be reduced dramatically. Due to the fact that the quality assurance is performed online during the process, the inline or offline part inspection could be reduced as well.

2 BALU - The research autoclave

The basis for the specification of the required parameters of BALU is based on current and future manufacturing tasks. Regarding these tasks the research autoclave has the following dimensions and operating parameters:

- Loading length, diameters, weight: 20m, 5.8m, max. 100t of invar (FeNi36)
- Power requirements: 3.8MW
- Temperature and pressure range: 420°C, 10 bar

Figure 1: BALU - The research autoclave.

For the manufacture of fiber composite components in autoclaves a pressure up to 10bar are needed. The appropriate medium is provided with the help of various system components. This is due to the integration of a plant for generating nitrogen in a compressed air system. There are two reservoir pressure containers available for the inert gas supply to the autoclave with a capacity of 200 m^3.The pressure inside the containers of 32 bar allows a total volume of 12800 m^3 nitrogen.

Figure 2: Reservoir pressure containers.

3 BALU - Infusion plant, quality assured sensing systems and simulation

Two-component mixing and metering unit for infusion processes

- Automatic mixing, metering and degassing of epoxy resins (e.g. Hexcel RTM6-2)
- Resin pressure up to 10bar
- Resin output up to 10 ltr./min
- Progressive infusionprocess even during automatic refilling
- Direct infusion process possible

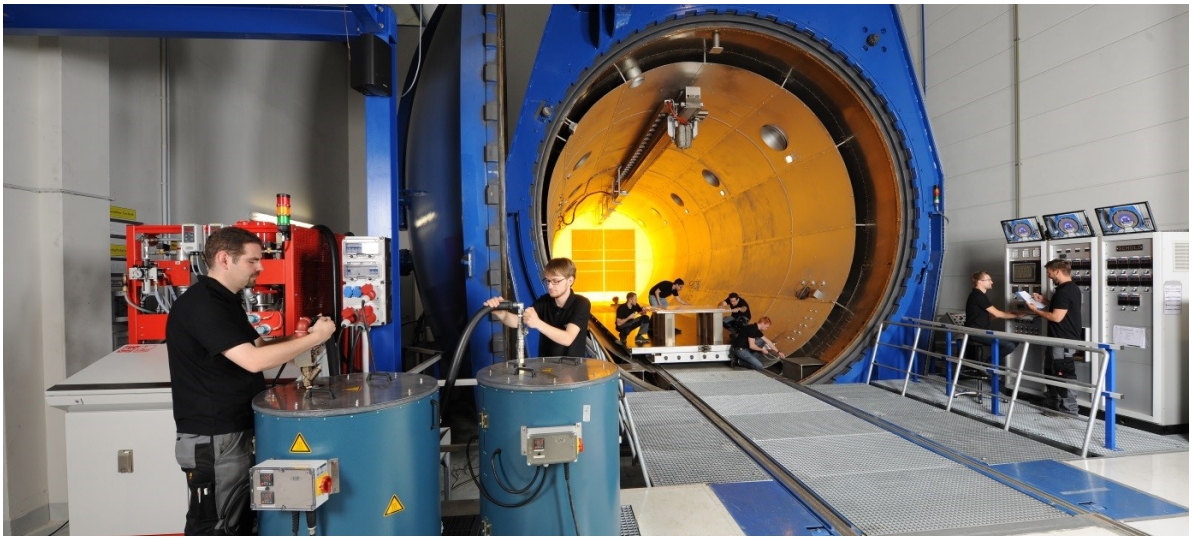

Figure 3: Infusion plant (left).

Thermography system inside autoclave

- Components temperature- and pressure-resistant (up to 250°C and 10bar)
- Pressure vessel with optical sensors and integrated water cooling system
- Completely integrated in autoclave system
- Linear drive system with total stroke of 18m
- Max. speed of 12cm/s

