DPF System S-Cube (S³ : Soot Solving System)

- MLF Volumetric Filtration and Active Regeneration

New Generation in Diesel Particulate Filter

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KT Mark Award
(2004. 6.)

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Object

Introduction

- CATech Inc.

- DPF system S-Cube
Profile of CATech Inc.

“Clean Air for our Descendants”

Company Vision

Leading Company with Innovative Technologies in Energy / Environmental Application for Clean Air

Main Product / Technology

Diesel Particulate Filter System (DPF)

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"Clean Air for our Descendants"
### Facts on **structured ceramic monolith filters**

#### Structured Ceramic monolith filter

#### Typical Active DPF system
(Fig. from DieselNet)

<table>
<thead>
<tr>
<th>Performance</th>
<th>High reduction efficiency with <del>100 % for soot and 80</del> 95% for PM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Durability Problem</strong></td>
<td>Thermal stress and crack propagation during regeneration process due to non-homogeneous filtration and heating</td>
</tr>
<tr>
<td></td>
<td>Special regeneration algorithm, essential for active DPF system (longer and slow regeneration)</td>
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<td></td>
<td>Surface filtration method, results in rapid pressure increase</td>
</tr>
<tr>
<td><strong>Price and maintenance</strong></td>
<td>High price (with catalyst)</td>
</tr>
<tr>
<td></td>
<td>Periodic cleaning and replacement of filter due to ash accumulation</td>
</tr>
</tbody>
</table>
**DPF system with catalyst**

- **General consent**
  - Durability problem, related to structured monolith filters, is occurred by periodic regeneration process in active DPF system, even with specially prepared regeneration algorithm and flow control valves.
  - Thus passive DPF system, such as continuous regeneration system by catalyst, may be the solution.

- **Drawbacks**
  - (a) ULSD
  - (b) Limitations
    - Exhaust temperature
    - PM emission level
    - Installation location
  - (c) High price

New DPF system is often sought.
Need for new DPF system with different concept
.... specially in Korea

- Demonstration program in Korea
  - ‘97~’98 : 1,400 Garbage trucks in Seoul
  - 4 DPF systems using structures filters
  - Installed after severe certification processes
  - Failed

- 15 years research experience
  - “Flame propagation within porous ceramic medium”
  - Limit on durability with structured ceramics !!

- System price in Korea
  - Feasible and economical price
Imagine

Sand, ..... Sand layer ......

Can it be used as DPF filter ?

.... Small granular chip can be used as filtering material for Nano-size DPM ??

Let us change DPF filter concept ...
Introduction of S-Cube:

Active DPF system,

Newly Certified

and Commercialized

S³ (S-Cube : Soot Solving System)
Volumetric filtration of Diesel PM by MLF (Multi-Layered Filter) of Ceramic Granular Chip and its Integration into Active DPF system

MLF (Multi Layered Filter)
- Innovative MLF design method and manufacturing
- Reduction over 95~100% for soot and 70~99% for PM
- High design flexibility on filter shape and efficiency
- Unique solution for filter durability problem
- Highly economical DPF system due to low filter cost
- Favorable and slow pressure increase rate
- Large loading capacity, regeneration at 300~700 Km driving
- No limitations on fuel, exhaust temperature and PM loading
- Muffler function

Regenerator (In-line burner)
- Quick regeneration within 6~15 min.
- Use only exhaust gas as oxidizer
- ~350 cc fuel for each regeneration

ECU & Actuators
- Independent system
- Optimized software
**MLF - Filtration Mechanism**

Back pressure increase $\propto$ due to filter structure + due to PM filtration

Ceramic filter (Surface filter)
- mean pore size: $\approx 12.5 \, \mu m$
- filter thickness: $\approx 0.7 \, mm$

$\Rightarrow \Delta P \propto$ mainly due to PM filtration
$\Rightarrow$ Steep increase with high PM filtration

**< Surface filtration by other structured filters >**

CATech MLF filter (Volumetric filtration)
- mean pore size: $100 \sim 1,000 \, \mu m$
- filter thickness: $> 20 \, mm$
- different chip size and thickness for layers

$\Rightarrow \Delta P \propto$ mainly due to filter structure
$\Rightarrow$ Slow increase even with high PM filtration

**< MLF filtration - unstructured filter >**
As the size of PM is reduced, it can be guessed that
- **Filtration by Diffusion** will be enhanced even with present MLF filter.
- **Thus it could be the solution for Nano-particle problem, which is difficult to expect from other structured (surface filtration type) filter systems.**
**S-Cube : 4 years development**

