Thermoplastic Composites Conference

Industrializing thermoplastic winding and Continuous Compression Molding

Addressing higher lot sizes via laser-assisted tape winding and continuous compression molding

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AVANCO GmbH

ACMA American Composites Manufacturers Association

AVANCO

people. innovation. success.

- Internationally operating composite solution provider
- Holding for the strong brands DYNEXA, INOMETA und XELIS
- Shared Services for the group (IT, HR, finances)
- Total of 315 employees

INOMETA

Thermoplastic Tape Winding

Laser-assisted tape winding for one-step out of autoclave processing

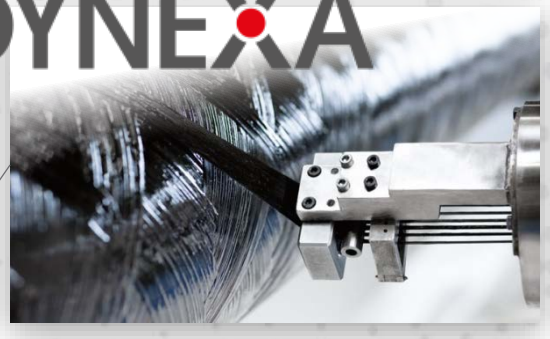
Functional Surfaces

Anti corrosion surface treatment and other functional surfaces for tubular applications

Rollers

High end composite and aluminium rollers for the paper, converting, printing and packaging industry

DYNEXA



Filament Winding

Thermoset filament winding of glass- and carbon fiber tubulars of up to 11 m in length

XELIS

Continuous Compression Moulding

Complex thermoplastic composite profiles and stamp-formed parts for aviation and industrial applications

High Expectations

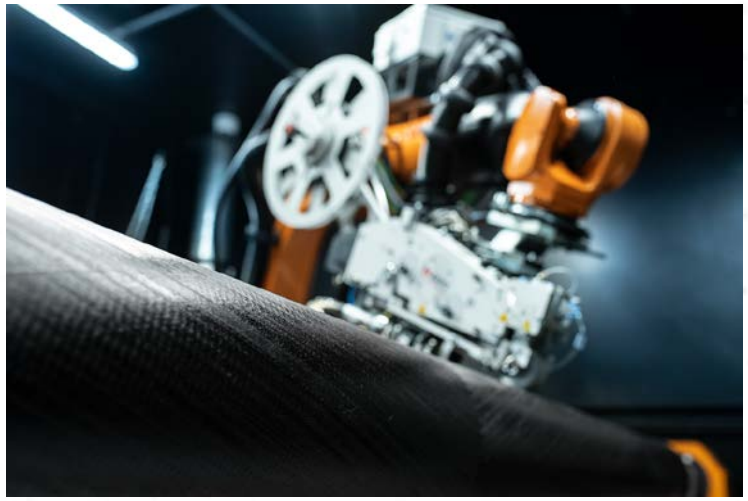
Demand for TPC is increasing but….

Challenges such as

- Low knowledge of customers
- Supply chain immatureness
- Long development cycle times
- Manufacturing issues (spring in effect)
- Missing process data monitoring

slow down implementation of serial programs

The AVANCO Group tackles some of these topics to create more confidence for serial programs



Laser assisted tape winding

Reducing time to market – Process automation - Increasing placement speeds

Laser assisted tape winding
Reducing time to market & trust-building

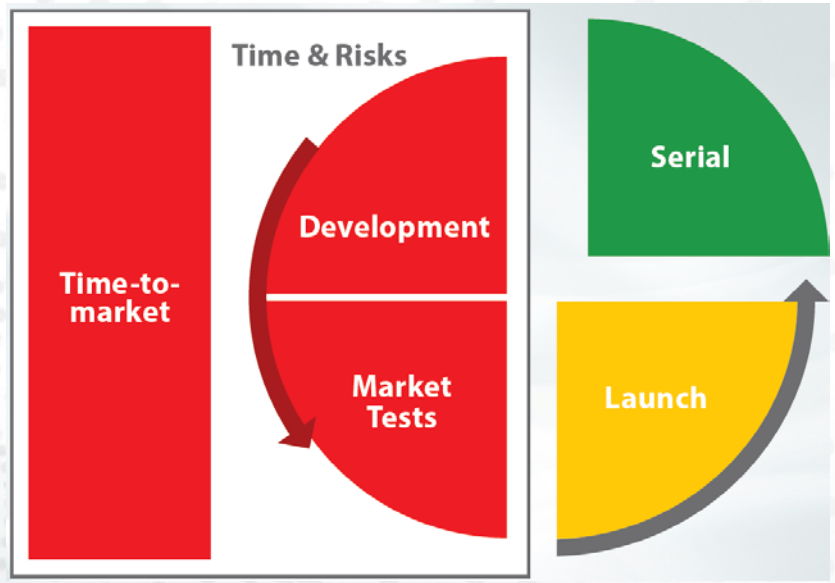
Thermoplastic composites are a relatively new field for a wide range of customers in industrial applications. Thus, providing reliable solutions, robust processes and short development times is necessary.

