Individualized mass production of tailored thermoplastic composite blanks

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Agenda

1. Introduction

2. Manufacturing of tailored thermoplastic composite blanks

3. Possible applications and summary
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Introduction of Fraunhofer IPT
Production Technology in Aachen

Founded in 1870
- 38,000 students, 5,750 graduates
- 9 faculties, 260 institutes
- 4,500 researchers, 496 professors
- € 788 million Budget
  (thereof € 315 million external funding)

Faculty of Mechanical Engineering
- 10,980 students, 1980 new immatriculations
- 863 graduates, 155 professors
- 1,050 researchers, 61 professors
- € 272 million budget,
  thereof € 77 million external funding via Fraunhofer Institutes and others

Focus Production Technology
- Laboratory for Machine Tools and Production Engineering
  total budget € 49 million
  1200 employees*
- Fraunhofer Institute for Production Technology IPT
  *) thereof ca. 50% students

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Introduction of Fraunhofer IPT
Lightweight Production Technology – Technological Competences

Technologies & Cross Section Processes

- Handling
- Tooling Technology
- Aluminum/Steel-Welding
- Cutting
- Pull-Winding Pulltrusion
- Fibre- & Tapeplacement

Technology Management
Risk Management & Life-Cycle-Assessment
Quality Management und Production Metrology
CAx-System Integration

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Advantages of unidirectional fibers
Advantages due to the use of unidirectional non woven fiber-reinforcement

Short fibers
- Length: 0.1 mm – 1 mm
- Fiber type: Short fibers

Long fibers
- Length: 1 mm – 50 mm
- Fiber type: Long fibers

Continuous Fibers*
(Endless filaments)

Woven Fabric
Non-woven Fabric

Critical fiber kinking
Critical effective fiber

Properties of fiber-reinforced plastic components depend on:
- Fiber and matrix materials
- Orientation of the fibers
- Fiber volume content

Basic rules for component design:
- High fiber volume content
- Fibers orientated in direction of the loads

Fully consolidated unidirectional (UD) layers

Stacking Manufacturing Process

schematic real

Increased performance of unidirectional fiber-reinforced compared to woven fabric reinforced components:
- Young’s modulus: + 18,4%
- Strength: + 38,6%
- Weight: - 50%
- Scrap rate: - 50% up to - 75%
- Component costs: - 30%

*Length only limited by component dimensions

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State of the art
Manufacturing of thermoplastic composite blanks

Continuous production
- Double belt press
  - Impregnation of textile fabrics with polymer matrix
- High volume production
- Limited flexibility
  - Constant blank thickness
  - Fixed fiber orientation, e.g. [0°/90°]

Tape placement
- Laser assisted in-situ consolidation of UD-tapes
- Limited productivity (robot based systems)
- High flexibility
  - Selective reinforcement possible
  - Unlimited fibre orientations possible [-90° .... 90 °]
  - Laser radiation allows for swift process control

Tailored thermoplastic composite blanks
- In-situ consolidation of unidirectional tapes using IR
- High volume production
  - Fixed tape laying head with compression belt system
  - Moving mould / rotating nc-table
- High flexibility
  - Selective reinforcement and unlimited fibre orientations possible

Sources: Hymmen, Bond Laminates, Fraunhofer IPT
Manufacturing of tailored thermoplastic composite blanks
Novel IR-based tape placement system

Process description
- Placement of unidirectional tapes on a rotary table
- In-situ consolidation using an infrared heater in combination with a consolidation roller
- Waste minimization using a “Cut and Add on the Fly” process
- Free choice of the direction of fibers enables load optimization

System properties
- Mold diameter: 1.2 m
- Max. tape width: 100 mm
  - Currently: 3 x 25 mm
- Process speeds up to 1 m/s
  - Currently: 200 mm/s for PA6/CF
High volume production of thermoplastic composite blanks
Tape placement with \textit{Cut on the Fly} and in-situ consolidation

\begin{itemize}
  \item Cutting system
    \begin{itemize}
      \item Pneumatic actuated knife
      \item Fast acting pneumatic valves (2 ms)
      \item Cutting time: 16 ms
    \end{itemize}
  \item \textit{Cut on the fly process}
    \begin{itemize}
      \item Cutting without stopping the tape
        \begin{itemize}
          \item Waste optimization
        \end{itemize}
      \item Achieved tolerances in test rig
        \begin{itemize}
          \item 44 mm/s tape speed: 0.8 mm
          \item 238 mm/s tape speed: 1.3 mm
        \end{itemize}
      \item Achieved tolerances during blank production:
        \begin{itemize}
          \item Ca. 1 mm between two layers
          \item Ca. 2.2 mm over blank thickness
        \end{itemize}
    \end{itemize}
  \item Main challenge
    \begin{itemize}
      \item Achieving good consolidation close to the edge of composite blank
    \end{itemize}
\end{itemize}

\begin{table}[h]
\begin{tabular}{|c|c|c|}
\hline
Tape feed & 400 ms & 400 ms \\
\hline
Tape speed: & 44 mm/s & 238 mm/s \\
\hline
Tape length: & 95 mm & 18 mm \\
\hline
Number of samples n & 20 & 8 \\
\hline
Mean tolerances & +0.44 mm & +1.5 mm \\
\hline
Std. & 0.23 mm & 0.43 mm \\
\hline
Min. tolerance & 0.1 mm & 0.6 mm \\
\hline
Max. tolerances & 0.9 mm & 1.9 mm \\
\hline
Tolerance zone & 0.8 mm & 1.3 mm \\
\hline
\end{tabular}
\end{table}
High volume production of thermoplastic composite blanks
IR assisted tape laying with Cut and Add on the Fly and in-situ consolidation

**Conventional Process**
- Process speed: 150 mm/s
- Good consolidation achieved over continuous tape placement process

**Cut and Add on the Fly**
- Process speed: 150 mm/s
- Accurate cut on the fly
- Good consolidation achieved even close to the cut edge
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High volume production of thermoplastic composite blanks

Process chain for high volume production of thermoplastic composite products

- High productivity
- High flexibility
- No post consolidation necessary
- High scalability
  - Multiple number of tapes possible
  - General principle allows to lay up and consolidate a 500 x 500 mm layer within 2 seconds
High volume production of tailored thermoplastic composite blanks
Process chain for high volume production of thermoplastic composite products

Integrated process chain for resource efficient manufacturing of thermoplastic composite structures

- Automated production of tailored thermoplastic composite blanks using UD-Tapes
  - Waste optimization
  - Load optimization
- Subsequent multifunctional thermoforming
  - Integration of inserts during forming
- On-line process monitoring
  - Air-coupled ultrasonic measurement
  - 3D-scanning using adaptive projection
- Adaptive gripper systems for handling of molten UD-composites
Summary
High volume production of tape-based thermoplastic composite blanks

- Combination of the flexibility of tape placement with productivity of double belt systems
- IR-based system reduces investment costs compared to laser-based machines
- Process results for PA6/CF:
  - Speed of 200 mm/s
  - One layer in < 1 min (500x500 mm)
- Upscaling possible

Load optimized fiber orientation
Thermoformed tape based shell structure
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