The PU technology platform for sound attenuation in automotive applications.

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Dr. Chris Skinner, Automotive Platform manager
VDI conference Bad Neuenahr, 24 – 25/01/2007
Huntsman Polyurethanes & European Automotive market trends

Moulded applications: Undercarpet & bulkhead
- What are the trends in this market segment
- How does a PU supplier innovate within this environment:
  - Example: Acoustiflex VEF+

Thermoforming applications: Engine bay & roofliners
- ACOUSTIFLEX® Absorbers
- How morphology drives performance
- Manufacturing of ACOUSTIFLEX® materials
- ACOUSTIFLEX® S, R & F
  - Acoustic characteristics & performance
  - Physical property set

Conclusions
Who is Huntsman?
The Huntsman growth story

Huntsman has been a leader in the consolidation of the global chemical industry

Compounded Annual Growth Rate: ~24%

1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 PF

Revenue ($ in Billions)

- Shell PP
- American Hoechst
- Monsanto MAN/LAB
- Texaco Chemical
- Texaco PO/MTBE
- Packaging Spinoff
- Rexene
- Nova Styrenics Sale
- Dow Ethyleneamines and Rhodia Surfactants
- Vantico
- ICI
- Ciba TE C4 Sale

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Polyurethanes
Who is Huntsman?
Mainly differentiated businesses

## Commodity Chemicals
- **Base Chemicals and Polymers**
  - Ethylene
  - Propylene
  - Cyclohexane
  - Paraxylene
  - MTBE
  - Polyethylene
  - Polypropylene
  - APAO
  - EPS

## Differentiated Chemicals

### Pigments
- Titanium Dioxide

### Performance Products
- Performance Specialties
- Performance Intermediates
- Maleic Anhydride & Licensing

### Polyurethanes
- Adhesives
- Coatings and Elastomers
- Automotive
- Construction
- Composite wood products
- Footwear
- Furniture
- TPU

### Materials and Effects
- **Advanced Materials**
  - Design & Composites Engineering
  - Power & Electronics
- **Textile Effects**
  - Apparel
  - Home textiles
  - Technical textiles

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2005 Revenue: $6,164m

2005 Revenue: $8,638m

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Huntsman Polyurethanes & the European Automotive market trends
EAME Automotive acoustics market: What do we see as the critical drivers in the market impacting polyurethanes?

Mature market

Differential growth rates

Recycling & ELD

Continuous cost down

Enhanced comfort

Weight reduction

Acoustic comfort

Weight reduction

Polyurethanes

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Interesting distribution of technologies, some very competitive areas with the low end under carpet PU foam market being an “ugly” place to be...

Our view of the “under-carpet” market from an OEM perspective….(majority of European EOMs)

Key Points:
- Increasing cost pressure from OEMs
- Trend away from HR to fibre (cost)
- Some conversion to VEF (German OEMs)

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We have a range of technologies to support the challenges our customers face.
Our view of the relative technology share per segment in the undercarpet market. Interesting to see the clear distribution of the VEF technology in upper midsize.
Polyurethanes

An example of innovation in the undercarpet market. Our technology offers a patented, unique balance of E modulus / hardness and 

- E modulus f(CLD)

- E modulus as a function of compression hardness: typical data obtained from machine test plates of 20 mm thickness

- Influence of Modulus on STL: typical data obtained from machine test plates of 20 mm thickness

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When plotting loss factor as a function of hardness...

![Graph showing loss factor versus CLD (40%) for different materials.]

- **loss factor** ACOUSTIFLEX VEF
- **loss factor** ACOUSTIFLEX® VEF*
Interesting to also have a look at emissions, acoustics and “Trittfestigkeit”. The properties can be varied to meet a wide range of specs……

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>ACOUSTIFLEX® VEF⁺</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>g/l</td>
<td>72</td>
</tr>
<tr>
<td>CLD 40% compression</td>
<td>kPa</td>
<td>4.9</td>
</tr>
<tr>
<td>CLD after hydrolysis</td>
<td>% delta</td>
<td>43 % loss</td>
</tr>
<tr>
<td>CLD after 7 days 140°C compression</td>
<td>% delta</td>
<td>no loss</td>
</tr>
<tr>
<td>Compression set after 7 days 140°C</td>
<td>%</td>
<td>9.5</td>
</tr>
<tr>
<td>Compression set after 7 days 140°C</td>
<td>%</td>
<td>11</td>
</tr>
<tr>
<td>Compression set after hydrolysis</td>
<td>%</td>
<td>23</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>kPa</td>
<td>110</td>
</tr>
<tr>
<td>Elongation</td>
<td>%</td>
<td>108</td>
</tr>
<tr>
<td>Hysteresis</td>
<td>%</td>
<td>21</td>
</tr>
<tr>
<td>Loss factor</td>
<td></td>
<td>0.40</td>
</tr>
<tr>
<td>E-Modulus</td>
<td>kPa</td>
<td>45 kPa</td>
</tr>
<tr>
<td>VOC</td>
<td>ppm</td>
<td>65 ppm (typical)</td>
</tr>
<tr>
<td>FOG</td>
<td>ppm</td>
<td>30 ppm (typical)</td>
</tr>
</tbody>
</table>
Huntsman developed these novel absorbers which deliver high sound absorption and thermoformability & stiffness using simple production assets.