Status quo

- Most customers have a working solution (e.g. thermoset or metallic) but are curious which advantages thermoplastic have to offer
- Limited material know-how and rare development time on the customer side are common inhibitors

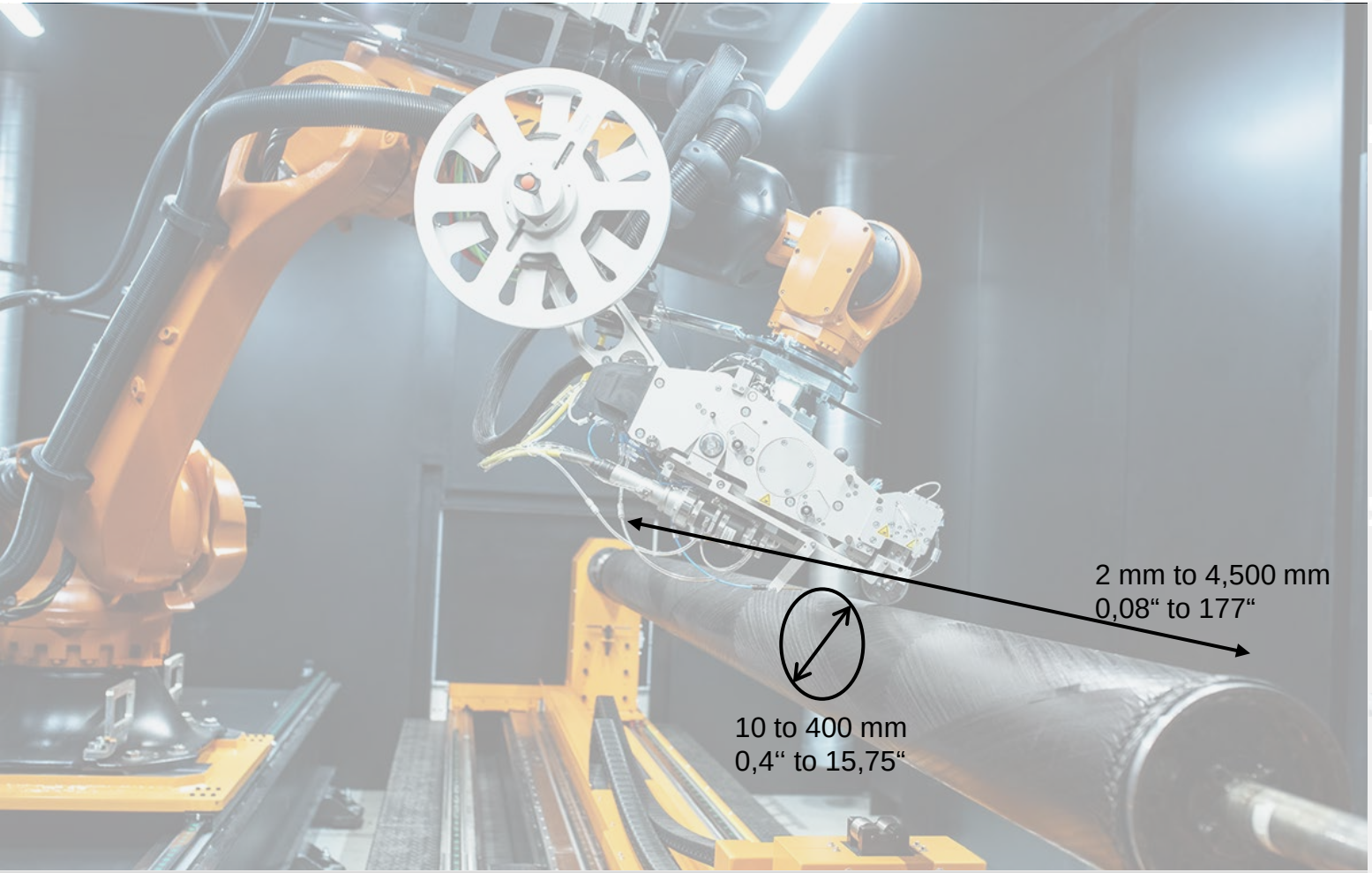
Our task

- Providing reliable material and process data to support the trust building process and incentivize the customer to use thermoplastics
- Characterizing process based influences on key quality parameters such as crystallinity, void content or mechanical properties
- Comprehensibly showing which economic benefits thermoplastics can offer despite an initially high material price



