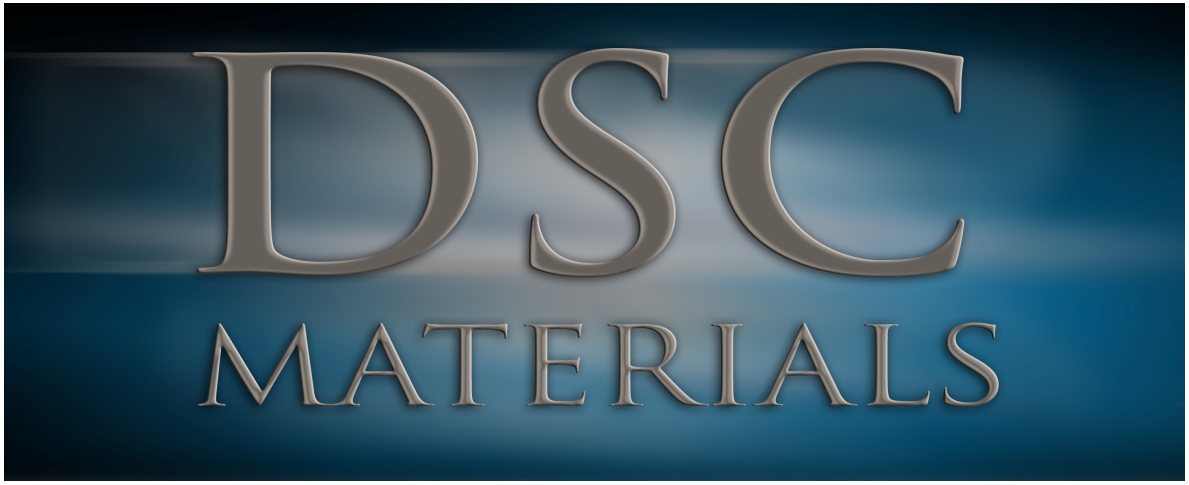
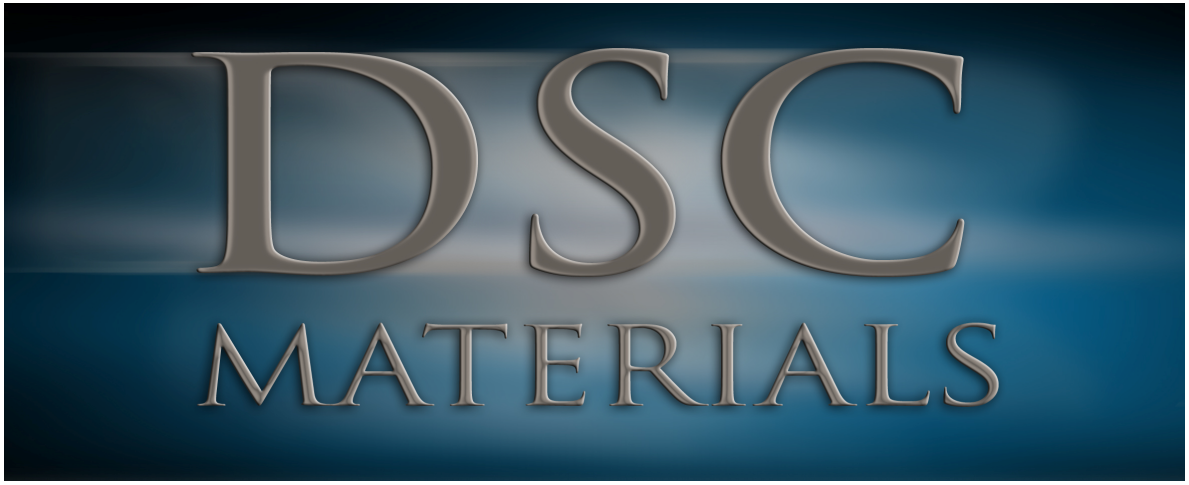


