DSC-Materials is a Metal-Matrix-Composite
DSC Al as a Piston Material

(a) Light Vehicle Diesel for OE Market
(b) Forged Lightweight Gasoline Pistons in DSC Al and DSC Mg for High Performance Applications
Light Vehicle Diesel (LVD) Pistons

Turbo-charged direct injection (TDi)
**Light Vehicle Diesel Engines**

**Main Market Driver**
- Emission / Fuel consumption
- Weight / NVH
- Durability/ Reliability

**Technology Trends**

**Engine Technology**
- Combustion development
  - Higher thermal and mechanical load
- Downsizing/higher specific power output
  - Higher thermal and mechanical load
- Filter technology for emissions
  - Higher transient temperatures

**Piston Technology Requirements**
- New materials for high temperatures and pressures
- Improved piston cooling
- Pin bore bushes (if possible)
**Light Vehicle Diesel Pistons**

**Technology Drivers**
- Increased Specific Power / Cylinder Pressure

**New Materials**
- Better Piston Cooling

**Projected: 2010**
- Specific Power: 75 kW/l
- Peak Cylinder Pressure: 200 bar

**Over last 10 years**
- Specific Power increased from 35KW/l to 60KW/l
- Cylinder Pressure from 130 to 180 bar

**FEA risk areas - piston**

**Engine downsizing is continuing!**
- Further reduction of oil consumption
- Particulate filters
- Multi point injection

---

_DSC MATERIALS_
Light Vehicle Diesel Pistons

Increasing Thermal Load results in Increased Piston Operating Temperature

By 2010 – expecting bowl rim temperatures of 430-440°C

Piston Temperature (°C)

Thermal load (kW/cm²)
High cycle mechanical fatigue at elevated temperatures (200-400°C) due to combustion loading with long time exposure to temperature.

Low cycle strain controlled fatigue due to temperature changes in the piston during operation (stop-start, deceleration).
Stress Distribution in the LVD Piston

Piston is essentially trying to bend around the steel pin
High mechanical stresses on bowl and pin hole

FOS = 1.00 @ crack location site
Piston Materials

• Achieving increases in low and high temperature fatigue strength with a new casting alloy is very difficult.

• To increase high temperature strength leads to reductions in ductility, more difficult casting (so more defects), reduced defect tolerance and lower melting temperature.

• All the major piston manufacturers are working on piston alloys but recognise that other solutions are needed if piston temperatures and cylinder pressures keep rising.

• DSC Al is a possible solution for high temperatures and pressures.
  – Very high fatigue strength at highly elevated temperatures
  – High melting point
  – Similar expansion coefficient to current piston alloys
  – Very good thermal stability since only an aluminium matrix + $\text{Al}_2\text{O}_3$
Ultimate Tensile Strength vs Premium Piston Alloy

Very much finer microstructure in DSC Al than in standard cast piston alloy.
A huge improvement over current premium piston alloys at elevated temperatures. Increases in low temperature fatigue strength will be obtained with an alloyed matrix rather than pure Al.
General Properties of DSC-AI with pure Aluminum as Matrix alloy

