Facts and Figures

F\textsuperscript{2}-Composite\textsuperscript{®} and F\textsuperscript{2}-Compositor\textsuperscript{®}

Short Version

Dr.-Ing. Markus Steeg
What is thermoplastic tape placement?

Tape placement is an automated, orientation variable, and position variable lay up process for unidirectional fiber reinforced tapes on molds. (Beresheim)

Tapes are welded on top of each other with a heating source. The preform is solid and can be transported and stored automatically.
Where to use thermoplastic tape placement?
Automotive scenario

Where to use thermoplastic tape placement?
Aviation scenario

http://www.compositesworld.com/articles/thermoplastic-composites-clip-time-labor-on-small-but-crucial-parts
What is F²-Composite®?

- fiber placement technology
- thin film melting and joining
- drive technology
- CNC techniques
- synchronization
- net-shape contour simulation
- waste simulation

What is F²-Compositor®?

- miniaturization and parallelization
- highly customizable machine for fiber placement
- design follows customers’ needs
- degree of automation follows customers’ needs
- output follows customers’ needs
F²-Compositor® design freedom

- Tape placement, flexible tape width
  F²-Compositor dimension 4 m x 2.65m*

- Tape placement, tape winding and both together, material supply on board
  F²-Compositor LabCube dimension 1.9 m x 1.4 m

- Tape placement, fixed tape width, UD material supply on board
  F².5-Compositor dimension 5.2 m x 0.9 m

- Tape placement, flexible tape width
  F²-Compositor dimension 4 m x 2.65m*

- Tape placement, fixed tape width, material supply on board
  F²-Compositor LabCube dimension 0.9 m x 0.8 m

*Shown without housing and material supply
F²-Composite®, one process scenario for thermoplastic tapes is overmolding

- UD-material
- optional with organic sheet
- injection molding „edge sealing, surface finish, rips, and clips“
- thermoforming „shaping the preform“
- automated transport
- heating without any prior consolidation
- automated transport
- automated transport
- automated transport
- quality control
- www.micro-epsilon.de
- extract final product

F²-Compositor® “undercut”

no further consolidation no trimming
## Facts F²-Compositor®

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<th>Investment range</th>
<th>Tape laying rate</th>
<th>Tape width per application unit</th>
<th>Necessary power to produce a consolidated preform: Heating source + movement</th>
<th>Exposure time polymer above the melting point, to manufacture a consolidated preform for further IR-processing</th>
<th>Placement speed with precision</th>
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<th>Tested polymers without reinforcement</th>
<th>Tested carrier substrate</th>
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</table>
|                         | 85 k€ up to 1.5 m€ EXW, with documentation, without qualification effort* | 5 kg/h up to 725 kg/h or more | 5 mm up to 75 mm | 1.5 kW/h up to 25 kW/h | 0.025 s | 1-3 m/s | 20-50 m/s² | 10 m² up to 38 m² | PP, PE, PA, PA derivates, PPA, PPS, PEEK, PEKK, “prepreg”, … | PP, PE, et. al. | None, polymer, polymer film, FRPC, sandwich, foam, steel, aluminium, wood, concrete | Waste intended to be none with miniaturization and design options of the F2-Compositor® | Coupling several small F²-Compositor® to an assembly line, possible and reasonable to have no waste and a high laying rate | **("VP", "QP", URS, FS, DQ, FAT, SAT, IQ, OQ, PQ)**

* less than competition (factor of 2-15)

** difficult to compare

unknown

unknown

unknown

unknown

unknown

unknown

unknown

unknown

unknown
What is the difference?

• We do not buy robots, we built them!
• We have our own customized drives!
• We have a single control unit, covering all processes!
• We have a much cheaper heating source!
• We do not use a laser, causing secondary costs for safety equipment and safety education!
• We generate the polymer melt only in the joining zone, so we have an energy efficient heating process!
• We use an energy recovery system to store and release the motion energy, especially on short tracks!
• We do not have a huge overhead!
Summary short version

• Old technology, reloaded with less mass, new drive technology and enormous control power
• The F²-Compositor® should be faster and cheaper than most other technologies available
• You will see an efficiency increase with customized machine design
Thank you for your attention

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Facts and Figures

F$^2$-Composite® and F$^2$-Compositor®

Long Version

Dr.-Ing. Markus Steeg
Where to use tape placement?
Automotive scenario

What is thermoplastic tape placement?

Tape placement is an automated, orientation variable, and position variable lay up process for unidirectional fiber reinforced tapes on molds. (*Beresheim*)

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What is F²-Composite®?
What is F²-Compositor®?

• F²-Composite®
  - fiber placement technology
  - thin film melting and joining
  - drive technology
  - CNC techniques
  - synchronization
  - net-shape contour simulation
  - waste simulation

• F²-Compositor®
  - miniaturization and parallelization
  - highly customizable machine for fiber placement
  - design follows customers’ needs
  - degree of automation follows customers’ needs
  - output follows customers’ needs
- Staff knowledge base derived from the Institute for Composite Materials (IVW) in Kaiserslautern, Germany

- Experience in thermoplastic winding technology since 1992
  - Design and implementation of 1st application unit for thermoplastic tape placement in 1998
  - Intellectual property in several areas surrounding fiber-placement
  - Support on this topic of:
    - 5 PhD-thesis
    - > 25 student research projects
    - > 40 diploma, bachelor or master thesis
    - > 10 public research projects
    - > 30 industrial collaborations
  - Approximately 5 million € of public funding
  - Approximately 5 million € of industrial funding

- F²-design does not simply fall from sky
F²-Composite®, one process scenario for thermoplastic tapes is overmolding.

