Inject the future.

Organomelt & in situ polymerization provide new opportunities for Injection Molding of Composite Structures

New injection molding technologies for stronger parts
Why lightweight construction?

> Reduction of CO2 emissions
> Electromobility

100 kg of weight reduction gains 0.4 l less need of petrol and roughly 10 g less CO2
Lightweight construction?

> Light weight construction means to place as few as possible of a material in a certain room, while fulfilling defined functions up to an optimum grade. (@ Prof. Bernd Kröplin, TU Stuttgart)

> Types of lightweight construction
  
  • By design
  • By material
Don‘t look for the **SUPER**-material –
get **composite strength**!

> Fibre
  - Glass
  - Carbon

> Matrice
  - Thermoset
  - Thermoplastic
Actual situation

Usage
> Mostly in advanced technical areas
  • Aircraft
  • Racing
> Low part numbers

Processes
> Composites with thermoset matrices
> Autoclave processes with low productivities
> High content of manual work
> Plane parts
Composite Technologies

Functionalisation of thermoplastic prepregs

„one shot – one part“

> Combining thermoforming and injection molding

> Fully automated, high productive processes

**Diagram:**
- **Mechanical Performance (Impact, Crash)**
- **Aspect Ratio l/d**
- **Thermoforming (low pressures)**
- **Compression (higher pressures)**
- **Injection molding**
- **Non-reinforced**
- **Short Fiber**
- **Long Fiber**
- **Mats (GMT)**
- **UD-Layers**

*ENGEL be the first.*
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Working with thermoplastic fabrics

Fabric

heating, forming, back molding

part

> Woven and non woven fabrics, or unidirectional reinforcements
> Fully impregnated and consolidated
FRP with thermoplastic matrixes

- High viscosities of thermoplastic melts
- The semi-finished products already contain the matrix material
Fully automated production of a structural part with a thermoplastic composite prepreg

- Fabrics about of different fibre systems (GF, CF, BF etc.)
- Heating up of fabric with IR
- In-Mold-Forming
- Backmolding
- Cutting, if needed (water jet/ laser)
A glance at the automation

Automation and handling concept, the key to productivity
Heating

> Heating via infrared

> Single/double-sided heating
  - Depending on the thickness

> Ventilation
  - Exhaustion and emitter protection

Heating of the thermoplastic composite sheets

Heat balance
Forming

> High rates of deformation
> Preforming via gripper system
> Draping within the mould
> Forming through clamping force
Backmoulding

> Moulding through the sheet
> Integral connection
  • Welded connection
  • Mixing of the components
  • Slightly crimping of the fabric

*Backmoulding of the rip structure*
Cutting

> Cutting via CO₂ laser
  • Laserhead mounted to robot with three axis of freedom

> With or without cutting
  • A matter of geometry
  • A matter of handling solution
Steering wheel carrier (K‘2010)
Composites for brake pedal

Advantage: integrating of functions

> 50% lighter than solution in steel
Textile fabrics

- Low cycle times
- No chemistry
- Welding and backmolding possible
- Unlimited storage
- High impact properties
- Simple recycling
- High input of material
- „Global“ solution!
Choosing UD-tapes

> Force orientated
> Optimized use of material
  - Building up of layers
  - Preforming and backmolding

\[ E_{||} >> E_{\perp} \]
Production of tape-layers

> Functionalisation by back molding
Production of tape-layers

- Lay up with robot
- Local welding by laser
Tailored blanks

- Optimized set up possible
- Low usage of material

- Still prepreg production necessary
- Two step process
- Heating for preforming step
Why using prepregs?

- Cost for prepregs
- Energy input for deconsolidation

Ideal would be
- Force orientated lay up with dry fibre structures
- Impregnation by back molding
- „One shot – one part“!

**Viscosity** plays against!
Influence of viscosity

- Thermoplastics at processing temperatures
- Honey at room temperature
- Thermosets at processing temperatures
- Motor oil at room temperature
- Blood at room temperature
- Monomers (Caprolactam)

Preconsolidated fabrics

Dry textiles
Infiltration with thermosets

Epoxy resins (EP)
- Density 1,1,-1,25 g/cm³
- Processed as fluid
- Chemical reaction by resins and hardener
- Low shrinkage during processing

> Bisphenol A + 2 Epichlorhydrin
Polyaddition reaction

Δ - HCl

weitere Polyadditionen

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High pressure - Resin Transfer Molding

Composites with epoxy-resins

> Impregnation of textile fabrics with thermosets
  • Stacking
  • Preforming
  • Lay up
  • Impregnation
  • Curing under temperature
  • Demolding & cutting

Source: BMW AG
Composites with thermosets

- Force orientated lay up of fibre structures
- Good impregnation
- Low shrinkage
- High mechanics

Long curing times
- No welding
- Recycling difficult
Thermoplastic resins?

**Insitu** – polymerisation (insitu: latin for „then and there“)

- Anionic polymerisation of caprolactam to Polyamid6
  - Monomers with very low viscosity
  - Preparation with activator and catalyst in HP-RTM-unit
  - Infiltration of textiles
  - Curing (polymerisation) under temperature

\[ T = 150^\circ C \]

![Diagram showing the process of polymerisation](image-url)
Cast polyamid

- For thick walled preproducts
- Very high impact properties

TECARIM PA 6G copolymer (Nyrim)
HD-RTM thermoplastic: insitu Polymerisation (anionic)
HD-RTM - Verfahren

- Mischkopf
- Formenträger
- Aufbereitungseinheit
Composite Technologies

Reactive injection molding

> Injection molding technology for HP-RTM
  • Energy saving
  • Low residence times
  • Low amount of material in process
  • Central controls for all functions

Mixing head

Caprolactam + Aktivator
Caprolactam + Katalysator

Insitu-prototype

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The best of both worlds…..

Reactive thermoplastic resins

> Force orientated lay up like with thermosets
> Low pressure impregnation
> Fully thermoplastic solution
  • Welding
  • Functionalisation
  • Recycling

> In development
  • Process technologies
  • Process times
Machine technologies for composite processing

> Horizontal clamp units
  • Easy to automate
  • Flexibel system also for other injection molding technologies
  • Holding of inserts as challenging factor
Machine technologies for composite processing

> Vertical clamping units
  • Insert
  • V-DUO
  • Easy accessibility
  • Working with gravitation, not against
Lab unit for development of large scale composite production

> Verticale Insert-clamping units
  - 4000 kN und 1000 kN
> 4-Station rotary table
> Multicomponent injection molding, injection compression molding, foaming
New vertical concepts for composite processing

> 2500 V-DUO
> Proven 2-platen clamping unit in new vertical design
Mounting process

> Shell technology
  - Thermoplastic halves
  - Introducing reinforcement
  - Conjunction with thermoplastic frame (TPE)
Upper cover tailgate, BMW 5
Center for lightweight composite technologies

Composite technologies need composite development!

- Establishing network for composite technologies
- Development of new processes
- Integration of reaction technologies
- Providing system solutions
- Lab for internal and external trials
Thank you!