Oxygen activity measurement in cast iron as a method to improve ecological features of engines.

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In order to meet the European exhaust standards (Euro 0-V on top), the combustion pressure in trucks must be raised to 200 bar [Vollrath 2003].
Increase of the specific performance in time

Bild 1: Anstieg des Spitzendrucks beim Pkw-Dieselmotor, insbesondere seit 1989
Reduce CO₂ emissions

The European car manufacturers (ACEA) agreed to reduce the CO₂ emissions from 180g/km (2002) to 140g/km in 2008.

Three options

- less weight,
- better fuel economy
- raise of the diesel engine share.

The first two objectives can be influenced by cast engines.

The specific mass of a Diesel engine has decreased from about 2,5 kg/kW (1990) to about 1,30 kg/kW in 2002.
An improvement of the fuel economy requires higher peak pressures during combustion.

Increase the internal combustion pressure raises of the specific performance.

Increasing the peak pressure with 10 bar raises the specific performance of the engine with 6,7 kW / liter engine cylinder capacity.
Trends

Future engines will be characterized by
- an increase of the specific performance (Downsizing) and
- a higher peak combustion pressure for diesel engines [Pischinger 2003].

Downsizing can reduce the fuel consumption of a high middle class car by about 25 percent.
Opel Calibra 1994

First motor in Compacted Graphite Cast Iron
Original motor Lamellar graphite cast iron

<table>
<thead>
<tr>
<th>Typ</th>
<th>Cylinder Wall thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6 l, 4-Zylinder-Reihenmotor</td>
<td>13.0 mm</td>
</tr>
<tr>
<td>2.0 l, 4-Zylinder-Reihenmotor</td>
<td>7.0 mm</td>
</tr>
<tr>
<td>2.5 l, 6-Zylinder-V-Motor, Standardversion</td>
<td>6.0 mm</td>
</tr>
<tr>
<td>2.5 l, 6-Zylinder-V-Motor, Rennversion</td>
<td>4.0 mm</td>
</tr>
</tbody>
</table>
Reducing cylinder wall thickness
lower mass, same external motor size
cylinder diameter 87 → 89 mm
for the same cylinder volume →
   smaller displacement of the piston
less friction → more power
less wear

Good experience with racing version → also CGI motor in the standard version
Smaller wall thickness but the same stiffness
E-modulus 130 GPa (LG) → 160 GPa (CG)
The current aluminium alloys and lamellar graphite cast iron have reached their mechanical limits.

With higher combustion pressure, also the internal cylinder temperature goes up from 200°C to 260°C.

Aluminium alloys considerably lose strength above 200°C. Cast iron room temperature mechanical properties remain the same up to 400°C.
Cast Iron

First bridge in cast iron on river Severn (UK) 1781
Cast iron

1948 Nodular cast iron

<table>
<thead>
<tr>
<th>Strength</th>
<th>250 MPa</th>
<th>800 MPa</th>
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</thead>
<tbody>
<tr>
<td>Production</td>
<td>42 M ton</td>
<td>21 M ton</td>
</tr>
<tr>
<td>Al- alloys</td>
<td>12 M ton</td>
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</tbody>
</table>
A new material

Higher strength
Good thermal conductivity
→ excellent material for new engines
But difficult to produce

<table>
<thead>
<tr>
<th>Density (Dichte)</th>
<th>Strength (E-Modul)</th>
<th>Tensile Strength (Zugfestigkeit)</th>
<th>Thermal Expansion (Wärmeausdehnung)</th>
<th>Thermal Conductivity (Wärmeleitfähigkeit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>134%</td>
<td>165%</td>
<td>200%</td>
<td>425%</td>
</tr>
<tr>
<td>37%</td>
<td>60%</td>
<td>98%</td>
<td>112%</td>
<td></td>
</tr>
</tbody>
</table>
A new production control tool
Oxygen activity measurement

Higher strength
Good thermal conductivity
→ excellent material for new engines
But difficult to produce
A new production control tool
Oxygen activity measurement
Heraeus Electro-Nite Belgium

Production window

![Graph showing nodularity vs. oxygen activity](image)

![Production scene](image)