Laser assisted tape winding

Application categories & necessity for industrialization



Production Capabilities

Applications	High Volume	Specialties	Functionalization	Hydrogen

High Volume applications

e.g. Rotor Sleeves / Rotor Cans

+ minimum cycle times
+ thin shell improves drive efficiency

Specialties

e.g. Pipes / Bearings / Downhole products

+ good chem. and temp. resistance
+ advantageous abrasion behavior

Functionalization

e.g. Hybrid IM / Thermoforming

+ material bonding / shapeability
+ process integration with short cycle times

Hydrogen

e.g. Pressure vessels / Storage modules

+ one step process via in-situ consolidation
+ sustainable material matching the liner

Laser assisted tape winding
Machine concept & automation aspects

New process routes are needed to address markets beyond aerospace and to meet expectations for increasing volumes and cost efficiency in industrial applications (e.g. rotor sleeves, rotor cans, …)

Rotor sleeve – product features and material requirements
+ thin shell improves drive efficiency (0.3 mm - 1 mm; 0,01” - 0,04”)
+ high temperature requirements (>120 °C, oftentimes 150 °C peak)
+ sometimes higher grade carbon or glass fibers required

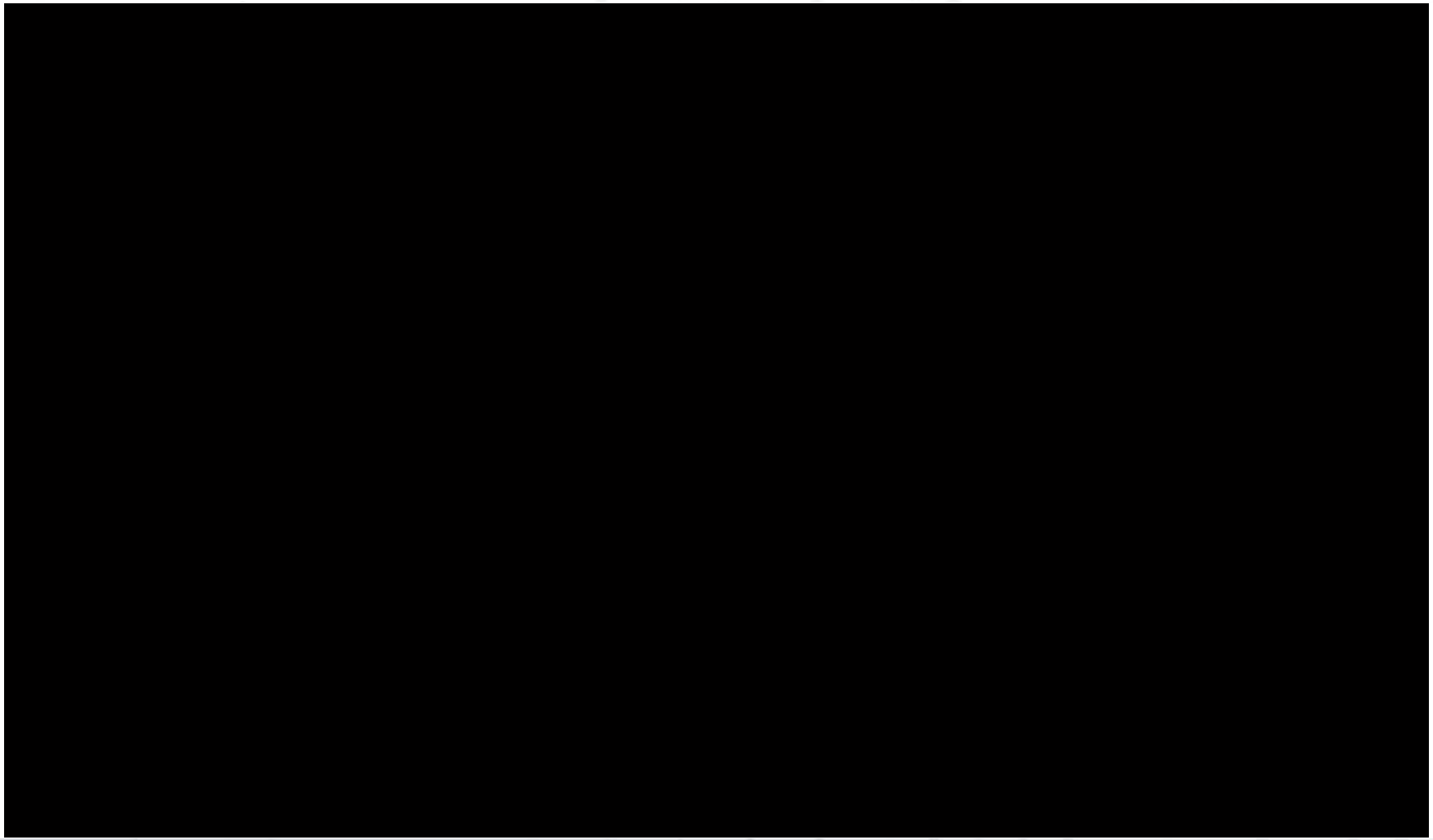
Customers are looking for a cost effective solution to address increasing lot sizes (10.000 – 1.000.000)