DSC-Materials

is a

Metal-Matrix-Composite



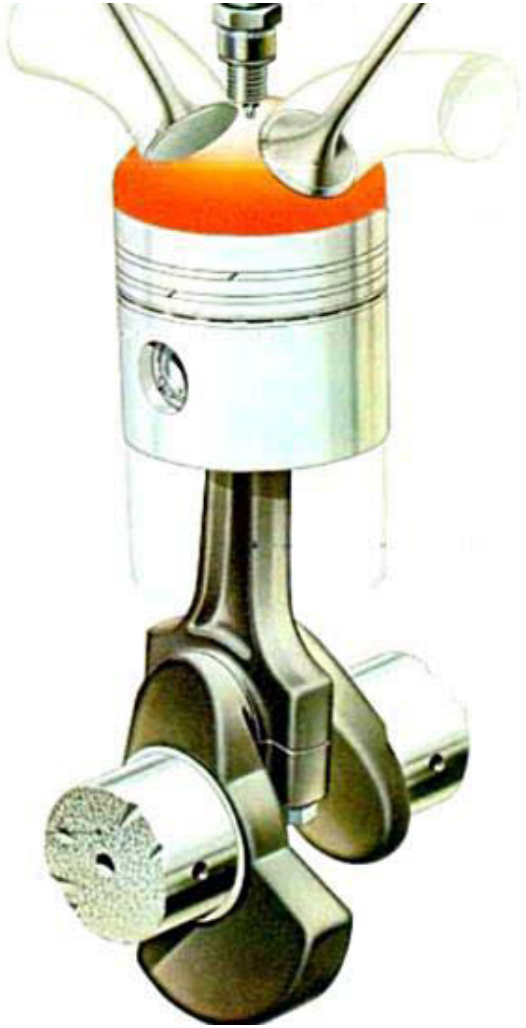
DSC Al as a Piston Material

(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

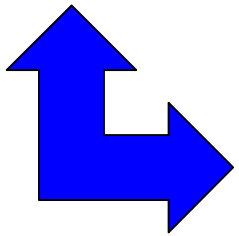
Turbo-charged direct injection (TDi)



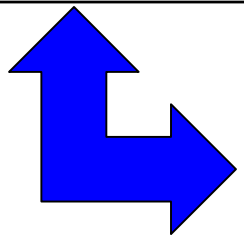
Light Vehicle Diesel Engines

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)

