One-Shot, Automated Molding of Structural Composite Parts

Jason Holbrook – Krauss Maffei Corporation - 2017

FiberForm
IMM with organo sheets

RTM
Carbon Fiber with PUR

CellForm (MuCell)
Foamed parts

IMC
Injection molding compounder
Lightweight portfolio covers the entire range of requirements

**RPM**
- RTM
- Long Fiber Injection

**FiberForm**

**IMM**
- Injection Molding Compounder
- Short glass fiber injection molding

Increasing mechanical properties

Increasing cost efficiency
Fiber Composite materials offer a wide spectrum
Fiber length vs. Product properties

Components complexity
mechanical properties
part costs

Injection molding

Unreinforced, Short Fiber, Long Fiber

Compression molding

Fabric, Fiber Mat, Direct Fiber, GMT

Fiber length in the component

0 10 100 1000 10000

Unidirectional

Quasi ∞
The importance of light weight design

CO₂ emission are directly linked to the weight of a vehicle

Increase of car weight because of:
- Convenience
- Safety
- Quality
- Legislation
- Interior

Consumption of a car is linked directly to the car weight

Weight causes about ¼ of fuel consumption
The importance of light weight design
Replacement of steel/ aluminum by carbon fiber

Challenges for OEM with fiber application
- Design of components
- Material selection
- Production know how
- Behavior of metal component
- Weight/ Quality/ Cost optimization
- Quality control
- Testing
- Recycling
- Tear 1 - network
Future of Urban mobility
BMW i3

Source.
FiberForm: Composite sheet integrated into injection molding
Textile Reinforced parts with functional integration

Combination of injection molding and thermoforming

Combination of both methods leads to:
- High strength and stiffness
- High design freedom
- High functional integration
- High degree of automation
- Short cycle times

Achievable stiffness, strength, Energy absorption capacity
Cost efficient production in an one-stage-process
FiberForm – schematic process description

1. Organo sheet intake
2. Organo sheet heating
3. Transfer into injection mold
4. Thermoforming
5. Injection molding
6. Final part removal
**Thermoplastic laminates offer many opportunities**

**Materials and set-up**

- Composite sheet based on a thermoplastic matrix
- Reinforcement is a woven fabric or an unidirectional fabric (UD-Tape)
- Local or continuous fiber reinforcement
- Various thermoplastic matrix systems (PP, PA, PPS, PEI, PEEK, …)
- Different fibrous reinforcements (glass, carbon, aramid or mixed forms)

- Optimized design for application is possible (fiber orientation, layer structure)
Application:
- Technology part K2010, similar to side impact beam ("TAT") by AUDI
- ~ 55 sec cycle time, ~ 590 g weight

Innovation:
- Transformation to thermoplastic with given construction space
- Process symbiosis of thermoforming and injection molding
- Back injection with consolidated composite laminates in one step

Benefit:
- Lightweight parts > -20% compared to steel
- Plastic parts with high impact strength
- Parts ready for assembly directly after demolding
K2013 – CX 300-1400
Hollow body demonstrator
FiberForm: Concept for the K-Show 2013

Hollow profile

Local reinforcement

Functional integration

Fasteners
Production cell available for customer trials in Munich
CX 300-1400 FiberForm in the technical center at KraussMaffei Munich
50% weight reduction compared to traditional injection molding!
CX 300 – 1400 FiberForm

Application
- Airbag housing
- PP/GF30 with PP-organo sheet
- Cycle time: < 40s

Innovation
- LRX as TwinZ – Robot Carriages
- Scales for monitoring the constancy of the shot weight, integrated in MC6
- IR-oven control integrated in MC6
- Blending of highly concentrated PP/LGF60
- Compact production cell (-25% of area)

Partner
- Takata, Siebenwurst, Bond-Laminates, Borealis, Motan-Colortronic
Cycle time reduction through LRX TwinZ
Further development of the FiberForm-Automation from NPE USA to Fakuma

Reduction of the cycle time by 5s through decoupling the organo sheet input process and the part removal process
Reduction of floor space through integration of the automation

Further development of the FiberForm-Automation from NPE USA to Fakuma

Reduction of the floor space required by 25% through integration of the automation in the safety enclosure of the IMM
FiberForm: Molding 2017
Prototype for a holder
Plastics 4.0 – Intelligent machines through QR-Code-Labelling
CX 300-1000 FiberForm

CX 300-1000 FiberForm

Automation - LRX 250 TwinZ

Infrared heating system

Peripherals
- Temperature management device
- QR-Code printer
- Organo sheets

Mold
- 1 Cavity
- Hot organo sheet is put onto holding pins
Semi-structural composite part in less than 40s of cycle time!