Polyurethanes

Morphology closely aligned to fibres

Conventional PU Rigid Foam

ACOUSTIFLEX® acoustic absorber

ACOUSTIFLEX® technology @ density 16kg/m³

Fibre technology @ density 35kg/m³

Conventional flexible foam @ density 40kg/m³

The very good acoustic attenuation properties of spot-welded fibres are matched at lower density by open cell foams.

Material beam deflection low

Same beam material with high deflection

Rigid material designed to be flexible during Thermoforming

Conventional flexible foam @ density 40kg/m³

Fibre technology @ density 35kg/m³

ACOUSTIFLEX® technology @ density 16kg/m³

Conventional PU Rigid Foam

Novel Rigid PU Morphology

Polyurethanes

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Clearly the most interesting feature is the morphology of the foam. Using the technique of x-ray tomography we can show this more clearly:
The technology provides a platform designed to meet the challenge of increased absorption & reduction in mass across a broad range of applications.
The technology is versatile, tunable and competitive against alternative materials

- Broad density range possible
- Capable of meeting a range of fire standards
- Stiff post thermoforming / fewer fixtures
- Excellent acoustics

KEY Points
- The technology is superior in acoustics to alternative technology at significantly lower densities
- The economics of the PU foam process on a green field site are again better than fibre / felt / PU slabstock
- The technology is extremely tunable (acoustics / fire resistance / density)

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“Golden Bucket” Process
- Max shot independent of cream
- Bucket sits on the mould base
- Chemicals fed into the bucket
- Stirrer mixes chemicals [~500 to 800 rpm]
- Bucket & stirrer assembly lifted
- Liquid flows to cover base surface
- Material creams & starts to rise filling mould.
- Block demoulded

Block size & storage
- High exotherm process
- Limited block height
- Not to be stacked on top of each other
- Environment for cooling important
- Standing prior to slitting is important

Typical process route
- Block is produced (discontinuous process)
- After resting period the block is slit to form foam blanks
- Blank is sandwiched between fabric (& glassfibres) as required by application
- Thermoformed in hot press
- Formed composite is cut and packaged

Schematic of process route

KEY ELEMENTS OF PROCESS
- Following the cutting of the block the full absorbance is reached
- No additional processes to enhance the acoustic performance of the ACOUSTIFLEX® material are required
- Capital investment cost is very low to achieve significant volume
What does the acoustic performance look like in an absorption test?
ACOUSTI FLEX® F
System tuning possible across a broad range of features
E.g. Fire resistance, Foam hardness.

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>kg/m³</td>
<td>16 - 25 kg/m³</td>
</tr>
<tr>
<td>CLD 40% - ISO 3386/1</td>
<td>kPa</td>
<td>2.2 - 4.5 kPa</td>
</tr>
<tr>
<td>Tear strength - ISO 8087</td>
<td>N/m</td>
<td>90 - 130 N/m</td>
</tr>
<tr>
<td>Tensile strength - ISO 1798</td>
<td>kPa</td>
<td>44 - 50 kPa</td>
</tr>
<tr>
<td>Elongation - ISO 1798</td>
<td>%</td>
<td>95 - 75 %</td>
</tr>
<tr>
<td>Comp. Set dry 50% Th - ISO 1856</td>
<td>%</td>
<td>38 - 44 %</td>
</tr>
<tr>
<td>FMVSS 302</td>
<td>mm/min</td>
<td>162 - NBR mm/min</td>
</tr>
</tbody>
</table>
Driving down the density as a response to cost pressure, makes the classic mass / decoupler systems have difficulty living up to the specifications, unless……

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ACOUSTIFLEX® F .....we change the way we develop the composite

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ACOUSTIFLEX® R
- System tuning possible across a broad range of features
  E.g. Fire resistance, Foam hardness.