DSC MATERIALS

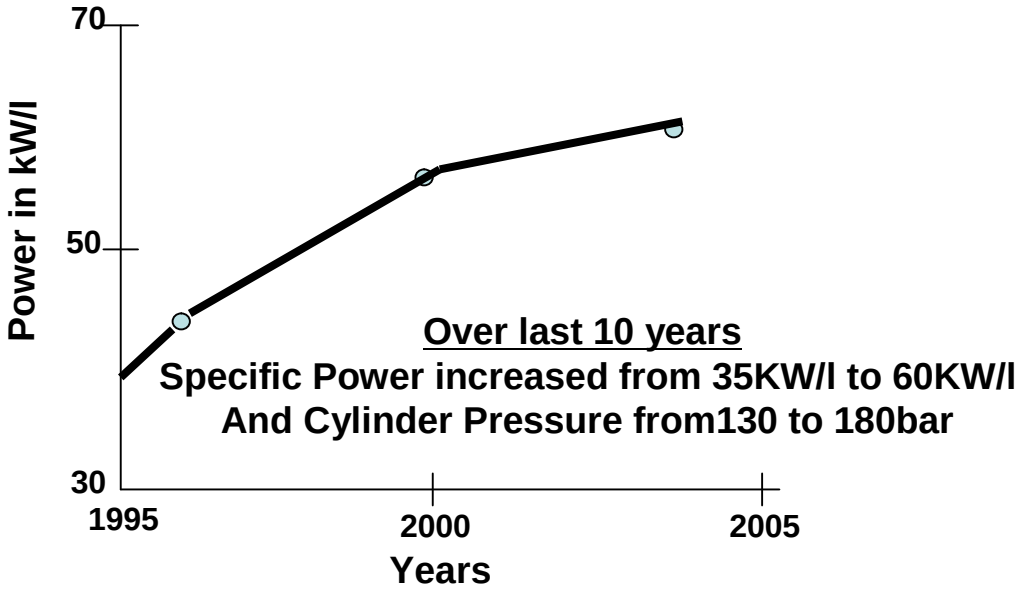
Light Vehicle Diesel Pistons

Technology Drivers

Increased Specific Power / Cylinder Pressure

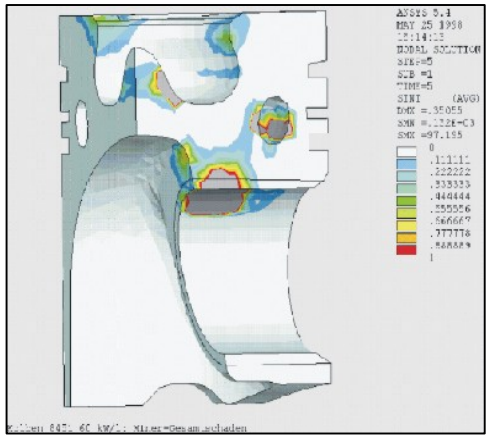
New Materials

Better Piston Cooling



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

FEA risk areas - piston



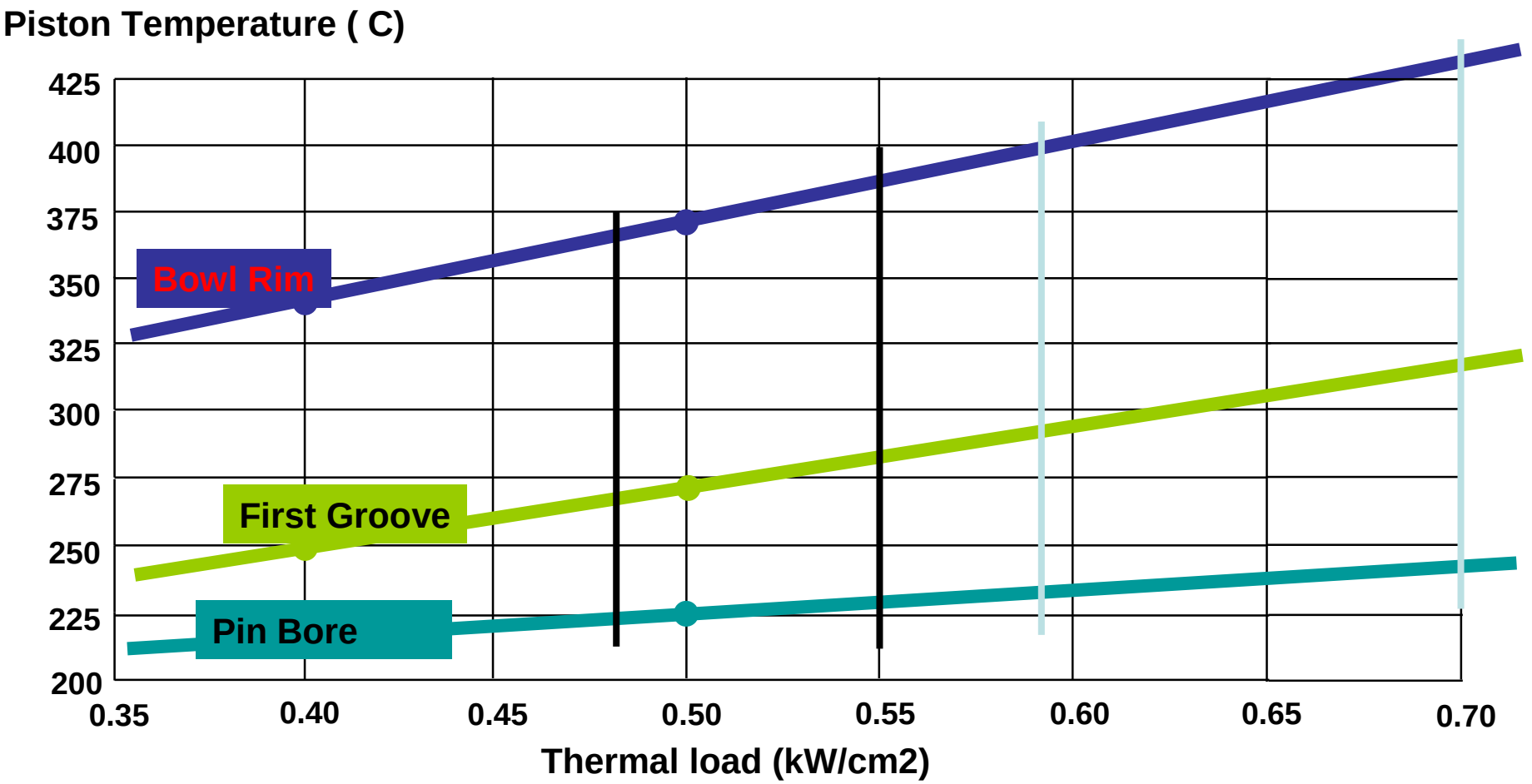
Engine downsizing is continuing!
Further reduction of oil consumption
Particulate filters
Multi point injection

DSC MATERIALS

Light Vehicle Diesel Pistons

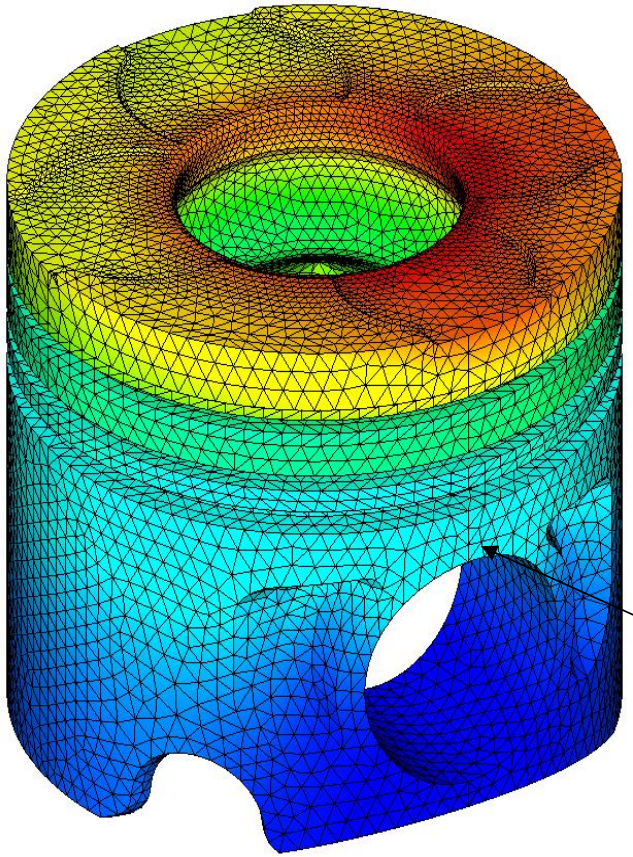
Increasing Thermal Load results in Increased Piston Operating Temperature

