Engine encapsulation
A synergic approach to exterior noise and CO₂ emissions reduction

Brussels, 18th December 2012
Maurizio Mantovani - Autoneum
Agenda

1. Who is Autoneum

2. Benefits of encapsulation in view of current and future CO$_2$ emission and exterior noise regulations

3. Concepts and materials for engine encapsulation

4. Conclusion
Who is Autoneum?

Autoneum is the global technology leader in **acoustic and thermal management solutions for motor vehicles**.

Competitive strengths:

- Leading provider of integrated solutions for Acoustic and Thermal Management
- Product leadership through technology and innovation
- Long-standing relationships with diversified, broad and balanced customer base
- Global footprint
- Operational excellence to maintain efficient cost structure
## Autoneum at a glance
### Key figures

<table>
<thead>
<tr>
<th>Autoneum Group – stock-listed and independent since May 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
</tr>
<tr>
<td>48</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>9,400</td>
</tr>
<tr>
<td>1,722</td>
</tr>
</tbody>
</table>
1. Who is Autoneum

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Main Factors Influencing Engine Encapsulation

• CO₂ reduction / NEDC / C.A.F.E.
• Exterior noise reduction

Regulation

Final-user perspective
• Real fuel-consumption
• Acoustic/Thermal comfort
• Reduction of engine wear

Technical requirements
• Thermal safety
• Weight balance
• Engine bay architecture
European Regulation 443/2009 on CO\textsubscript{2}

- From 2012 OEM’s that do not fulfill their fleet target will pay a penalty per vehicle per excess gram CO\textsubscript{2} according to following rules:
  - 1\textsuperscript{st} gram = € 5.-
  - 2\textsuperscript{nd} gram = € 15.-
  - 3\textsuperscript{rd} gram = € 25.-
  - Above 4 grams = € 95.-

- Only part of the fleet considered until 2015
  - 65% in 2012
  - 75% in 2013
  - 80% in 2014
  - 100% from 2015 onwards

- From 2019 100% of the fleet charged with € 95 per excess gram CO\textsubscript{2}/km
European Regulation 443/2009 on CO₂

- Regulation applies for passenger cars (category M1*)
- Each vehicle has a specific CO₂-target based on its mass: \(1372 \text{ kg} = 130 \text{ g/km}\)
  
  this values are used for calculating the fleet target, that will be used for the tax

\[
\text{Specific vehicle CO}_2 \text{-emission target} = 130 + a \cdot (M - M_0) \\
\text{a} = 0.0457 \\
M_0 = 1372 \text{ kg} \\
M = \text{vehicle mass}
\]

*) Vehicles used for the carriage of passengers and comprising no more than 8 seats in addition to the driver’s seat

Source: www.transportenvironment.org
Encapsulation for CO$_2$ emissions reduction

The engine is not fully efficient until it has warmed up to operating temperature.

Lubricants/fluids perform best at operating temperature and keep engine friction to a minimum.

Engine encapsulation mainly allows cold start from higher temperature.
Encapsulation for CO₂ emissions reduction

C-segment diesel car

Ambient temperature: -7°C
Engine oil initial temp.: -7°C

Ambient temperature: -7°C
Engine oil initial temp.: 31°C

CO₂ emission reduction during ECE 1: -29%
Overall CO₂ reduction: -13%
5.9. Engine starting temperature

The starting temperature of the engine influences the CO₂ emissions. A higher engine temperature reduces friction losses of the lubricant and moving parts. A percentage reduction factor of CO₂ emissions in relation to a temperature increase of the engine (temperature of coolant) can be given. This value refers to the NEDC including a cold start.

6.1. Potentially qualifying technologies

<table>
<thead>
<tr>
<th>No.</th>
<th>Technology</th>
<th>Technology class</th>
<th>Mean expected benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q01</td>
<td>Engine heat storage</td>
<td>4</td>
<td>1.5 g CO₂/km</td>
</tr>
<tr>
<td>Q02</td>
<td>LED lighting</td>
<td>1</td>
<td>1.3 g CO₂/km</td>
</tr>
<tr>
<td>Q03</td>
<td>Battery charging solar roof</td>
<td>3</td>
<td>1.9 g CO₂/km</td>
</tr>
<tr>
<td>Q04</td>
<td>Efficient alternator</td>
<td>6</td>
<td>0.6 g CO₂/km</td>
</tr>
<tr>
<td>Q05</td>
<td>Thermoelectric generator</td>
<td>5</td>
<td>0.6 g CO₂/km</td>
</tr>
</tbody>
</table>
New Pass-by Noise Regulation
M1 vehicles

Source: ACEA booklet “Setting the right sound level”
Technology trend
Powertrains becoming noisier

Our OEM customers report typical powertrain noise radiation increases of 2-3 dB due to:

- Higher combustion pressure
- Turbo-chargers also in petrol engines
- Direct gasoline injection
- Faster valve actuation
- Lightweight engine construction

However, some effective technologies being introduced, like integration of exhaust manifold in engine block.
Consequences of new pass-by noise regulation and technology trends

Tires are more important in new test method and countermeasures need to be developed to reduce their contribution. However, it seems to be difficult to reduce tire contribution below 68 dB(A). Shielding of tires is difficult to envisage due to technical limitations and users acceptance. With new limits of 68-69 dB(A) it will be therefore necessary to reduce all other noise sources. Powertrain and exhaust encapsulation may be necessary.

Source: LMS European Vehicle Conference 2012
Powertrain exterior noise reduction
Example of NISSAN-Autoneum project

Target from OEM - Reduction of 4 dB(A) of the powertrain exterior noise

• By an encapsulation and absorption treatment in engine bay and underbody

• Which satisfies the operational thermal safety of the components.

