Lightweighting strategies with Chemical Foaming of thermoplastic parts in Automotive Applications

MATERIAUTEC
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Climate change and CO₂

OPPORTUNITIES FOR PLASTICS IN AUTOMOTIVE
The global automotive industry is working hard to reduce the environmental impact of cars

- Road transport is responsible for **16% of total man made CO₂ emissions**
- In the recent years, the automotive industry delivered already **13% reduction of CO₂ emissions** through improved vehicle performance (1995-2005)
- Further efforts are being done in multiple areas
  - Engine and transmission
  - Improved aerodynamics
  - Friction reduction
  - **Light weight materials**
  - Alternative fuel technologies
  - Hybrid, plug-in
  - ... and others

*Source: OICA*
Global targets for CO2 emissions reductions for cars

- Standards for cars and for commercial vehicle/light truck are now compared separately.

- EU 2021 target of 95 g/km becomes the current most stringent numerical standard

- US 2025 target of 97 g/km

- Japan standards 2020 CO2 emission target of 122 g/km (high market share achieved by hybrids in Japan, expected to be on par with or surpass the EU’s 95g/km target)

- South Korea’s to set a 2020 target which will move them to a leadership position in passenger car CO2 emission standards.

Source: ICCT (The international Council of clean transportation)
Weight reduction continues to be a need and an opportunity for vehicle producers

Fleet average CO₂ emissions are being continuously reduced

New cars sold in 2014 in the EU emitted on average 123.4 g CO₂/km significantly below the 2015 target of 130 g CO₂/km.

Average emissions levels in 2014 were below 130 g CO₂/km in 17 of the 28 Member States.

Nearly 20% of the car is made of plastic materials

Increased use of plastics and chemically foamed plastics allow significant density reduction

Source: ICCT 2014
Light weighting strategies

Foamed plastics allow significant density reduction

- **Material**
  - Steel 7,83
  - Aluminium 2,74
  - Magnesium 1,74
  - Chemically foamed PP 0,47
  - Natural cork 0,24

Thermoplastics can easily be foamed by CFA

**CFA: Chemical Foaming Agents**
Fundamentals of chemical foaming technology

HYDROCEROL®
Basic principle of Chemical Foaming Agents
Types of Chemical Foaming Agents

**Exothermic agents**

CFA (exo) \(\xrightarrow{+\Delta E}\) \(N_2 + \Delta E_2 + \text{organic subprod.}\)

**Endothermic agents**

CFA (endo) \(\xrightarrow{+\Delta E}\) \(\text{CO}_2 + \text{H}_2\text{O} + \text{inorganic subprod.}\)

**Active ingredients**

- azodicarbonamide
- sulfonylhydrazide
- 5-feniltetrazol

**Active ingredients**

- sodium bicarbonate
- citric acid and its salts

**DSC profile**

- Exothermic decomposition
- Endothermic decomposition
Properties of Chemical Foaming Agents

- Activation range
- Polymer processing temperature

![Graph showing activation range and polymer processing temperature for citrate, mixture citrate/bicarbonate, mixture citrate/bicarbonate, and bicarbonate.](image)

![Images of NaHCO₃ and Citrat](image)
The chemical foaming process

Plasticizing  Reaction  Dispersion  Foaming (nucleation and expansion)

Injection

Extrusion

Blow molding
Chemical Foaming Agents (CFA)

APPLICATION IN INJECTION MOULDING
Benefits of usage of Hydrocerol® in Injection Moulding

- Density reduction to save material and weight
- Reduction of sink marks
- Process Aid, Cycle Time Reduction
- Increased dimensional stability, less warpage
- Clamping force reduction, Smaller machines
- Improved Thermal and acoustic insulation
- Worldwide availability, standard machines useable
Thermoplastic foam injection moulding (TFIM), Machine Set Up

TFIM with Hydrocerol®
- appropriate temperature setup needed
- dosage by gravimetric or volumetric feeding
- better with shut off nozzle
→ low investment