CX 300-1000 FiberForm: Information about the production cell

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
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<tbody>
<tr>
<td>Clamping force</td>
<td>3,000 kN</td>
</tr>
<tr>
<td>Screw size</td>
<td>50 mm</td>
</tr>
<tr>
<td>Part</td>
<td>Prototype for a holder</td>
</tr>
<tr>
<td>Material</td>
<td>PA 6: DURETHAN BKV 55 TPX</td>
</tr>
<tr>
<td></td>
<td>glass fiber reinforced</td>
</tr>
<tr>
<td></td>
<td>PA: TEPEX® dynalite 102-RG600(2)/47 % black</td>
</tr>
<tr>
<td>Part / Shot weight</td>
<td>190 g</td>
</tr>
<tr>
<td>Mold</td>
<td>1 Cavity / Company Siebenwurst</td>
</tr>
<tr>
<td>Cycle time</td>
<td>39 sec</td>
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</table>
Simplified FiberForm process: the new generation of heating up

- **Reduced rejects**
  Preheating program for shortened start-up processes

- **Uniform heating up**
  Synchronous heating up of the individual heating zones by using a control algorithm developed in-house

- **Highest component quality**
  Highly dynamic controller prevents the set temperature from being exceeded

- **Process transparency**
  Quality monitoring of the entire heating curve graphically displayed in the MC6

FiberForm – The new generation of heating up

CX 300-100 FiberForm: Innovations within the infrared heating system
FiberForm – The new generation of heating up
Visualization: Integration of infrared heating system control in MC6

Display of heating curves

Monitoring of heating zones
Final part on conveyor belt and QR-Code scan operation
Plastics 4.0 with QR-Code
Intelligent automation concept saves cycle time
Linear robot LRX 250 TwinZ

Multiple kinematics – easily control many axes

- LRX 250 TwinZ linear robot with 2 x 25 kg payload
- Twin robot with mechanically coupled axes
- MC6 integration of all axes
- Incorporate up to 24 axes with one control system
- Compact automation integration within the injection molding machine enclosure
Application example - Marker binding for tour skiing
MARKER Kingpin – Development with the S&W GmbH

Functional integration via 3 hot runners (Needle valve)

Injection molded edge surrounding – 1mm wide

Organo sheet
Application example - Connection of two organo sheets
Audi A6 Infotainment carrier

Part information
- Production cell: CX 300 - 1400
- Injection molding material: PA6 GF30
- Organo sheet: PA6 GF
- Cycle time: < 60s
- Weight: 325g
  - Approx. 50% savings in weight compared to steel part

Partners
KraussMaffei Technologies...FiberForm History
...long-term experience with continuous fiber-reinforced FVK

Frontend with organic sheet in the upper belt

Technology carrier – TAT

SpriForm – cross beam

Airbag housing – Takata

A second fully automated production cell is available for customer projects!
RTM process family
selection of the technologies according to part design/property

RTM process family:
- HP-RTM
- T-RTM
- C-RTM
- Surface RTM
- Wet pressing
Advantages of the HD-RTM Process:

- Especially for parts with complex 3D geometries
- Fast filling of a closed cavity
- Complete impregnation of fiber preform by raised cavity pressure
- Short cure times leading to short cycle times
- Injection from the side
Compression RTM Technology
High Pressure Impingement and Press Stroke

Advantages of the C-RTM process:

- Especially for 2D parts to avoid the wash out effect
- Fast filling of cavity, cavity not entirely closed (0,3mm)
- Fast curing chemical systems
- Impregnation of fiber preform with press stroke movement
- Lower press force need without cavity pressure (compared to HP-RTM)
- Use of Aluminium tools
- Injection from the centre
Advantages of Wetmolding process:

