AN UPDATE ON THE 
DIESEL EXHAUST AFTERTREATMENT (DEXA) CLUSTER 
OF THE EU GROWTH PROGRAMME


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The present cluster of projects is aiming at providing a complete and integrated approach at the European level, on passenger vehicle diesel exhaust aftertreatment, with emphasis on particulate emissions control for Euro IV and beyond, emission standards.
A systems approach to diesel emission control

Fuel/Lube oil
- Effects of Sulfur - content/composition on emissions and aftertreatment system

In-cylinder measures
- Advanced Fuel Injection
- Combustion mode

Real time soot nanoparticle measurement

Exhaust Aftertreatment System
- Novel device designs (filters, catalysts)
- CAE tools for system Design/Optimization/Control (traps, DeNOx system, Ox. Cat.)

Size/Composition
- Raw vs. Dilute
The cluster consists of 4 projects involving 15 partners from 7 different European countries with long-term R&D experience in Diesel exhaust aftertreatment and engine technologies.
DEXA Cluster Projects

The DEXA cluster focuses on 3 aspects of diesel particulate emissions:

- component technology integration in two demonstrator vehicles (Project ART-DEXA)
- system design and simulation tools (Projects SYLOC-DEXA, STYFF-DEXA)
- quality assessment and measurements of nanoparticles (Project PSICO-DEXA)
ART-DEXA
DURATION: 1/2/2000-31/1/2003
Coordinator: Gianmarco Boretto
CR FIAT

SYLOC-DEXA
DURATION: 1/2/2000-31/1/2003
Coordinator: Peter Prenninger
AVL List GmbH

STYFF-DEXA
DURATION: 1/5/2002-31/04/2005
Coordinator: Wilhelm Branstaetter
U. LEOBEN

PSICO-DEXA
DURATION: 1/1/2000-31/12/2002
Cluster Coordinator: Athanasios G. Konstandopoulos
CERTH/CPERI
DEXA CLUSTER STRUCTURE -1

PSICO-DEXA
Particle Size & Composition
• Assessment and benchmarking of methods
• Assessment of engine management effects
• Assessment of aftertreatment technologies effects

DELIVERABLE:
M&T methodology for quality assessment of Diesel Exhaust Particulate Aftertreatment Technology

ART-DEXA
Advanced Regeneration Technologies
• Basic trap selection and materials screening
• Active regeneration measures screening
• Trap and control system manufacturing
• Bench performance testing-integration with DeNox technology
• Vehicle performance testing
• Demonstrator

DELIVERABLE:
Demonstration of reliable and cost-effective Diesel Exhaust Particulate Aftertreatment Technology

SYLOC-DEXA
System Level Optimization and Control
• Sub-module development
• Validation data for sub-modules
• Simulator development
• Simulator validation and system optimization
• Optimized demonstrator design

DELIVERABLE:
Efficient and cost-effective concurrent engineering design tools for Diesel Exhaust Aftertreatment Technology

Cluster of Critical Technologies: Diesel Exhaust Aftertreatment (DEXA)

STYFF-DEXA
Cluster of Critical Technologies: Diesel Exhaust Aftertreatment (DEXA)

**STYFF-DEXA**
Dynamic Flow Analysis in Foam Media
- **Reconstruction** methods for foams
- **Lattice-Boltzmann** flow solver
- **Particle Submodule** development
- **Acoustics submodule** development
- **Simulator validation** and interface to SYLOC-DEXA

**DELIVERABLE:**
Validated simulation tool for particle filtering and acoustics application of foams in Diesel Exhaust Aftertreatment Technology

**OTHER PREMTECH PROJECTS**

**OTHER EU PROJECTS**

**FUTURE PROJECTS**

**EW PROJECT**
ART-DEXA Summary

É Basic Trap Selection and Material Screening
É Different trap concepts have been investigated both internal and external to the project
É Three promising component technologies have been selected for further development for demonstrator vehicles

É Active Regeneration Measures Screening
É Active engine management leading to regeneration potential and its effect on fuel consumption and driveability has been studied

É Trap and Control System Manufacturing
É Filter operation, diagnostics and control algorithms have been developed and programmed
É Control system manufacturing is achieved
SYLOC-DEXA Summary

É Submodel procurement is completed
  - Filters
  - Catalysts

É Database of component technologies is in place
  - Exhaust system layouts
  - Filter materials and configurations
  - Catalysts

É Computational interfaces/platforms defined
  - Engine cycle simulation
  - Exhaust pipe CFD
  - Filter/Catalyst parameters

É Validation Data collection in progress
  - Emission control components procured and tested
  - System lay-out for vehicle demonstrators completed
PARTICULATE EMISSION CONTROL SYSTEMS: EXPERIMENT AND SIMULATION

Experiment: juggled lines  Simulation: Solid lines

Engine speed: 2400 rpm  Load: 50%
Kick-off was in July 2002

Emphasis is on novel computational techniques for soot aggregate transport and reaction in porous media in a parallel computing environment.

Particle Emission Control as well as Noise-Abatement is studied employing porous cellular structures.