Machine and processing concept
- Reducing non-productive times is key
- Cutting and handling of thin-walled parts is challenging
- Tracking material and quality data is needed

AVANCO is solving this with an innovative machine concept by AFPT using variothermal mandrels and integrated cutting technology
(more information at ACMA Thermoplastic Composites Conference - Lucas Ciccarelli - March 24th 8:45 am)

Laser assisted tape winding

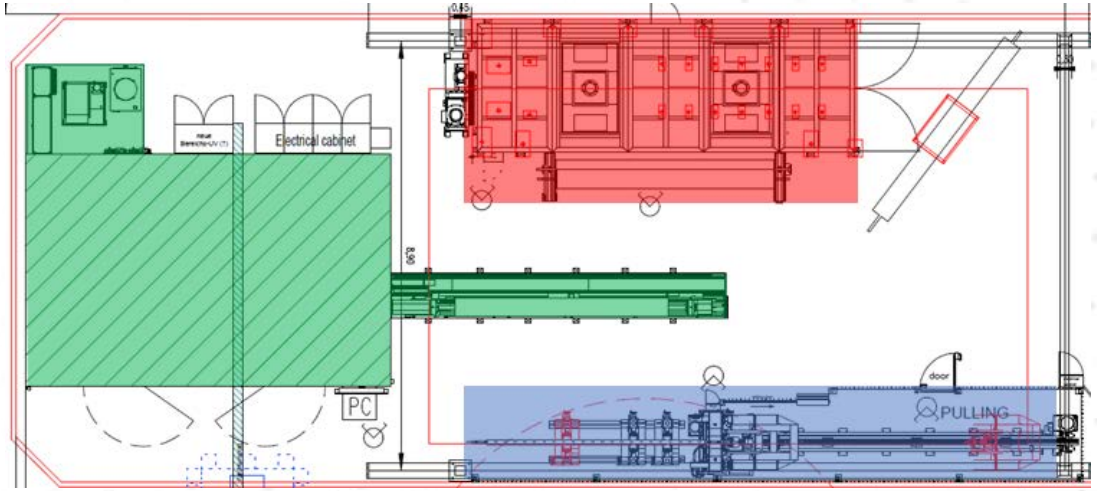
Machine concept & automation aspects



Laser assisted tape winding

Machine concept & automation aspects

Increasing productivity is also a key challenge for thicker walled parts, when the previously shown automation concept reaches its limits. Hence, the conventional winding approach needs to evolve.



Winding Mandrel heating Part extraction

Additional winding axis

1. Two complete winding axis increase productivity significantly
2. Axis can slide out of the laser housing for pre- and post-processing activities

Paternoster oven

1. Preheating of up to eight mandrels for subsequent winding processes
2. Variable oven width for different mandrel sizes and automated unloading kinematic

Additional industrialization aspects

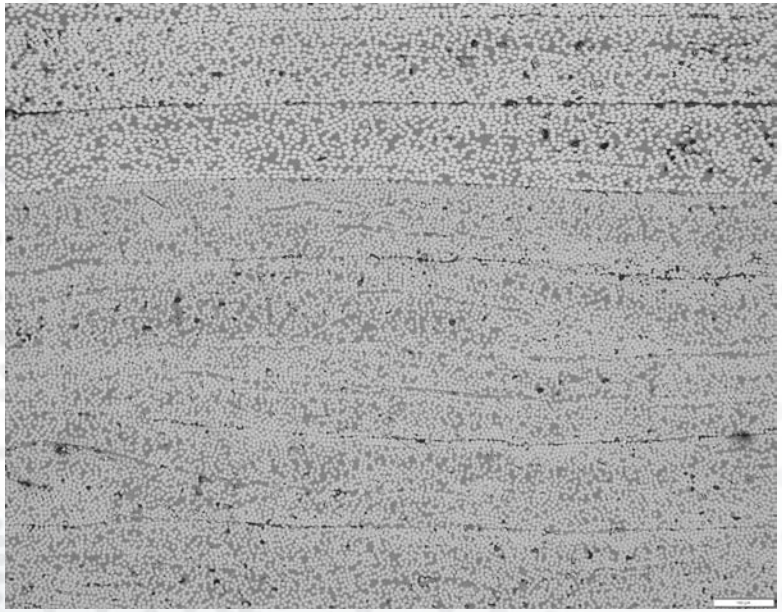
- Integrated quality data recording and evaluation
- Automatic exclusion of defined scrap areas (e.g. turning zone) from the resulting data cloud
- Customer individual reports of quality and material data for tracebility and poof of process robustness

Laser assisted tape winding

Consequent process and material analysis – PPS and PEEK

Following up on providing reliable material and process data AVANCO teamed up with Teijin to extensively analyze their carbon fiber PPS, LM-PAEK and PEEK tapes using among others microscopic cross-sections and thermal analysis via DSC.