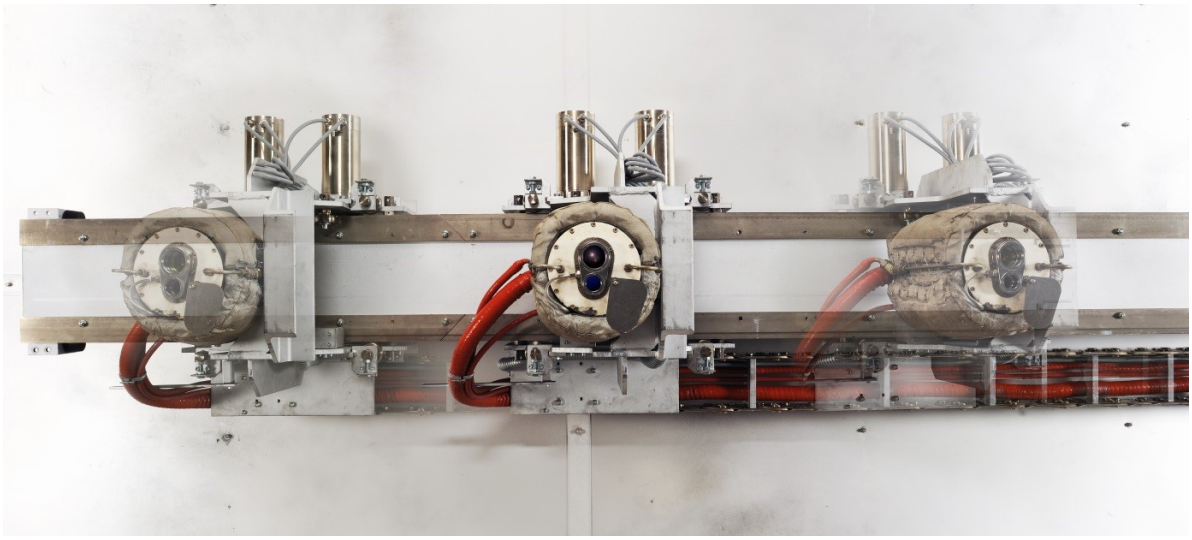

Figure 4: Thermography system inside the autoclave.

Other sensing systems

- Ultrasonic and dielectric measuring systems to monitor the curing process (resin flow, laminate thickness)
- Thermographic system for global temperature measurement, leakage detection in vacuum housings etc.
- Resin flow and mixing ration measurement in infusion processes with special and optical sensing systems

Figure 5: Piezoceramic sensing systems for cure monitoring.

CFD and curing simulation (virtual autoclave)

- Optimization of autoclave processing and loading conditions
- Early detection of process deviations
- Optimization of the autoclave aero-thermodynamics

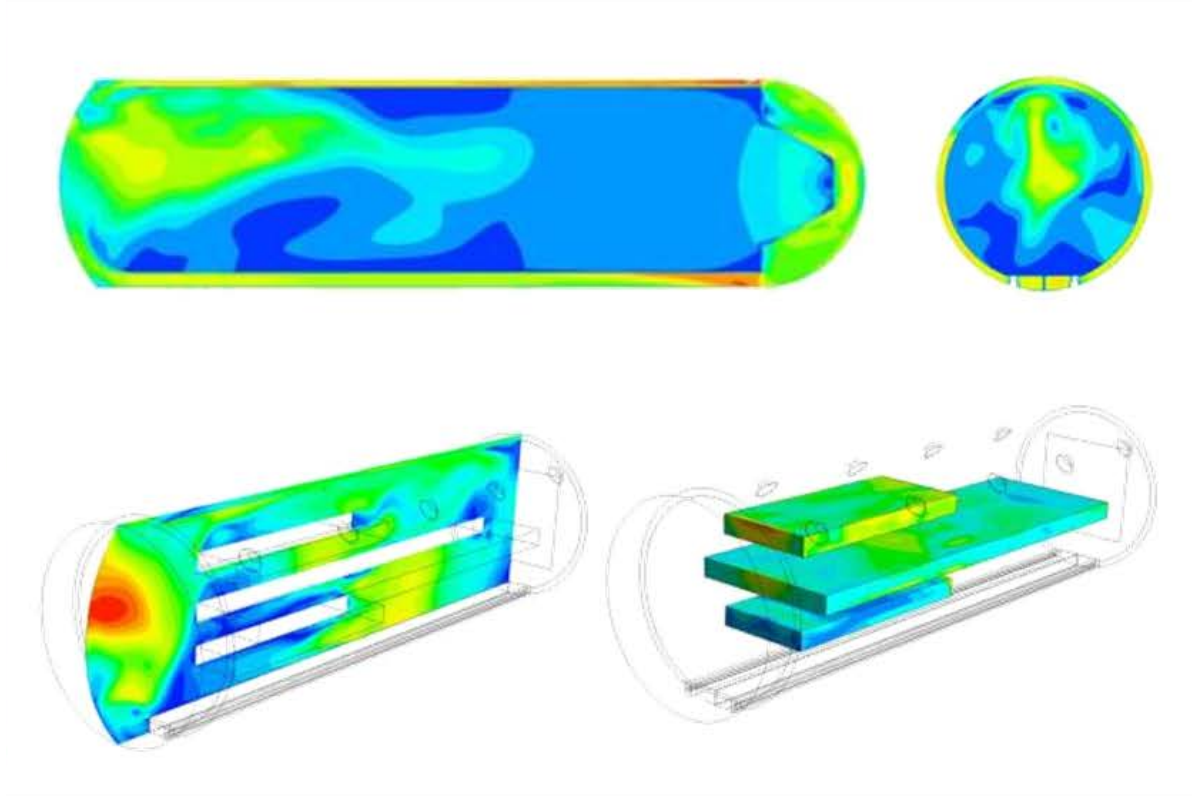

Figure 6: Virtual Autoclave - CFD and curing simulaiton.

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