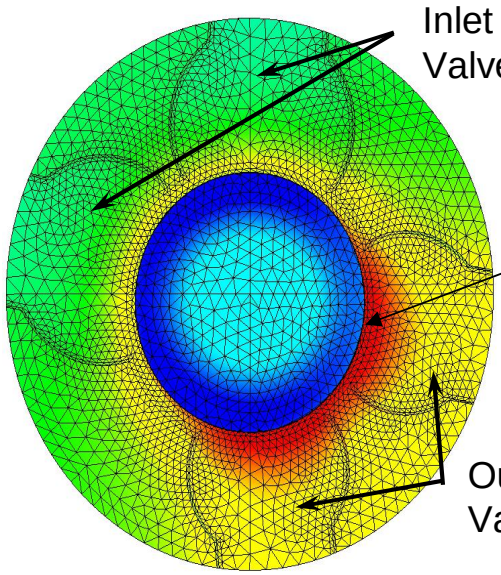
By 2010 – expecting bowl rim temperatures of 430-440 C



DSC MATERIALS

Temperature Distribution in the LVD Piston





410ºC in latest diesel engines in service

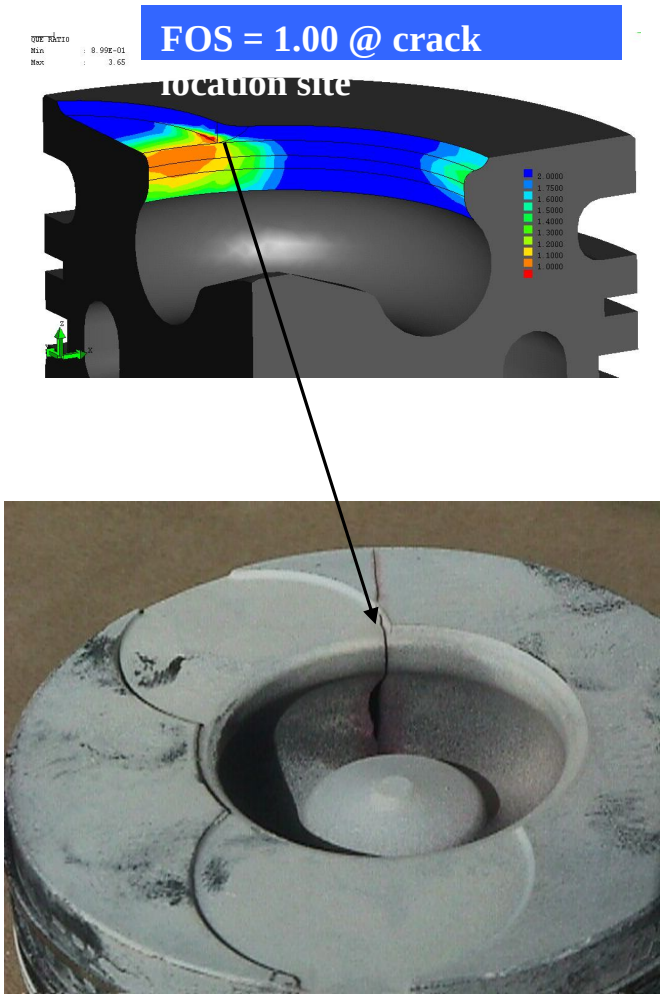
240ºC in latest engines

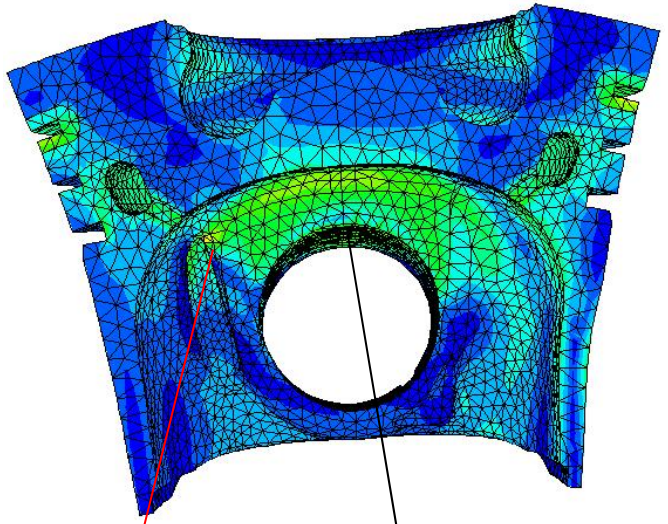
- High cycle mechanical fatigue at elevated temperatures (200-400ºC) due to combustion loading with long time exposure to temperature
- Low cycle strain controlled fatigue due to temperature changes in the piston during operation (stop-start, deceleration)