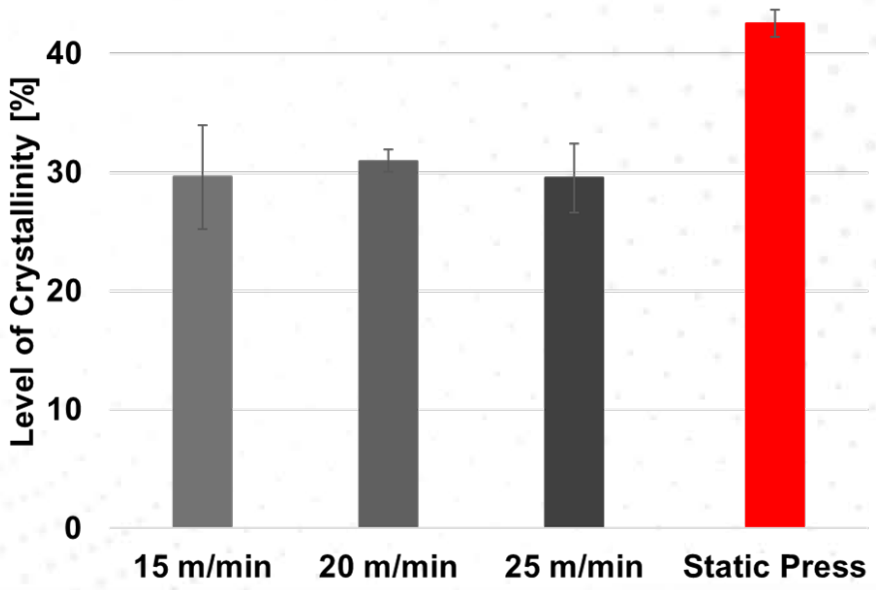
Increasing placement speed
from 12 to 25 m/min for
various winding angles

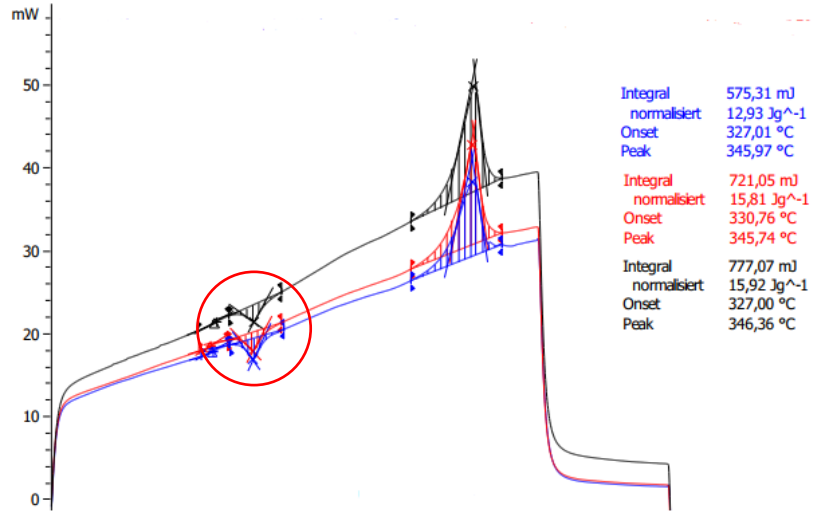


- Successful definition of robust process parameters for joint partner projects
- Fine tuning of the parameters in done within the customer projects but the preliminary work saves valuable development time