Results will be incorporated into the SYLOC-DEXA toolkit.
PSICO-DEXA Summary

É Size measurement techniques
   É Mobility techniques define the standard and real time performance has been demonstrated (TDMPS). New analysis to connect number and mass based distributions for fractal particles
   É Multiwavelength optical techniques are promising

É Composition measurement techniques
   É Baseline/Post-catalyst/Post filter changes of particles studied with emphasis on sulfate formation
   É Neutron activated Gamma-ray spectroscopy for trace elements on particles is demonstrated

É Joint size-composition measurement techniques
   É Thermophoretic Sampling/AEM, Size specific photoelectric yield, and size specific gamma-ray spectroscopy are developed and applied

É Assessment of Engine Management & Aftertreatment Effects
   É Strategies and aftertreatment technologies based on ART-DEXA
   É Assessment of technologies under normal and regeneration operation
DEXA CLUSTER DELIVERABLES (March 2003)

- **ART-DEXA**
  - Two optimized vehicle demonstrators with advanced particulate emission control

- **SYLOC-DEXA**
  - Exhaust aftertreatment system simulator tool and its application for the optimization of demonstrator system layout

- **PSICO-DEXA**
  - Database of engine management and emission control technology effects on particle size & composition

- **STYFF-DEXA**
  - Validated computational engine for reconstruction of porous cellular structures
UNIVERSAL LOGNORMAL SIZE DISTRIBUTION-1
1.9L Turbo Diesel DI engine with conventional fuel injection

\[ S_g = 1.85 \pm 0.04 \]

6 operating points:
- 2400rpm & 91.5Nm
- 1500rpm & 75Nm
- 1500rpm & 35Nm
- average
- 1700rpm & 70Nm
- 2000rpm & 120Nm
- 2700rpm & 90Nm
1.9L Turbo Diesel DI engine with common rail fuel injection

- 3500 rpm & 150 Nm
- 2500 rpm & 95 Nm
- 2050 rpm & 95 Nm
- 2050 rpm & 47 Nm
- 4000 rpm 105Nm
- 2400 rpm 91.5Nm
- 1500 rpm 75Nm
- 1500 rpm 35Nm
- 2050rpm 140Nm
- 3000rpm & 180Nm
- 2500rpm & 186Nm
- 2050rpm & 187Nm
- 3000rpm & 140Nm
- 2050rpm & 140Nm

average

\[ S_g = 1.88 \pm 0.09 \]
UNIVERSAL LOGNORMAL SIZE DISTRIBUTION
Comparison to Literature

- CR-engine
- Conventional engine
- Harris & Maricq (2002) lower limit
- Harris & Maricq (2002) upper limit
DMA-PAS/DC IN SERIES SETUP
FOR SIZE RESOLVED COMPOSITION MEASUREMENT

Exhaust pipe

150 C

Rotary diluter

Impactor 2.5 μm

85Kr neutraliser

DMA

85Kr neutraliser

PAS

DC

UCPC
FUCHS SURFACE OF A DIESEL AGGREGATE

\[
\text{Fuchs}(x) = \rho x^2 1.657 \frac{\text{Kn}(x)}{\text{SCF}(x)} = \bar{e} \rho x^2 1.657 \text{Kn}(x) x^2 \sim x
\]

\[
\text{Kn}(x) = \frac{2I}{x} \quad I = n \sqrt{\frac{\rho MW}{2RT}} \quad \text{SCF}(x) = 1 + \text{Kn}(x)(1.257 + 0.4e^{-\frac{0.4}{\text{Kn}(x)}})
\]

<table>
<thead>
<tr>
<th>Mob. Diam.</th>
<th>Mob. surface</th>
<th>Number of primary particles in aggregate</th>
<th>Fuchs surface</th>
<th>Fractal aggregate surface</th>
<th>Fuchs fractal aggregate surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_m$</td>
<td>$pD_m^2$</td>
<td>$N_A = k_m(D_m/d_0)^{1.82}$</td>
<td>$\text{Fuchs}(D_m)$</td>
<td>$N_A pd_d^2$</td>
<td>$N_A \text{Fuchs}(d_0)$</td>
</tr>
</tbody>
</table>
FRACTAL PREFACCTOR OF DIESEL AGGREGATES: SMPS vs. LPME* CORRELATION

The SMPS vs. LPME correlation is the same for:

$$N_A = k_m \left( \frac{2R_m}{d_0} \right)^{D_f}$$

- $k_m = 3.9$ \* $D_f = 1.82$ \* $d_0 \approx 32$ nm or
- $k_m = 1.76$ \** $D_f = 2.4$ \** $d_0 \approx 32$ nm

* If particles are DLCCA clusters
** Based on mass vs. mobility measurements of Kittelson & McMurry (2002)

Konstandopoulos et al. (2001)* If particles are DLCCA clusters

Based on mass vs. mobility measurements of Kittelson & McMurry (2002)
Example calculation for

\[ N_A = k_m \left( \frac{2R_m}{d_0} \right)^{D_f} \]

\[ k_m = 3.9 \quad D_f = 1.82 \]
PAS/Total Fuchs Fractal Area For Different Engine Loads

- 1500 rpm 5 bar
- 1500 rpm 2 bar

PAS/Fuchs Fractal Area (fA/nm²/cm³)

Mobility Diameter (nm)
BEYOND THE DEXA-CLUSTER

In response to the EU CALL FOR Expressions of Interest (6/02) the DEXA CLUSTER Partners have formed the

ECONET
Network of Excellence to address the

NEEDS FOR FUTURE EMISSION CONTROL SYSTEMS

- Compactness (size reduction by > 50%)
- Cost (target to be defined in €/kW of engine power)
- Flexibility and tolerance to new fuels and engines