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>20</th>
<th>100</th>
<th>150</th>
<th>200</th>
<th>220</th>
<th>240</th>
<th>275</th>
<th>280</th>
<th>300</th>
<th>340</th>
<th>350</th>
<th>400</th>
<th>430</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.T.E. [ppm]</td>
<td>16.2</td>
<td>16.8</td>
<td>17.2</td>
<td>17.6</td>
<td>17.7</td>
<td>17.9</td>
<td>18.2</td>
<td>18.3</td>
<td>18.3</td>
<td>18.7</td>
<td>18.7</td>
<td>19.1</td>
<td>19.4</td>
</tr>
<tr>
<td>Therm. Cond. [W/mK]</td>
<td>120.0</td>
<td>118.2</td>
<td>117.0</td>
<td>115.9</td>
<td>115.5</td>
<td>115.0</td>
<td>114.2</td>
<td>114.1</td>
<td>113.7</td>
<td>112.8</td>
<td>112.5</td>
<td>111.4</td>
<td>110.7</td>
</tr>
<tr>
<td>Specific Heat [J/gK]</td>
<td>0.893</td>
<td>0.941</td>
<td>0.971</td>
<td>1.001</td>
<td>1.013</td>
<td>1.025</td>
<td>1.046</td>
<td>1.049</td>
<td>1.061</td>
<td>1.085</td>
<td>1.091</td>
<td>1.121</td>
<td>1.139</td>
</tr>
<tr>
<td>Density [g/cm³]</td>
<td>3.11</td>
<td>3.10</td>
<td>3.10</td>
<td>3.10</td>
<td>3.10</td>
<td>3.10</td>
<td>3.09</td>
<td>3.09</td>
<td>3.09</td>
<td>3.09</td>
<td>3.09</td>
<td>3.08</td>
<td>3.08</td>
</tr>
<tr>
<td>Youngs Modulus [GPa]</td>
<td>138.0</td>
<td>132.5</td>
<td>129.0</td>
<td>126.0</td>
<td>124.0</td>
<td>121.5</td>
<td>119.0</td>
<td>118.5</td>
<td>117.0</td>
<td>113.5</td>
<td>113.0</td>
<td>108.5</td>
<td>105.5</td>
</tr>
<tr>
<td>U.T.S. [MPa]</td>
<td>490.0</td>
<td>400.0</td>
<td>350.0</td>
<td>290.0</td>
<td>270.0</td>
<td>250.0</td>
<td>215.0</td>
<td>210.0</td>
<td>190.0</td>
<td>150.0</td>
<td>140.0</td>
<td>100.0</td>
<td>90.0</td>
</tr>
<tr>
<td>0.2 P.S.</td>
<td>450.0</td>
<td>360.0</td>
<td>310.0</td>
<td>255.0</td>
<td>235.0</td>
<td>215.0</td>
<td>185.0</td>
<td>180.0</td>
<td>165.0</td>
<td>125.0</td>
<td>120.0</td>
<td>80.0</td>
<td>70.0</td>
</tr>
<tr>
<td>10⁷ Fatigue Strength 50% [MPa]</td>
<td>194.9</td>
<td>184.4</td>
<td>177.9</td>
<td>171.3</td>
<td>168.7</td>
<td>166.0</td>
<td>161.4</td>
<td>160.8</td>
<td>158.1</td>
<td>152.9</td>
<td>151.6</td>
<td>145.0</td>
<td>141.1</td>
</tr>
<tr>
<td>10⁸ Fatigue Strength 50% [MPa]</td>
<td>100.6</td>
<td>95.4</td>
<td>92.1</td>
<td>88.8</td>
<td>87.5</td>
<td>86.2</td>
<td>83.9</td>
<td>83.9</td>
<td>82.3</td>
<td>79.6</td>
<td>79.0</td>
<td>75.7</td>
<td>73.7</td>
</tr>
<tr>
<td>10x7 Fatigue Strength 95% [MPa]</td>
<td>100.6</td>
<td>95.4</td>
<td>92.1</td>
<td>88.8</td>
<td>87.5</td>
<td>86.2</td>
<td>83.9</td>
<td>83.9</td>
<td>82.3</td>
<td>79.6</td>
<td>79.0</td>
<td>75.7</td>
<td>73.7</td>
</tr>
<tr>
<td>10x8 Fatigue Strength 95% [MPa]</td>
<td>85.3</td>
<td>80.9</td>
<td>78.1</td>
<td>75.3</td>
<td>74.2</td>
<td>73.1</td>
<td>71.1</td>
<td>71.1</td>
<td>69.7</td>
<td>67.5</td>
<td>67.0</td>
<td>64.2</td>
<td>62.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The strength increases significantly if DSC-AI is infiltrated with an alloy instead of pure Aluminum.
DSC Aluminium for Turbo-charged
Highly Rated Direct Injection Diesel Pistons

Bowl edge insert using DSC Aluminium is the logical way forward
Only use it where it is needed to keep costs down!
Infiltration of DSC Al preform by squeeze casting or low pressure
Piston Material and Product Options

<table>
<thead>
<tr>
<th>Price</th>
<th>Specific power output [kW/l]</th>
<th>Standard Alloy</th>
<th>Premium Alloy</th>
<th>New Material</th>
<th>STEEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-20 Euro</td>
<td>110 120 130 140 150 160 170 180 190 200 210 220 230</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- DSC Al?
- New Material
- Premium Alloy
- Standard Alloy
- STEEL
High Performance Gasoline Pistons in DSC Al and DSC Mg
DSC-Al as a Material for Brake Systems

- DSC-Al is the material of choice for high performance Brake Calipers
- Brake Caliper design is driven by stiffness. DSC-Al shows a 80% increase in stiffness compared to other high performance Aluminum alloys
- DSC-Al is now selected as a material for current and future brake systems for high performance and electro cars
High performance Brake Caliper

DSC-Al is selected as a material of choice by leading brake system companies for brake calipers and other brake system components.

DSC-Al will be introduced for high performance automotive brake calipers.
Aluminum Brake Drum for an electro car

As a material of choice for brake systems it is now selected also for electro car brake components. DSC-Al lightweight and temperature resistance will help the car designer to reduce the weight. Because of the excellent perspective of electro cars in the near future this is a very important application.