Target met at all exterior microphones
Thermal safety guaranteed

Source: ATZ January 2010
Under engine shield
Drag and exterior noise reduction

Up to 5% fuel consumption reduction thanks to aerodynamic underfloor

→ Aerodynamic design (CFD capabilities required)

→ Super-Lightweight materials required

Under-engine shield is a key component for aerodynamic drag and exterior noise reduction
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Two approaches to Engine Encapsulation

**Body-mounted encapsulation**

*Advantages:*
- Well compatible with current vehicle development processes
- Encapsulation far from heat and vibration

*Challenges:*
- Minimize air leakage at pass-troughs
- Mounting sequence
- Large surface to be insulated

**Engine-mounted encapsulation**

*Advantages:*
- Small surface to be insulated
  → Lower material usage
- Closer to heat and noise source
  → Efficiency

*Challenges:*
- More heat and vibration
  → development of new materials
- More difficult to realize due to complex geometries and interfaces
Example of engine encapsulation on the market

Mini Cooper D (2011)

Under engine shield:
RUS™ carrier on front-wheel-drive version.
Injection moulded plastic carrier with noise-absorbing inserts on 4-wheel-drive version

Hoodliner:
Thermoformed slab foam carrier with non-woven face fabric and rear layer, 0.28kg.

Engine side closings:
Noise-absorbing engine side closings, RUS™, 0.41kg (4 parts).
Engine cool-down performance

$\Rightarrow$ CO$_2$ emissions reduction

<table>
<thead>
<tr>
<th>Body mounted</th>
<th>Engine mounted</th>
<th>Body + Engine mounted combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-Segment (Petrol)</td>
<td>B-Segment (Petrol)</td>
<td>B-Segment (Petrol)</td>
</tr>
<tr>
<td>D-Segment (Diesel)</td>
<td>J-Segment (Petrol)</td>
<td></td>
</tr>
<tr>
<td>F-Segment (Diesel)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Segment (Petrol)</th>
<th>Max value</th>
<th>Computed using EU regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-Segment</td>
<td>3.18%</td>
<td>1.70%</td>
</tr>
<tr>
<td>D-Segment (Diesel)</td>
<td>2.11%</td>
<td>0.84%</td>
</tr>
<tr>
<td>F-Segment (Diesel)</td>
<td>1.78%</td>
<td>0.71%</td>
</tr>
<tr>
<td>B-Segment</td>
<td>2.86%</td>
<td>1.76%</td>
</tr>
<tr>
<td>J-Segment (Petrol)</td>
<td>1.48%</td>
<td>0.83%</td>
</tr>
<tr>
<td>B-Segment (Petrol)</td>
<td>3.52%</td>
<td>2.04%</td>
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The need for lightweight

Contribution of driving resistance types to fuel consumption during NEDC of mid-size car

- Weight critical due to rolling and braking losses in conventional cars
- In hybrid and EV, weight must be reduced to allow for heavy battery and extend range

1 kg of vehicle weight reduction = 2.50 to 4.20 € reduction of penalty per vehicle sold in Europe
Materials for engine encapsulation
Lightweight and multifuncional

Theta-Fiber™
Lightweight, thermo-acoustic structural material

- High thermal resistance
- Solid plastic substitution (lightweight)
- Improved vibration behavior
- High acoustic absorption
- Structural properties
- High recycling content

Theta-Cell™
Reduce weight & increase acoustics

- Super lightweight
- Temperature stable
- Acoustic excellence
- Flame resistance
- Glass free, no irritations
- Versatile layer combinations

ThetaFiber
Substitution of solid plastic with integrated absorption and 50% weight reduction

Comparison

<table>
<thead>
<tr>
<th>Frequency [Hz]</th>
<th>200</th>
<th>250</th>
<th>315</th>
<th>400</th>
<th>500</th>
<th>630</th>
<th>800</th>
<th>1000</th>
<th>1250</th>
<th>1600</th>
<th>2000</th>
<th>2500</th>
<th>3150</th>
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<tbody>
<tr>
<td>Absorption coefficient [-]</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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</tr>
</tbody>
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Sound absorption of ThetaCell equal to glass-wool at 50% weight

Average 2591-P01 - Glasswool (Toyota Prius original hoodliner)
Average 2591-P06 - Theta-Cell (B19 P23 22mm->15mm M*)
Ultra Silent ™
Lightweight textile underbody applications
Lightest product on the market for integrated aerodynamic shielding and acoustics

RUS™
100% PET
unique technology product

<table>
<thead>
<tr>
<th>Properties</th>
<th>Super lightweight</th>
<th>Recyclable Glass free, no irritations</th>
<th>Design flexibility to optimize weight and stiffness</th>
<th>Sound absorption</th>
</tr>
</thead>
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Advantages of engine encapsulation

• CO$_2$ and fuel consumption reduction
• CO- und HC-Reduction
  → Catalytic converter reaches operative temperature in shorter times

• Exterior noise
  → Up to 5dB Exterior noise reduction

• Reduction on engine wear
  → Reduction of friction during the cold starts

• Higher Comfort during Winter
  → Faster heat up of the interior of the vehicle, thanks to heat storage
Conclusion

• Storage of heat in the powertrain by means of an engine encapsulation is key to further reducing emissions and fuel consumption during cold starts.

• Engine encapsulation concepts open new potentials for reducing CO₂ and exterior noise simultaneously.

• New engine bay architectures are currently in an early development stage with several OEM’s in Europe and outside Europe.

• To introduce engine encapsulation in a sustainable way one needs to exploit lightweight and multifunctional material technologies.