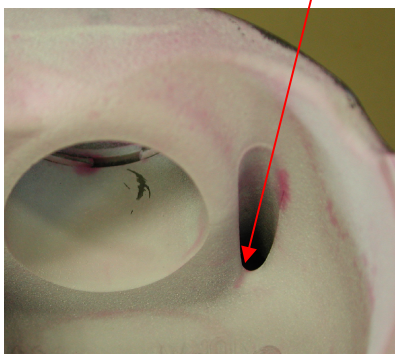
DSC MATERIALS

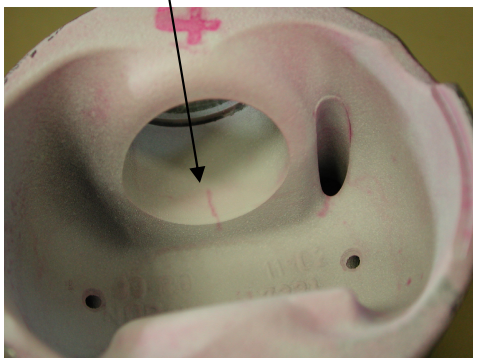
Stress Distribution in the LVD Piston

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







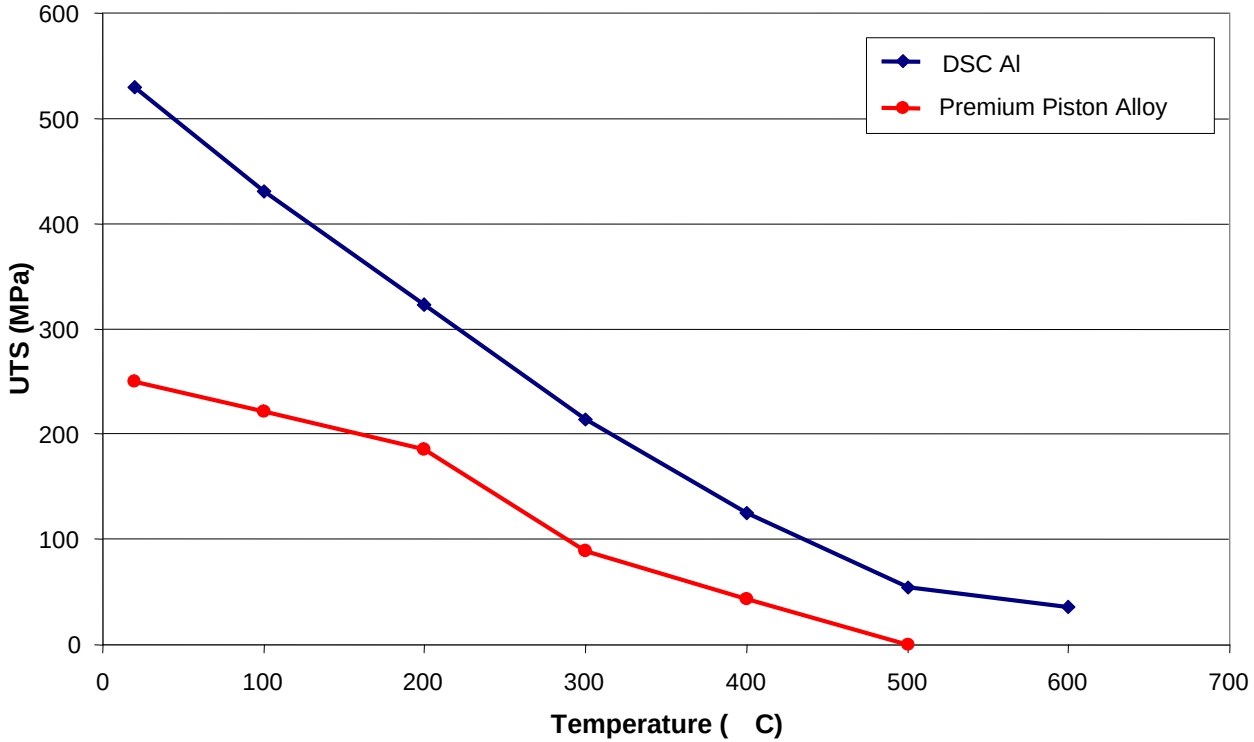


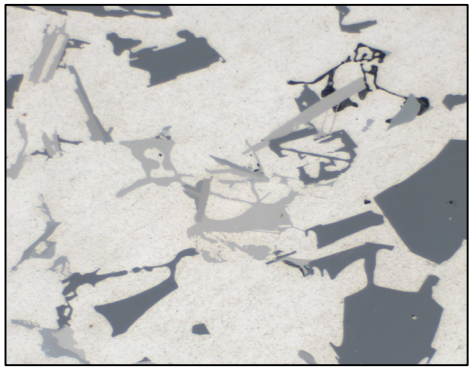
Piston Materials

- 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 + Al_2O_3

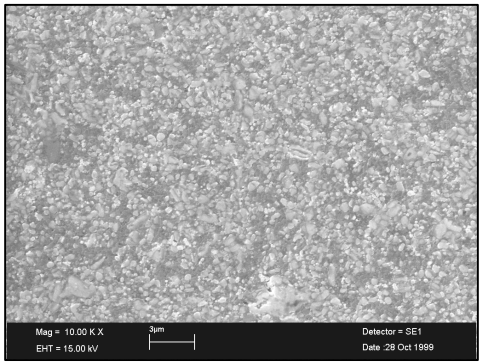
DSC MATERIALS

Ultimate Tensile Strength vs Premium Piston Alloy



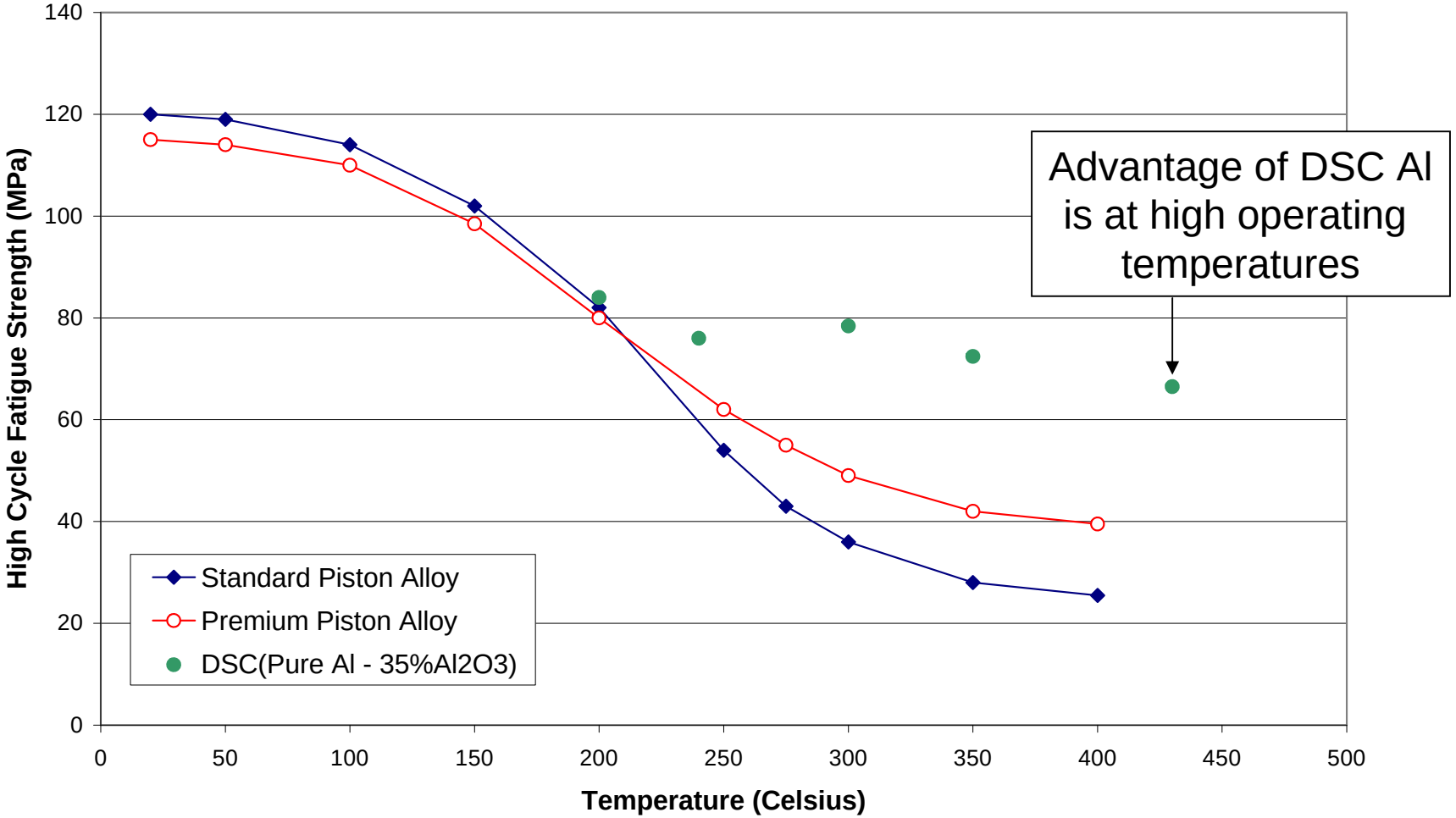


Very much finer microstructure in DSC Al than in standard cast piston alloy



DSC MATERIALS

High Cycle Fatigue Behaviour of DSC Al



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

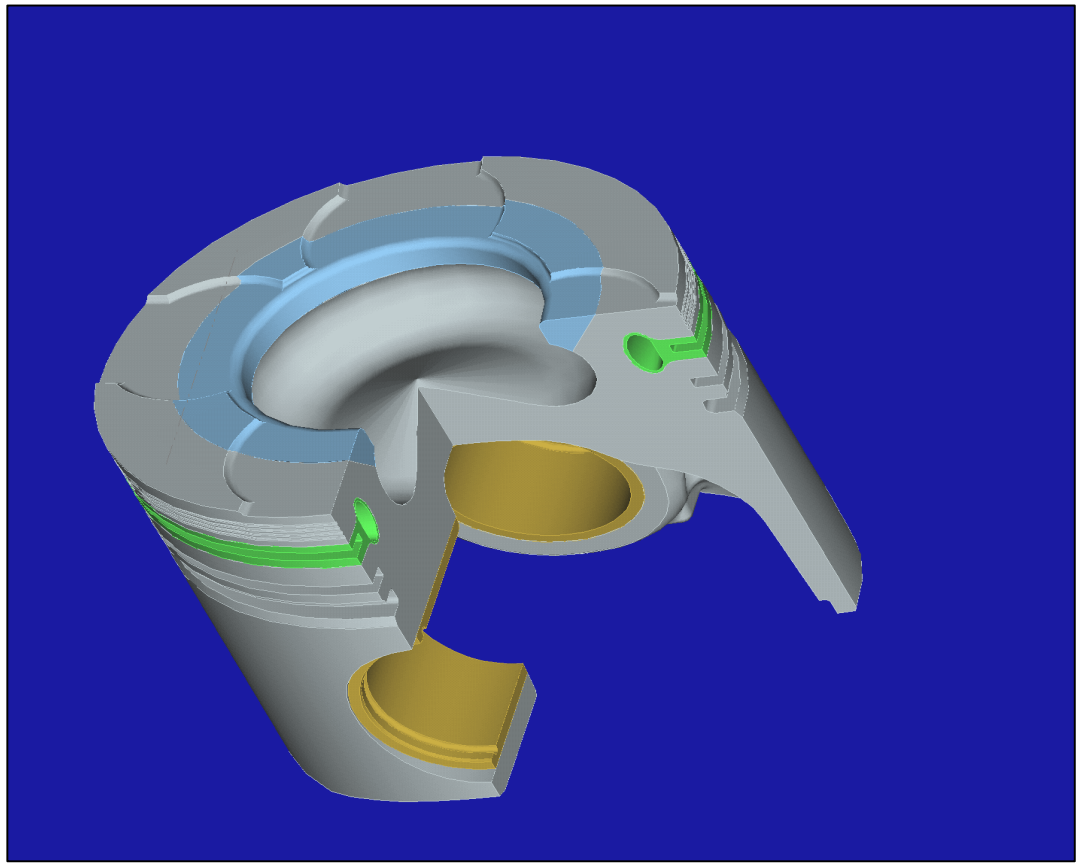