UD-material

automated preform lay-up F²-Compositor® “undercut”

automated transport

no further consolidation

no trimming

heating without any prior consolidation

thermoforming „shaping the preform“

automated transport

injection molding „edge sealing, surface finish, rips, and clips“

quality control

www.micro-epsilon.de

extract final product
Tape laying rate vs. waste

Estimated tape waste for contours:
- approximately 30%

- waste ↑
- power ↑
- tape width ↑
- tape thickness ↑
- investment ↑
- anisotropic intrinsic efficiency ↓

*strongly depending on tape width and shape of the contour
Market desires, our point of view

**accepted waste**

- ~ 30%
- ~ 4.5 €/kg GF-PP
- ~ 400 €/kg CF-PEEK

**desired laying rate**

- ~ 500 kg/h

**investment in fiber-placement**

- ~ 2000 k€

**price of tape**

- ~ 400 €/kg

**Is the branch willing to invest into material efficiency?**

- Main motivator for the machine design is waste!

**Is the branch willing to invest for output performance?**

- automotive
- sport and leisure
- oil & gas
- aviation
- building
Market desires

Is the branch willing to invest into material efficiency!

Main motivator for the machine design is waste!

~ 30%

heterogenous branch deliverables could **not** be answered with a rigid machine concept

price of tape

investment in fiber-placement

~ 2000 k€

Is the branch willing to invest for output performance!

*automotive* 🚗 *sport and leisure* 🏋️‍♂️ *oil & gas* 🏨 *aviation* ✈️

**accepted waste**

~ 4.5 €/kg for GF-PP

~ 450 €/kg for CF-PEEK

Desired laying rate ~ 500 kg/h

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F²-Compositor® design freedom

bidirectional fiber-placement

F²-Compositor®
within the scope of geometry and physics
F²-Compositor® design freedom

bidirectional fiber-placement

amount of dependent application units

F²-Compositor® within the scope of geometry and physics

ΔY = const.
F²-Compositor® design freedom

bidirectional fiber-placement

amount of dependent application units

F²-Compositor® within the scope of geometry and physics

amount of independent application units
F²-Compositor® design freedom

bidirectional fiber-placement

amount of dependent application units

F²-Compositor®
within the scope of geometry and physics

multi-material lay-up

carbon UD

amount of independent application units

glass UD
F²-Compositor® design freedom

bidirectional fiber-placement

multi-cross sections

F²-Compositor®
within the scope of geometry and physics

multi-material lay-up

amount of dependent application units

amount of independent application units

width 1 ≠ width 2
thickness 1 ≠ thickness 2
F²-Compositor® design freedom

bidirectional fiber-placement

amount of dependent application units

automated quality control of the material/preform

F²-Compositor® within the scope of geometry and physics

multi-material lay-up

amount of independent application units

multi-cross sections

width 1 ≠ width 2
thickness 1 ≠ thickness 2

carbon UD

glass UD

www.micro-epsilon.de
F²-Compositor® design freedom

- Simplex or duplex
- Multiple application units
- Multiple application units and parallelization
- Pendulum operation
- Curved path
- Tool movement or conveyor movement
- Mixing technology, e.g. rapid prototyping
- Focusing on near UD
F²-Compositor® design freedom

- **F²-Compositor**
  - Tape placement, flexible tape width
  - Dimension: 4 m x 2.65 m

- **F²-Compositor LabCube**
  - Tape placement, tape winding and both together, material supply on board
  - Dimension: 1.9 m x 1.4 m

- **F².5-Compositor**
  - Tape placement, fixed tape width, UD material supply on board
  - Dimension: 5.2 m x 0.9 m

- **F²-Compositor LabCube**
  - Tape placement, fixed tape width, material supply on board
  - Dimension: 0.9 m x 0.8 m

*Shown without housing and material supply*
Option to reduce waste

50 mm application unit

Dimensions:
- 325 mm
- 400 mm
- 150 mm
- 75 mm
- 100 mm
- 125 mm
Option to reduce waste

50 mm application unit

50 mm and 25 mm application units

red = waste 7.4%
Option to reduce waste
Multiple tape geometries

50 mm application unit
red = waste 7.4%

50 mm and 25 mm application units
Option to reduce waste

50 mm application unit

25 mm application unit
Minimize waste

50 mm application unit
red = waste 30.3 %
$\sim 1.1 \text{ Mio } \text{€} / \text{a}$

25 mm application unit
red = waste 16.3 %
$\sim 0.59 \text{ Mio } \text{€} / \text{a}$

CF-PPS
55 Fvol-%
200 € /kg
2 mm thick
50.000 / a
Option to reduce waste
Near net shape + injection moulding

50 mm application unit
25 mm application unit
Minimize waste
Near net shape + injection moulding

50 mm application unit
red = waste
7.7 %
~ 0.28 Mio € / a

25 mm application unit
red = waste
1 %
~ 0.04 Mio € / a

CF-PPS
55 Fvol-%
200 € /kg
2 mm thick
50.000 / a

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F²-Composite®
Automotive scenario, seat structure

40 % less waste
F²-Composite®
Flexible sections
Flexible sections

within the scope of geometry and physics
What is the difference?