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>23</th>
<th>28</th>
<th>33</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>kg/m³</td>
<td>23</td>
<td>28</td>
<td>33</td>
</tr>
<tr>
<td>Compression hardness - ISO 844</td>
<td>kPa</td>
<td>70 - 80</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>Stiffness - SAE J949</td>
<td>N/m</td>
<td>6</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Tensile strength - ISO 1798</td>
<td>kPa</td>
<td>140</td>
<td>155</td>
<td>180</td>
</tr>
<tr>
<td>Elongation - ISO 1798</td>
<td>%</td>
<td>14 - 18</td>
<td>17 - 20</td>
<td>24 - 28</td>
</tr>
<tr>
<td>Fogging - DIN 75201</td>
<td>%</td>
<td>92</td>
<td>92</td>
<td>92</td>
</tr>
<tr>
<td>Fogging - DIN 75201</td>
<td>mg</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>FMVSS 302</td>
<td>mm/min</td>
<td>72 - 80</td>
<td>&lt; 70</td>
<td>&lt; 70</td>
</tr>
</tbody>
</table>
Kundt tube assessment of standard commercial headliner foam versus ACOUSTIFLEX® R22 (foam samples)

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The materials are also made using the simple batch block process.

“Probably the best headliners in the world”

- Lightweight
- Acoustic
- Phenolic / amine free
- Thermoformable
- Low odour
- Consistent quality
- Clean process
- No needle punching required

Simple process
Relatively low waste
Easy to change system
Low investment cost

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Under-bonnet & Engine Bay Components

ACOUSTI FLEX® S
## Properties range of current systems

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Density</strong></td>
<td>kg/m³</td>
<td>17 - 19</td>
<td>17 - 19</td>
</tr>
<tr>
<td><strong>CLD 40% - ISO 3386/1</strong></td>
<td>kPa</td>
<td>25 - 32</td>
<td>26 - 34</td>
</tr>
<tr>
<td><strong>Tensile - ISO 1798</strong></td>
<td>kPa</td>
<td>60 - 70</td>
<td>65 - 77</td>
</tr>
<tr>
<td><strong>Elongation - ISO 1798</strong></td>
<td>%</td>
<td>17 - 19</td>
<td>15 - 20</td>
</tr>
<tr>
<td><strong>Fogging - DIN 75201</strong></td>
<td>%</td>
<td>86</td>
<td>97</td>
</tr>
<tr>
<td><strong>Fogging - DIN 75201</strong></td>
<td>mg</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>FMVSS 302</strong></td>
<td>mm/min</td>
<td>72 - 80</td>
<td>NBR</td>
</tr>
</tbody>
</table>
A lightweight solution with excellent sound attenuation properties & better low frequency performance vs. fibrous materials

<table>
<thead>
<tr>
<th>type</th>
<th>weight / m²</th>
<th>thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustiflex S</td>
<td>360</td>
<td>20</td>
</tr>
<tr>
<td>Dual density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Felt 1</td>
<td>1840</td>
<td>23</td>
</tr>
<tr>
<td>Felt 2</td>
<td>960</td>
<td>19.2</td>
</tr>
<tr>
<td>Felt 3</td>
<td>1045</td>
<td>20.9</td>
</tr>
<tr>
<td>Felt 3</td>
<td>1020</td>
<td>17</td>
</tr>
</tbody>
</table>

Kundt tube 20mm. Acoustiflex S versus Felt

- Acoustiflex S18F1
- Dual density fibre
- Felt 1 - 1000 gr
- Felt 2 - 1000 gr
- Felt 3 - 1200 gr
A lightweight solution with excellent sound attenuation properties & better low frequency performance vs. alternative foams.

![Absorption coefficient vs Frequency graph for Acoustiflex S vs alternative foams, showing 20 mm foam thickness.](image-url)
Acoustic comfort and weight reduction

- Excellent acoustics
- Interesting CLD / E mod ratio
- Low emission
- Wide hardness range possible
- Good physical properties
- Fast demould time (<80s)

- No additional steps to acoustic activity
- Simple and clean processing
- Less work in progress
- Deep draw potential (elongation >70%)
- Low waste & simple production

Polyurethanes
ACOUSTIFLEX® Conclusions on the technology

- No additional steps to acoustic activity
- Simple and clean processing
- Less work in progress
- Deep draw potential (elongation > 20%)
- High stiffness to allow modular design
- Low waste & simple production
- Reduced debris on airbag deployment
- Superior acoustics

ACOUSTIFLEX®

Acoustic comfort and weight reduction

ACOUSTIFLEX® R

- Fire retardant to a range of standards
- Cost competitive vs felt
- Simple and clean processing
- Not friable
- Deep draw potential
- Low waste & simple production
- Self supporting – fewer clips
- Superior acoustics

ACOUSTIFLEX® S

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My contact details should you have other questions:

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