DSC MATERIALS

General Properties of DSC-Al with pure Aluminum as Matrix alloy

Temperature		(°C)	20	100	150	200	220	240	275	280	300	340	350	400	430
C.T.E.		[ppm]	16.2	16.8	17.2	17.6	17.7	17.9	18.2	18.3	18.3	18.7	18.7	19.1	19.4
Therm. Cond.		[W/mK]	120.0	118.2	117.0	115.9	115.5	115.0	114.2	114.1	113.7	112.8	112.5	111.4	110.7
Specific Heat		[J/gK]	0.893	0.941	0.971	1.001	1.013	1.025	1.046	1.049	1.061	1.085	1.091	1.121	1.139
Density		[g/cm³]	3.11	3.10	3.10	3.10	3.10	3.10	3.09	3.09	3.09	3.09	3.09	3.08	3.08
Youngs Modulus		[GPa]	138.0	132.5	129.0	126.0	124.0	121.5	119.0	118.5	117.0	113.5	113.0	108.5	105.5
U.T.S.		[MPa]	490.0	400.0	350.0	290.0	270.0	250.0	215.0	210.0	190.0	150.0	140.0	100.0	90.0
0.2 P.S.		[MPa]	450.0	360.0	310.0	255.0	235.0	215.0	185.0	180.0	165.0	125.0	120.0	80.0	70.0
10^3 Fatigue Strength	50%	[MPa]	194.9	184.4	177.9	171.3	168.7	166.0	161.4	160.8	158.1	152.9	151.6	145.0	141.1
	95%	[MPa]	178.3	167.1	160.1	155.0	151.0	147.0	143.0	143.0	140.0	129.5	127.0	126.0	125.0
10x7 Fatigue Strength	50%	[MPa]	100.6	95.4	92.1	88.8	87.5	86.2	83.9	83.9	82.3	79.6	79.0	75.7	73.7
	95%	[MPa]	91.6	86.1	82.6	81.0	78.5	76.0	73.5	73.5	72.0	68.5	66.5	66.0	65.5
10x8 Fatigue Strength	50%	[MPa]	85.3	80.9	78.1	75.3	74.2	73.1	71.1	71.1	69.7	67.5	67.0	64.2	62.5
	95%	[MPa]	77.9	73.2	70.2	68.5	66.5	64.5	63.0	63.0	61.0	57.5	56.5	56.0	55.5

Note: The strength increases significantly if DSC-Al is infiltrated with an alloy instead of pure Aluminum.