Laser assisted tape winding

Consequent process and material analysis – PPS and PEEK





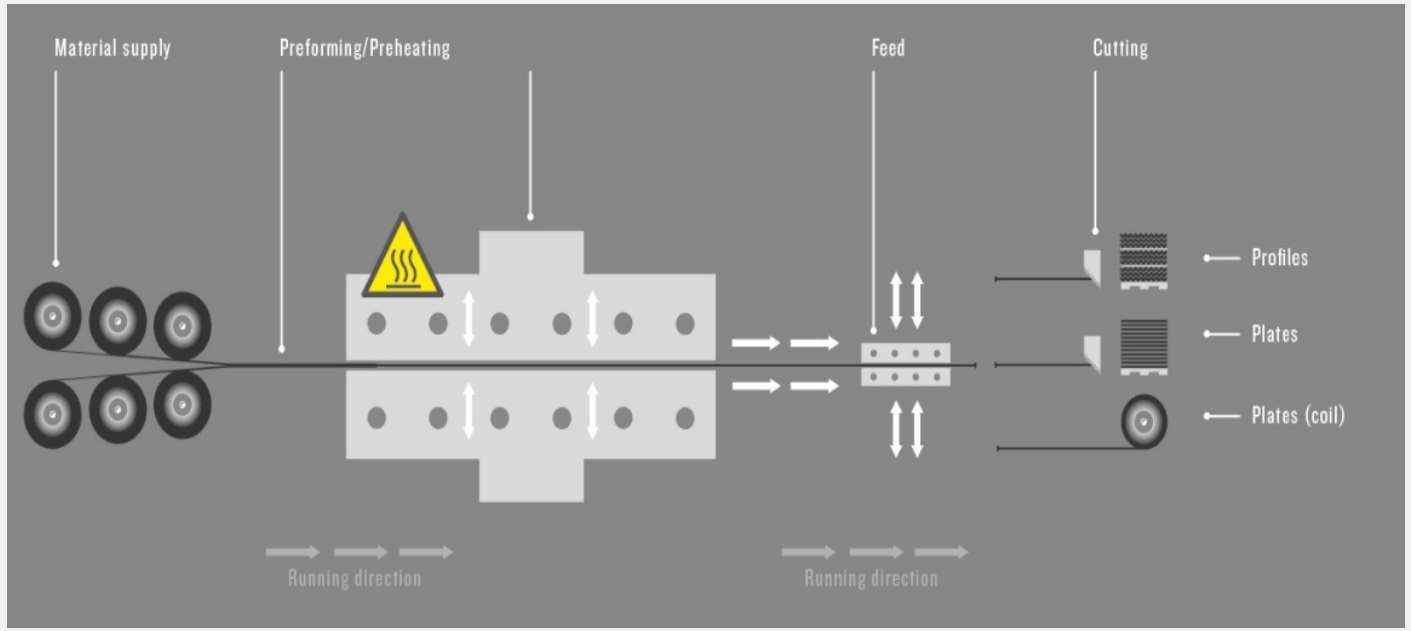
Cold crystallization peak at 15 m/min: -2,04 J/g

- No visible decrease in level of crystallinity from 15 m/min up to 25 m/min
- Due to measurable appearance of cold crystallization, level of crystallinity lower than static press consolidation
- Further trials to evaluate minimum placement speed / maximum crystallinity levels

Continuous Compression Molding

Process development – Mold technology – Highlight projects

Continuous Compression Molding

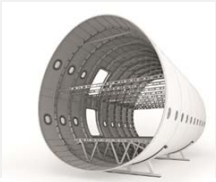


Charecteristics

High Volume | Shapes | Quality

High Volume applications

- Stringers for fuselages
- Stiffeners for battery cases

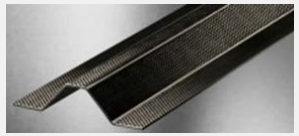


High fabrication speeds

+ T-profile, 40 plies : 12 m/h
+ Closed U-profile, 9 plies: up to 40 m/h

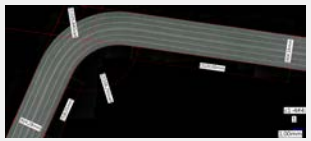
Various shapes

+ Established for laminate production
+ Applicable for profiles such as Ω, T I Beams