Source: Frauenhofer ICT
Thermoplastic foam injection moulding (TFIM), 2 processes:

« Classical » injection molding process

« Core back expansion » injection molding process
Chemical Foaming Agents in “Classical” Injection Molding

**Important parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Back Pressure</strong></td>
<td>A specific pressure of 40 bars should be applied to avoid premature foaming. Recommendation: use of shut-off nozzle.</td>
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<tr>
<td><strong>Holding Pressure</strong></td>
<td>Should be as low as possible (ideally zero) to allow nucleation and expansion of the dissolved gas.</td>
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<tr>
<td><strong>Shot weight</strong></td>
<td>Reduced, to give room for the gas to expand (needed if weight reduction is required).</td>
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<tr>
<td><strong>Injection Speed</strong></td>
<td>As high as possible, to prevent premature expansion of the gas and forming of silver streaks.</td>
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<tr>
<td><strong>Temperature profile</strong></td>
<td>Dependent on CFA type.</td>
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<tr>
<td><strong>Mold Venting</strong></td>
<td>Needs to be optimized, to get highest weight reduction and smooth surface.</td>
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Chemical Foaming Agents in “Classical” Injection Molding
Surface appearance

Equipment/Process

*CFA* can usually be processed on every common injection molding machine

- Shut-off-nozzle, to avoid premature foaming
- Gates and flow path should be configured in a way as to allow a fast and even mold filling
- Very good venting at the end of the flow path
Surface Finish

HYDROCEROL®
smooth surface

Physical Foam,
streaks visible,
often no painting possible
Core Back Expansion Process

Phase 1: Injection
- In the 0.5 - 1mm opened cavity
- Fast injection of melt
- App. 1 – 2 s dwell time

Phase 2: Expansion
- Expansion of the mold up to 5mm in one or two directions
- The density of the part is controlled by tool opening

Phase 3: Cooling
- The density of the part is controlled by tool opening

Conventional TSG
- Excellent weight to strength relation
- Very high degree of foaming possible (above 50%)

Core Back Expansion
PP Glassfiber with 2% Hydrocerol® ITP 815
Density Reduction controlled by mold opening

PP Glassfiber compact
1,6mm thickness

unfoamed Material, $\rho = 1.07$ kg/l

24% Density Reduction
2,1mm thickness

$\rho = 0.81$ kg/l

46% Density Reduction
3,0mm thickness

$\rho = 0.57$ kg/l

56% Density Reduction
4,6mm thickness

$\rho = 0.47$ kg/l

Source: LyondellBasell, SFIP Congress 2011
Core back expansion
Choice of Matrix polymer

Delamination with wrong choice of PP

High melt strength PP with good sandwich foam

Source: LyondellBasell, SFIP Congress 2011
Weight reduction in Automotive

APPLICATION EXAMPLES
CFA in structural application
Dashboard carrier

- Reference: BMW 3 and 5 series dash board carrier

- Polymer: PP 20% LGF

- Process: BMW SGI Process
  - Weight Reduction 20%

- 2012 Technology transfer to new BMW models

- 1.5 – 2.0% Hydrocerol®
CFA in application
Air Ducts

- Reference: Audi A8 Air Duct
- Polymer: LDPE
- Part: Air ducts, Blow Molding
- Benefits:
  - Weight reduction (30%)
  - Easier assembly
  - Acoustic insulation
  - Heat insulation

2% Hydrocerol®
CFA in visible application
Much more to come...

- Decorated Gearbox
- Door Panels
- Interior trims
- Wheel Arch
- ...

Decorated Gearbox
Door Panels
Interior trims
Wheel Arch
Conclusions
Conclusions

Chemical foaming …

- is a well-established technology which can be broadly used across multiple plastic processing methods and applications

- allows plastic molders to produce lighter articles without major investments

- can contribute to achieve automotive industry challenges related to CO₂ emissions and overall carbon footprint reduction
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