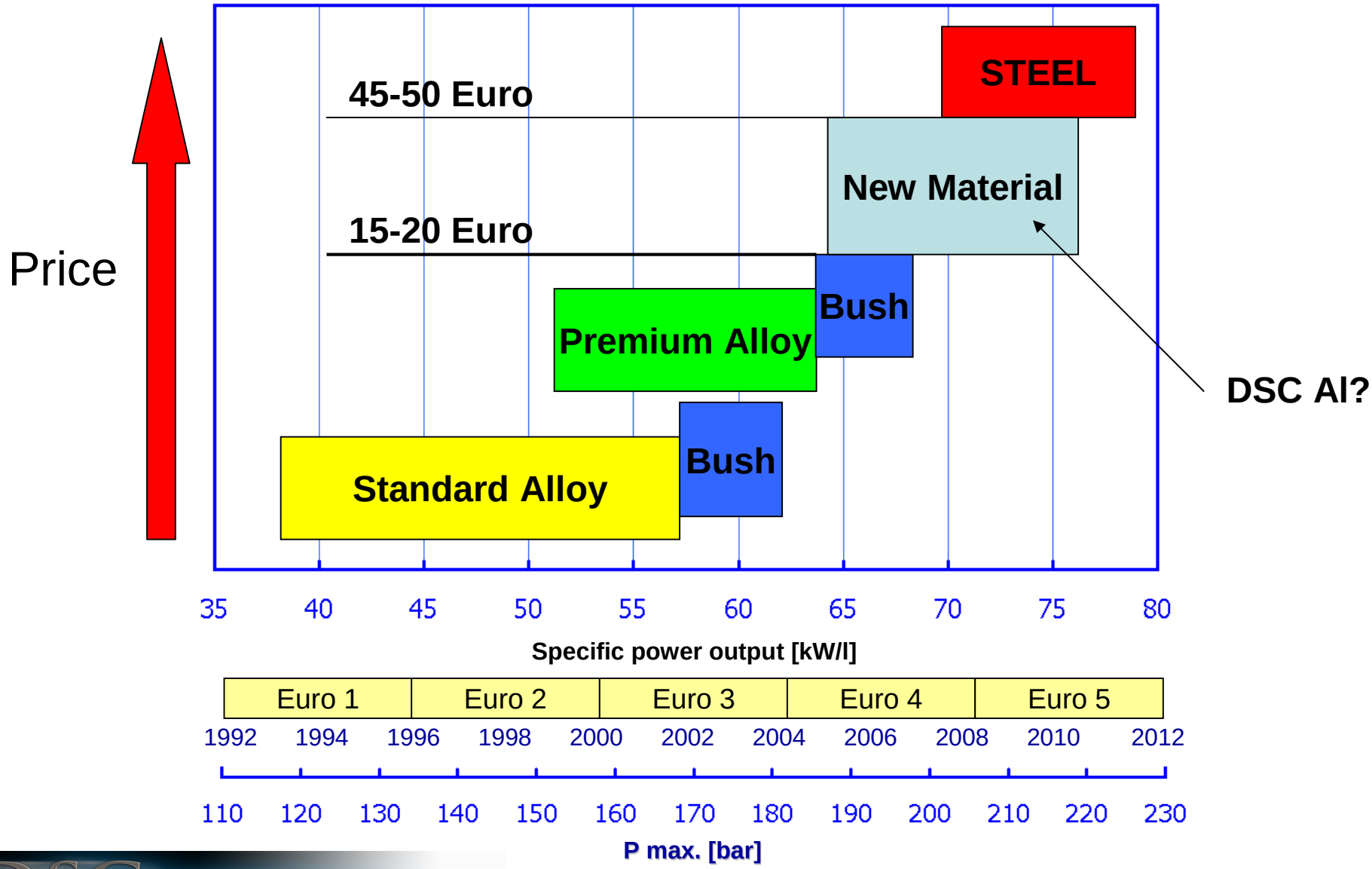
DSC Aluminium for Turbo-charged Highly Rated Direct Injection Diesel Pistons



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

DSC MATERIALS

Piston Material and Product Options



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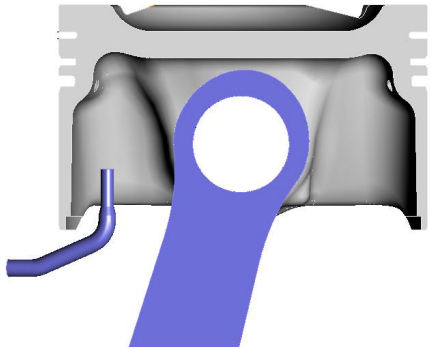

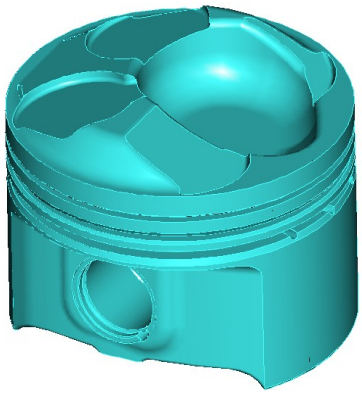

High Performance Gasoline Pistons in DSC Al and DSC Mg

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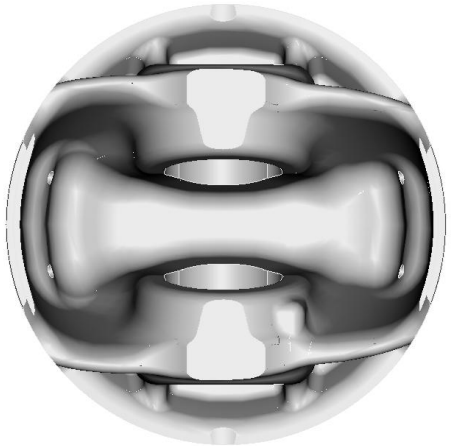

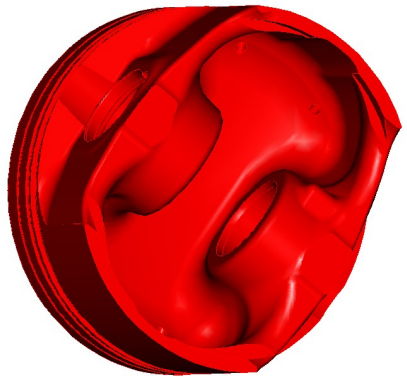

DSC-Al as a Material for Brake Systems

- 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.