- Processing of fast reacting chemical systems with high pressure impingement
- Use fiber mats made out of recycled fiber pieces
- No cavity pressure – less sophisticated tool design
- No cavity pressure – less press force needed
Wet-RTM Technology
Return of recycled fibres into CFRP parts

- Roof
- Underbody structure parts
- Rear seat structure
Which are typical applications for HP-RTM?
Structural parts and carbon designer parts

- Underbody structure
- Seat structure
- Side Frame
- Roof and Bonet
European Automotive industry is already using RTM Structural parts in series production
**Composite surface technology**

Motivation of the joint development

- Sink marks due to different shrinkage of reinforcement and matrix
- In general direct conventional spray-coating is not possible
- Sink marks and other surface defects can be covered by In-Mold Coating with ColorForm technology
- Post shrinkage must be controlled
Lightweight design & high quality surfaces
efficient combination of two megatrends force further developments

2013 Roof element Roding R1

<table>
<thead>
<tr>
<th>Key characteristics</th>
<th></th>
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<tbody>
<tr>
<td>Dimensions</td>
<td>772x585 mm</td>
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<tr>
<td>Total part weight</td>
<td>2.570 g</td>
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<tr>
<td>(weight of surface material)</td>
<td>(230g)</td>
</tr>
<tr>
<td>Substrate thickness</td>
<td>2 mm</td>
</tr>
<tr>
<td>Surface layer thickness</td>
<td>0.2 mm</td>
</tr>
<tr>
<td>Fiber content (by volume)</td>
<td>50%</td>
</tr>
<tr>
<td>Fiber Layup</td>
<td>quasiisotrop</td>
</tr>
<tr>
<td>Cycle time</td>
<td>6 min</td>
</tr>
</tbody>
</table>

Surface Quality met the specification of German automotive OEMs
Summary K-Show Application
World premier – Surface RTM

World-new two-step RTM infusion and overmolding process
High quality paintable surface for CFRP automotive exterior parts
Joint project among technological leaders of PU and light weight manufacturing companies
Combination of high-performance light weight parts with high quality surface enhancement

www.surface-rtm.com
Cooperation among company research Team VW, BASF, KM
B-Pillar Reinforcement Part

- EA absorption properties – pole crash test
- Replacement high strength steel – weight reduction 36%
- Different wall thicknesses applied – 6.3mm to 12mm
- Fiber volume content from 54% to 58%
- Injection and curing less than 5min (target less than 3min)
- Recyclability combination with an injection molding process
Carbon Composite Network
Network to Supply “Turn Key Solutions”
Injection Molding Compounder – IMC
Get the benefit together
Injection Molding Compounder (IMC) – Principle

Injection molding:
- Single screw
- Material processing
- Discontinuous process

Extrusion:
- Twin screw
- Material compounding
- Continuous process
Continuous and discontinuous – Two in One

Schematic process description

- Melt buffer
- Shut-off nozzle
- Re-direction valve
- CX-, GX- or MX-clamp
- Weighing, dosing and conveying systems
- Start-up valve with container
- Twin screw extruder
- Shot-Pot-Injection piston
Less is more... Less cost - more profit
Material cost savings – Save one stage’s added value

- Transport Dosing
- Predrying
- Plastification
- Homogenisation
- Degassing
- Granulating
- Cooling
- Predrying
- Transport Silo
- Weighing
- Packaging

- Injection molding

$\Delta 0.30 – 1.00 \$/kg
One for all – Do you know a more flexible system?
Highest flexibility – Material choice

Fibers
- Longer fibers and homogenous dispersion

Blends
- Specialties - Reactive Blends, fiber reinforcement,

Fillers
- High fill grades, substitution possibilities

Benefit:
- Material cost savings – At least 0,30€/kg
- Almost everything is processable
**Improved material quality because of reduced thermal stress**

One-heat-process – Better material quality

One-heat-process
- One plasticizing operation less
- Less shear stress
- Less thermal stress

Benefit:
- Higher part quality – particularly with temperature sensitive materials like PA
- More homogeneous material and improved flow behavior

### Conventional vs. IMC

- **Conventional**
  - Plasticizing at Compounder
  - Plasticizing at manufacturer
  - Product