• We do not buy robots, we built them!
• We have our own customized drives!
• We have a single control unit, covering all processes!
• We have a much cheaper heating source!
• We do not use a laser, causing secondary costs for safety equipment and safety education!
• We generate the polymer melt only in the joining zone, so we have an energy efficient heating process!
• We use an energy recovery system to store and release the motion energy, especially on short tracks!
• We do not have a huge overhead!
Online measurement of tapes

- Moving Tape
- Detection of:
  - top side and bottom side synchronized
  - ledge
  - width
  - thickness
  - area
  - "Ra", "Rt", "Rz"
Online-surface detection of Aramid-PEEK-tape
### Facts F²-Compositor®

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investment range</strong></td>
<td>85 k€ up to 1.5 m€ EXW, with documentation, without qualification effort*</td>
<td>less than competition (factor of 2-15)</td>
</tr>
<tr>
<td><strong>Tape laying rate</strong></td>
<td>5 kg/h up to 725 kg/h or more</td>
<td>difficult to compare</td>
</tr>
<tr>
<td><strong>Tape width per application unit</strong></td>
<td>5 mm up to 75 mm</td>
<td>unknown</td>
</tr>
<tr>
<td><strong>Necessary power to produce a consolidated preform: Heating source + movement</strong></td>
<td>1.5 kW/h up to 25 kW/h</td>
<td>less than competition (factor of 50-100)</td>
</tr>
<tr>
<td><strong>Exposure time polymer above the melting point, to manufacture a consolidated preform for further IR-processing</strong></td>
<td>0.025 s</td>
<td>less than competition (factor of 40,000)</td>
</tr>
<tr>
<td><strong>Placement speed with precision</strong></td>
<td>1-3 m/s</td>
<td>faster than competition (factor of 2-4)</td>
</tr>
<tr>
<td><strong>Acceleration, deceleration with precision</strong></td>
<td>20-50 m/s²</td>
<td>faster than robots (factor of 10-25)</td>
</tr>
<tr>
<td><strong>Workshop area to install a F²-Compositor® with all infrastructure</strong></td>
<td>10 m² up to 38 m²</td>
<td>less than competition (factor of 2-20)</td>
</tr>
<tr>
<td><strong>Tested polymers with reinforcement</strong></td>
<td>PP, PE, PA, PA derivates, PPA, PPS, PEEK, PEKK, “prepreg”, …</td>
<td>same as competition</td>
</tr>
<tr>
<td><strong>Tested polymers without reinforcement</strong></td>
<td>PP, PE, et. al.</td>
<td>unknown</td>
</tr>
<tr>
<td><strong>Tested carrier substrate</strong></td>
<td>None, polymer, polymer film, FRPC, sandwich, foam, steel, aluminium, wood, concrete</td>
<td>unknown</td>
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<tr>
<td><strong>Waste</strong></td>
<td>Waste intended to be none with miniaturization and design options of the F2-Compositor®</td>
<td>difficult to compare</td>
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<tr>
<td><strong>Design options</strong></td>
<td>Coupling several small F²-Compositors® to an assembly line, possible and reasonable to have no waste and a high laying rate, Automatic spool change upon request F²-Compositor® to F² “out of plane“-Compositor</td>
<td>unknown</td>
</tr>
</tbody>
</table>

*(*VP“, “QP“, URS, FS, DQ, FAT, SAT, IQ, OQ, PQ*)
Several partners are usually involved in a FRPC process chain
- (Precursor)
- Fiber
- Polymer
- Tape production
- Preform production
- Pre-product
- Product in platform
- OEM

> Interface losses are common

Tape
- Global established capacity is not huge
- Technology of melt-impregnation has physical speed limits
- Standardization is missing
- Price of tape is not following the rule of raw material mixture + usual value adding
- Price/mass is calculated for the 1st life-cycle for new equipment

The global average OEM-competence in FRPC design with hybrid, anisotropic materials, including topology and structural optimization to offer clever assemblies is rather low

URS is often not FRPC compliant
Summary long version

- ASH can deliver rapid fiber-placement solutions
  - We have know-how along the complete technology chain
  - We deliver customer or product specific machines
- F²-Compositor® is an adaptive machine, that can process multi-materials and multi cross-sections
- Unfortunately, every business case has to be considered individually, to balance technical and economic advantages
- Main motivator for industrial implementation is waste
- Our technology does not improve the quality of the semi-finished product
- Online quality inspection of the semi-finished product or the preform is possible
- Please challenge us to bring the composites to real production!
Thank you for your attention

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