Quality

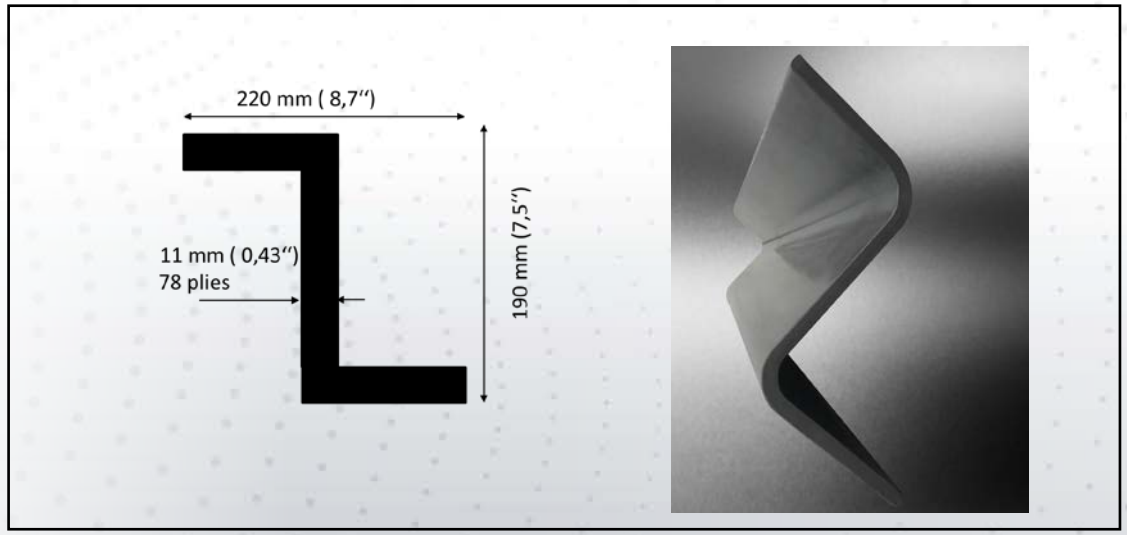
+ Dimensional accuracy
+ Low porosity < 0,5%
+ „Aircraft OEM approved“

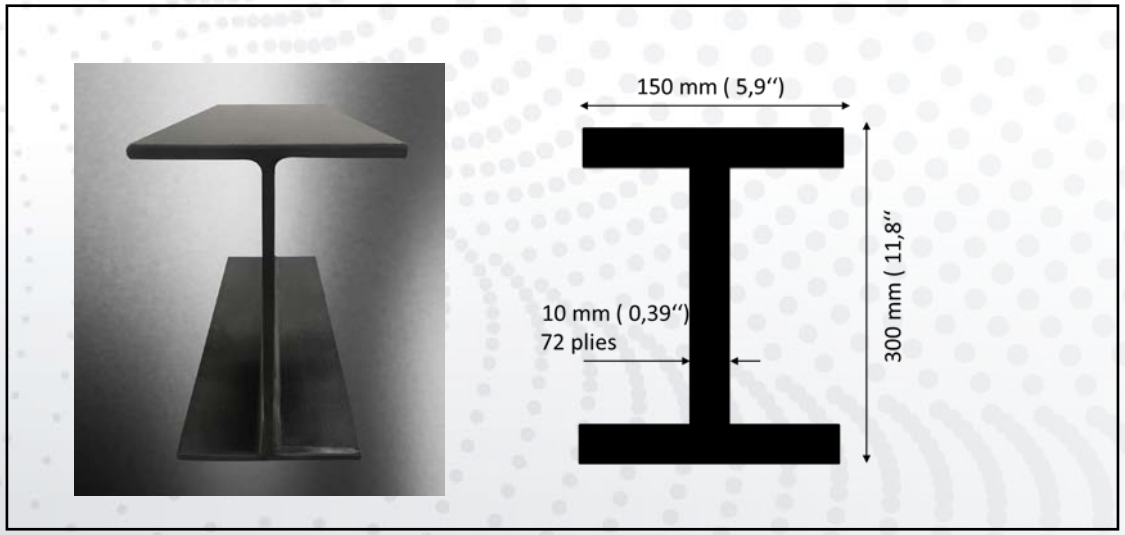


Examples

Profiles which have been realized

Profile CCM machines designed to fabricate the complex profiles used to make the C, T, H, J and U beams





Conquering serial programs
What does it take ?

Serial programs require robust processes to be supported by

- Material (supply chain)
- CCM machine
- Press tooling
- Process parameter

AVANCO competence

- Tooling design
- Process development
- Serial product implementation
- Manufacturing under repeatable conditions

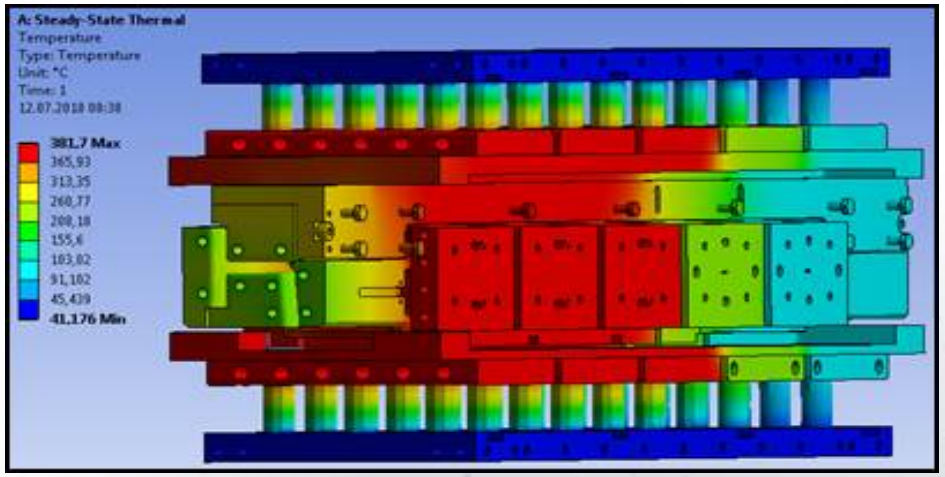
CCM tooling
CCM's heart

- Cavity is divided into five zones.
- First 3 zones are heating zones (example PEKK: temperatures range from 360-400°C)
- 4th and 5th zone: temperatures start to drop to begin the cooling and promote crystallinity