- **IMC**
  - Plasticizing at manufacturer
  - **needless**
  - Product
Material responsibility – We assist you
Continuous extrusion process – Clear-cut documentation

Ongoing cycles
Percentage of single components
Screw speed
Mass temperature
Control of roving quantity
Throughput
The IMC-Technology in operation
Overview of current IMC-applications
CellForm - Accurate, more lightweight
Andreas Handschke, KraussMaffei Technologies GmbH
Munich 2015
**Basics**

CellForm-Technology

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### TSG
Chemical foaming
- Indirect introduction of gas

### OCM (SGI)
Opening Compression Molding
- Foaming with opening stroke

### MuCell
Physical foaming
- Direct introduction of gas

**Chemical Foaming**
- MuCell

**Additional Process**
- Contact

**CellForm Advantages**
- Dimensional stability
- Reduction of material/weight
- No sink marks/flashes
- Reduction of cycle time
- Less clamping force
The physical behavior is the advantage...
MuCell basics

- Integral foam structure, closed-cell
- Microcellular cell structure: 30 - 100 µm
- Homogeneous cell formation and -size
- In general, all thermoplasts can be foamed
  → MuCell is for stable parts
  → MuCell is universally usable

- SCF has the incompressibility of a liquid and the diffusion properties of a gas
- Over 90% of all MuCell-applications run with N2
- 0,2%-2% gas percentage, depending on material
MuCell: launched in the millennium

Historical overview

- **1979:** MIT, Boston: Development phys. foaming
- **1969:** KM-TSG-Mach.
- **1998:** Marketing Trexel
- **2001:** Series start-up
- **2006:** Visible part cable cover
- **2007:** Large-scale part; door panel
- **2012:** Visible housing with pulse cooling
- **2013:** High glossy surface, painting, etc.
- **2014:** Visible housing with pulse cooling

- **2012:** I-panel, MuCell-optimized

Picture Press release Borealis
The core of the machine

MuCell™ – Plasticizing unit

- Non-return valve
- Machine nozzle
- Pressure release bolt
- Melt pressure sensor
- Spraying protection
- Active back pressure
- Standard 3-zone area for plasticizing
- Middle non-return valve
- Wipe- and mixing zone
SGI: Opening Compression Molding (OCM)

Advantage
- High material reductions possible
- Defined, controlled foaming degree
- High bending stiffness possible

Machine equipment
- CellForm-package (chemical or MuCell)
- Hydraulic for OCM
- OCM-Software
- For direct stroke via machine movement
  - compression molding package + parallelism control (+ parting line control)

Standard foaming:
- Non-complete volumetric filling
- Foaming until cavity is full

OCM:
1) complete volumetric filling
2) Foaming starts with opening
If weight and dimensional stability is decisive
MuCellTM - Application

<table>
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<tr>
<th>Door panels</th>
<th>Valve hood</th>
<th>Carrier part for printer</th>
</tr>
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<td>![Door panel image]</td>
<td>![Valve hood image]</td>
<td>![Carrier part image]</td>
</tr>
<tr>
<td>![Water pump housing]</td>
<td>![Door lock cover]</td>
<td>![Side cover image]</td>
</tr>
</tbody>
</table>

- Door panels
- Valve hood
- Carrier part for printer
- Water pump housing
- Door lock cover
- Side cover
Versatile possibilities
MuCell® - Applications in the Automotive industry

2K-motor cover

Filter housing

Instrument panel

Visible parts
Higher invest, less costs

Saving per year

- Rise of productivity: 18%
  - Cycle time reduction: 45s → 37s = 8s
  - 480,000 parts → 583,000 parts → 100,000 parts more

- Higher Investment: +82,700 €
  - AX230 → AX130: -73,800 €
  - MuCell-Investment: +100,000 €
  - DMH: +56,500 €

- Energiecosts: +20,700 €

- Material saving: -95,500 €
  - 35% = 59g
  - 59g x 583,000 parts = 34,397kg
  - Foaming agent 0.5% → 540 €

ROI of production system: 1.1 years
Over 130 MuCell-machines
THANK YOU FOR YOUR TIME

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FiberForm
IMC