 „High-Pressure Resin Injection –
Key Technology for Large-Scale Production“

Authors:

Matthias Graf
DIEFFENBACHER GMBH
Maschinen- und Anlagenbau
Heilbronner Str. 20
75031 Eppingen, Germany
matthias.graf@dieffenbacher.de

Raman Chaudhari
Fraunhofer-Institut für Chemische Technologie (ICT)
Joseph-von-Fraunhofer-Straße 7
76327 Pfinztal, Germany
raman.chaudhari@ict.fraunhofer.de
HP-RTM
Basic Advantages

1. Excellent Part Properties
   - Distinguished mechanical properties - bidirectional
   - High surface quality
   - Paintable on both part sides

2. Process Reliability
   - Self cleaning mixing head
   - Stable temperature control inside the metering machine up to 120°C

3. High Productivity
   - Relatively short cycle times compared to LP-RTM process
   - IMP possible
   - High degree of automating possible
HP-RTM Production Line
Process Chain

Turn Key Supplier for HP-RTM Application

- Comprehensive, product-oriented process and line concept
- Completely automated production
- Cycle Times less than 180 seconds
- High process stability
- Process monitoring
HP-RTM
Motivation and Targets

- Development of a completely automated CFRP production line for large series matching the requirements of the automotive industry.

- **Targets:**
  - Cycle time \( \leq 3 \) min per part resp. working cycle
  - Complete automation without manual operation
  - High availability
  - Reproducible parts quality - high process stability
  - High degree of process control and automatic fault detection
1. Vacuum Infusion Process - VIP

- Semi finished cuts
- Preform
- Preform placement on mold
- Cover preform with vacuum film
- Apply vacuum; inject resin; impregnation and curing
- Cured component

2. Resin Transfer Molding - RTM

- Semi finished cuts
- Preform
- Preform placement in matched rigid mold
- Inject resin; impregnation and curing
- Cured component

3. Vacuum Assisted Resin Transfer Molding - VARTM

- Semi finished cuts
- Preform
- Preform placement in matched rigid mold; apply vacuum
- Inject resin; impregnation and curing
- Cured component
RTM – Process Technology

High Pressure Compression RTM – HP-RTM

Advantages of High Pressure Compression RTM:

- Rapid mold filling
- Improved impregnation quality
- Accelerated resin reactivity system can be applied – short cycle time
- Significant reduction of air entrapments and voids
- Excellent surface properties
- Low tolerance in thickness and 3D shape
- High process stability and repeatability
- Use of internal release agent – self cleaning system
**RTM – Process Technology**

**HP - RTM Process Types**

**High-pressure Injection**

HP - I RTM

Impregnation of the preform by flow through cross section (X/Y direction)

**High-pressure Compression**

HP- C RTM

Impregnation of the preform by flow in plane of the part area (Z direction)
RTM – Process Technology

HP - Injection RTM Process Flow

- Insertion of the dry 3D fiber preform
- Complete closure of compression mold; cavity height = part thickness
- Resin and hardener are mixed in the injection head and injected into the cavity
- Flow resistance by penetrating the preform creates counter-pressure dependent on the injection speed
- High-pressure buildup by injection system
- Curing by heat and demolding of the part
RTM – Process Technology

HP – Compression RTM Process Flow

- Insertion of the dry 3D fiber preform
- Closure of compression mold with impregnation gap = part thickness + flow gap
- Resin and hardener are mixed in the injection head and injected into the cavity
- Low flow resistance – resin flows over and into the preform
- High-pressure build-up by compression stroke of the press – Z- impregnation
- Curing by heat and demolding of the part
Advantages of HP – RTM

- High reduction of void content
- Excellent surface quality
- No gas inclusion front that needs to be flushed out
  → reduced resin consumption

Advantages of HP - Compression RTM

- Improved permeability with gap impregnation
  → Fast injection of the necessary resin quantity into the mold without fiber displacement
- Improved and faster fiber impregnation
  → Avoidance of dry fibers on the parts surface
  → Full penetration of the fiber tows
- Short filling times permit the use of highly reactive resins
  → short cycle times
HP–C RTM Process Technology

Material data:

- Saertex glass fiber core (S14EU960-01210-01300-487000)
  - UD
  - MC sizing,
  - 1218 g/m²
  - 4 layers

- Epoxid resin
  - Huntsman Araldite LY 564
  - Huntsman hardener XB 3458
  - Resin/hardener mix:
    100:20 (wt.-%); 100:24 (vol.-%)

- Viscosity of resin mix: 60 mPa*s
HP–C RTM Process Technology

Process data:

- Resin Injection temperature: preheated up to 60°C
- Mixing pressure: 100 bar
- Final cavity pressure: 60 bar
- Injection duration: 17s
- Injection quantity: 365g
- Curing time: - 4 min with 100°C mold temperature
- Dimensions of the mold cavity:
  Panel 830 mm x 210 mm x 3 mm
Injection with 2 mm impregnation gap

Injection with 1 mm impregnation gap
HP–RTM Process Technology
Pressure flow during injection

- Cavity pressure HP-CRTM
- Cavity pressure HP-IRTM

- Press closes to defined mold gap or completely;
- HP-RTM equipment builds high pressure required for mixing

Start of Resin injection
End of resin injection
Part curing

Cavity pressure [bar]

Time (s)
HP–RTM Process Technology
Pressure flow during injection

HP – I RTM

HP – C RTM

Part size: 910 x 560 x 2,5mm - curing time = 240s
HP-RTM – Production Line
Press Technology

Line Control

- Incorporation of all machinery components into one central control
- Central control enables to run and monitor the machine with 1 operator
- Central monitoring system with automatic alarm system
**RTM Press Technology**  
Operation Modes for RTM - Visualisation

**Injection in opended mold**  
(Compression RTM)

Closing of slide to a specific index position (gap) and resin injection and impregnation by final closing

**Injection molding flow-front-control**

Programmable slide tiltage during closing- and pressing process for flow-front-control

**Injection in closed mold**

Mold closing and pressure build up and resin injection
HP–RTM Process Technology
Layout Production System

- Draping Station
- Preform Handling
- DCL-Press
- Shuttle Table
- Dosing/Injection Unit
- Composite Router
- Net Shaping
- Preform Buffer
- CNC Cutter
- Preform Handling
Thank you very much for your attention!