→ laminate exits the die, $T_{laminate}$ is below Tg (example PEKK, < 159°C)

- Key for semi-crystalline TPC:

"make sure the material spends adequate time in the crystallization zone (4th zone) to reach sufficient mechanical properties



Challenges

- Each profile requires its own tool, each tool is different, each tool is complex
- Achievement of complex final profile geometries
- Due to the movement, material experiences intensive temperature cycle (high heating /cooling rates)

→ Spring-in effects/torsion are caused by material behaviour (shrinkage of polymers, ply lay-up)

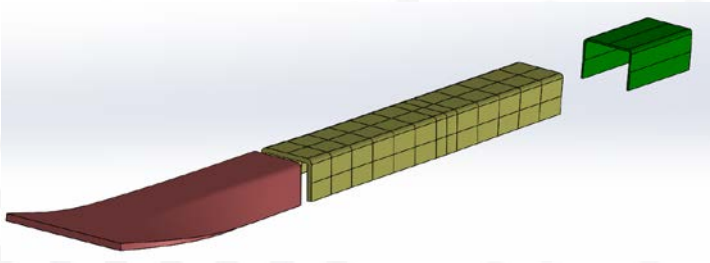
CCM tooling
AVANCO approach

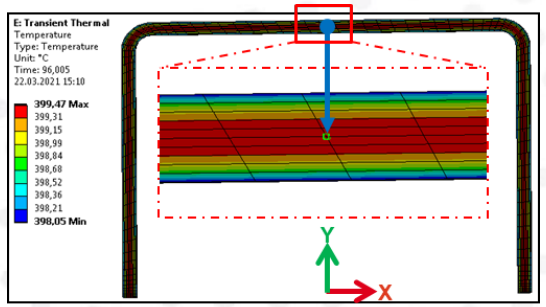
- Concept
  - Based on experiences and material behaviour
- Modeling profile evolution
- Tool pre-design
- Theoretical process model (temperature)
- Determination of temperature profile @ material level
- Simulation of material behavior (spring in effects)
  - Calculations by means of Solidwork/ Ansys
    - CAD Model
    - Ply lay-up
    - Material properties
    - Process parameter set-up
- Thermal compensation calculations

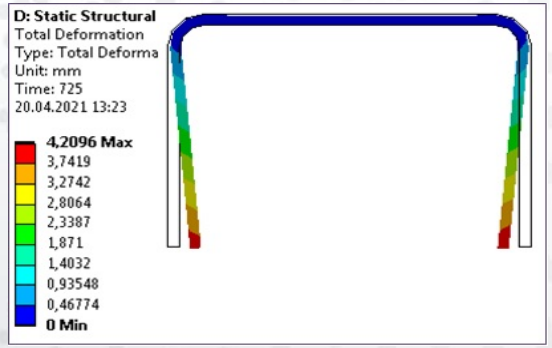
→ Enable desired tooling shape to maintain dimension and pressure

- Parameterization of tool design

→ Linkage to material and thermal compensation calculation to model







Achievements & Goals
Building up on recent achievements

- AVANCO supported a customer‘s project for the development of 8 tooling in a period of 10 month
- 13m (42 feet) long profiles were manufactured with a weight of 150 kg (330 lbs) per profile
- Tool commissioning / prototype production was performed in 2-3 days

[redacted] tragen ein Profil aus dem Faserverbundstoff. Der 13 Meter lange Träger wiegt 150 Kilogramm. »Aus Stahl würde er 1,25 Tonnen wiegen«, sagt [redacted]

Future improvements

- Digital process chain with process models based on real process data

→ Individual process steps to be linked in the sense of data transfer

→ Increase traceability of the data in the case of possible deviations

- Complete automation and data consistency in the sense of "Industry 4.0“

→ Increase continuous quality / Reduce testing effort for quality control

AVANCO Composites – Summary & Outlook

- Thermoplastic composite technologies identified as key technologies
  - Reduce time to market
  - Increase process robustness (data basis, simulations)

- Further developments
  - Increase process automation
  - Implement digitalization