Processing of High Performance Thermoplastic Composites

Spring Semester 2017
131-5048-00L Manufacturing of Polymer Composites

Joanna Wong 16 June 2017
Outline

- Introduction to Thermoplastic Composites
- Materials in Thermoplastic Composites
- Basics of Thermoplastic Composite Processing
- Intermediate Materials for Thermoplastic Composites
- Processes for Thermoplastic Composites
- Joining Techniques
- Recycling
Processes for Thermoplastic Composites

- Autoclave processing of thermoplastic composites
- Continuous belt lamination
- Thermoplastic Composite Pultrusion
- Thermoforming
- Stamp Forming
- Automated Tape laying processing
- Thermoplastic Composite Filament Winding
- Additive Manufacturing
- Thermoplastic LCM
Autoclave Processing
Autoclave vacuum bagging

- Release film
- Vacuum bag
- Bleeder
- Vents
- Laminate
- Seal
- Autoclave table
- Mould

Typical autoclave cure cycle
Processes for Thermoplastic Composites

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Continuous belt lamination

- Double belt press
- Unwind station
- Heating
- Cutting unit
- Trimming station
- Double belt press
- Upwind station
- Palletizing

Material flow
Continuous Belt Lamination

- Unwind for multi-layer lamination
- Resin hopper for thermoplastic layer
- Process widths to 60”
- Variable feed rates up to 120”/min.
- Continuous run wind up capability
- Pressure capability from atmospheric to >1500 PSI
- Processing temperatures in excess of 750°F
- Sheeting capability
Continuous Belt Lamination
Processes for Thermoplastic Composites

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Thermosetting Composite Pultrusion
Thermoplastic Composite Pultrusion

Kim, Lee, Friedrich “A model for a thermoplastic pultrusion process using commingled yarns” Composite Science and Technology 61, 8, 105-1077 (2001)
Thermoplastic Composite Pultrusion

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Processes for Thermoplastic Composites

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Main steps for the fabrication of thermoplastic composites using thermoforming processes

- Mold preparation
- Release agent
- ...
Compression moulding

- Preparation of the mould
- Release agent
- Cutting of the fabric plies
- Mould feeding

- Closing of the mould, cold forming
- Starting of the mould program

- De-moulding
- Trimming
- Post-production

Preparation → Heating → Consolidation → Cooling → Demoulding
Process variant: Tubular blowing process

**Preparation**
- Preparation of the mould
- Release agent
- Cutting of the fabric plies
- Draping of the silicon tube
- Mould feeding

**Heating**
- Closing of the mould, cold forming
- Pressurisation of the silicon tube
- Starting of the mould program

**Consolidation**

**Cooling**
- De-moulding
- Ventilation of silicon tube
- Trimming
- Post-production

**Demoulding**
Process variant: independent heating and cooling

- Preparation of the mould
- Release agent
- Cutting of the fabric plies
- Mould feeding

- Transfer of the mould in the hot-press
- Closing of the mould, cold forming
- Starting of the mould program

- Transfer of the mould in the cold-press
- Cooling down to demoulding temperature

- Transfer of the mould in the de-moulding station
- De-moulding
- Trimming
- Post-production
Process variant: QUICKTEMP-process

- Metallic mould with low thermal mass
- Integrated resistance heating
- Integrated cooling fluid system
- Thermal insulator with integrated resistance heating
Flow Moulding of Glass Mat reinforced Thermoplastics „GMT“

Stamping of Weave reinforced Thermoplastics (eg. Twintex)
State of the Art in Automotive Industry

Twintex® Fabric

GMT

Twintex® Fabric

Twintex® reinforcement remains In the inlay zone

GMT fills the cavity

Source: Ronnie Törnvist (Quadrant Plastic Composites AG), 1st Swiss Sampe Technical Conference, Zurich 2002
Recent Component Examples

Source: Ronnie Törnlqvist (Quadrant Plastic Composites AG), 1st Swiss Sampe Technical Conference, Zurich 2002
Overview: Processing routes

Thermoplastic

Prepregging

Fiber Matrix

Contact heating

Heating

Impregnation

Consolidation

Double belt lamination

Impregnation

Consolidation

Organic sheet

Contact-free heating

Heated preform

Stamp forming (rubber forming)

Forming

Solidification

Stamp forming (metalforming)

Forming

Solidification

Diaphragma forming

Heating

Consolidation

Forming

Solidification

Compression moulding:

Heating

Consolidation

Forming

Solidification

Component
Factors influencing the laminate quality

- Consolidation time
- Consolidation pressure
- Cooling speed
- Degree of crystallinity
- Residual stress
- Fiber wetting consolidation
- Polymer degradation
- Heating time
- Heating strategy
- Over-heating

Preparation → Heating → Consolidation → Cooling → Demoulding
Some general rules…

- Preform selection strongly influences processing route and vice versa!
- Thermoplastic matrix has to show an adequate thermal stability considering the selected processing route
- Viscosity of the polymer matrix should be sufficient to ensure a complete consolidation
- Cooling speed is depending on the selected thermoplastic material
Processes for Thermoplastic Composites

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### Stamp forming

<table>
<thead>
<tr>
<th>Preparation</th>
<th>Heating</th>
<th>Consolidation</th>
<th>Cooling</th>
<th>Demoulding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation of the mould</td>
<td>Heating of the preform outside of the moulding device</td>
<td>Transfer of the mould in the press</td>
<td>Demoulding</td>
<td></td>
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<td>Release agent</td>
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<td>Cutting of the textile or pre-consolidated sheet material</td>
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#### Process Steps:
- **Preparation**
  - Preparation of the mould
  - Release agent
  - Cutting of the textile or pre-consolidated sheet material
  - Fixation of the material to the frame
- **Heating**
  - Heating of the preform outside of the moulding device
- **Consolidation**
  - Transfer of the mould in the press
  - Forming
  - Cooling
- **Cooling**
- **Demoulding**
  - Demoulding
  - Trimming
  - Post-production
Stamp Forming

- Stamp forming is a non-isothermal moulding process for reinforced or neat plastic sheet-like preforms.
- If reinforced sheets are subjected to stamp forming, they have usually experienced consolidation prior to moulding.

U. Thomann, Direct Stamp Forming of Non-Consolidated Carbon/Thermoplastic Fibre Commingled Yarns, Diss. ETH No. 15302, Zurich, 2003
Stamp forming process

U. Thomann, Direct Stamp Forming of Non-Consolidated Carbon/Thermoplastic Fibre Commingled Yarns, Diss. ETH No. 15302, Zurich, 2003