Filter with MLF type
(SC-060MB, ~7L)
- D = 26cm, L=45cm, 32Kg
- Annular type cylinders
- PM capacity : ~40 g/Reg.
S-Cube : DPF System – In-Line Burner Regeneration

Regeneration
- Every 300~700Km
- at engine idling
- manually starting
- ~6 min~15min.
- ~350cc Diesel fuel
S-Cube : DPF System – Electric Heater Regeneration

Regeneration
- at engine stop
- 220vAC External power
- ~6.0 Kwh (60 min.)

<Control Box & Air Compressor>  <Switch Box>  <Signal gage>  <Signal lamp>
MLF – Design Parameters

A. Design aspects
- Chip Size Distribution, Df
- Layer Thickness, L
- Filtration Area, (velocity u)

B. Environmental aspects
- Particulate Size Distribution (dp)
- Temperature
- Engine displacement and RPM (velocity u)
- Local/total filtered mass of particulates (porosity)

Calculated local filtration rate for various sizes of particulate in layered clean filter at a typical flow condition.
MLF - Design

- Design with Nano-size PM movement analysis
  → for filter surface area, thickness, pressure drop and efficiency.
Driving with S-Cube DPF

- Pressure, $P$, increases with PM loading during real road driving.
- Mass of filtered PM, $M_s$, is calculated by pressure, RPM and temperatures.
- $T_f$ and $T_o$ represent temperatures before and after the filter, respectively.
- Vehicle: 4,330 cc NA ISUZU ELF truck - 0.5 g/kwh PM emission by Japan D-13 mode.
- Driving: In urban area of Tokyo.
Regeneration by In-line burner

Fuel penalty due to regeneration:
- ~ 350cc for each regeneration for SC-060MB DPF system (~7L Engine)
- If regeneration at every 350 Km with fuel mileage of 10Km/L vehicle → 1% fuel penalty.
**S-Cube: Performance**

*Official performance test data from Japan and Korea test centers*

### Test data at Tokyo Metropolitan Environment Research Institute

#### Japan D-13 mode: (PM 91% ↓)

<table>
<thead>
<tr>
<th></th>
<th>CO (g/kWh)</th>
<th>HC (g/kWh)</th>
<th>NOx (g/kWh)</th>
<th>CO2 (g/kWh)</th>
<th>PM (g/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>装着前</td>
<td>3.33</td>
<td>0.21</td>
<td>4.21</td>
<td>1340</td>
<td>0.45</td>
</tr>
<tr>
<td>装着後</td>
<td>3.82</td>
<td>0.19</td>
<td>4.03</td>
<td>1360</td>
<td>0.04</td>
</tr>
</tbody>
</table>

#### Japan 10・15 mode: (PM 85% ↓)

<table>
<thead>
<tr>
<th></th>
<th>CO (g/km)</th>
<th>HC (g/km)</th>
<th>NOx (g/km)</th>
<th>CO2 (g/km)</th>
<th>燃料消費率 (km/L)</th>
<th>粒子状物質 (g/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>装着前</td>
<td>0.61</td>
<td>0.12</td>
<td>0.90</td>
<td>258</td>
<td>10.1</td>
<td>0.05</td>
</tr>
<tr>
<td>装着後</td>
<td>0.68</td>
<td>0.13</td>
<td>0.88</td>
<td>266</td>
<td>9.80</td>
<td>0.01</td>
</tr>
</tbody>
</table>

#### Smoke test with load: (100% ↓)

#### Smoke test by free acceleration: (100% ↓)

*Power output reduction: less than 2% with D-13 mode test*
S-Cube: Strength - Economical DPF system without any limitations

1. Free of durability problem
2. No limitation on fuel, exhaust temp., PM level
3. Solution for Nano-PM problem
4. Quick and intensive regeneration
5. Economical active DPF system
**S-Cube : Drawback**

1. **Heavy and large:**
   ~ due to the reason that to make same pressure level with other structured filters.

2. **High CO/HC emission at the moment of burner start-up**
   ~ plan to apply “Clean-up catalyst” to one of filter layers.

Categorized by regeneration method

- DPF system with In-line burner – exported to Japan retrofit market
- DPF system with electric heater regeneration  (external electric power)
- DPF filter only on vehicle + external hot gas supplier (available in Dec. ’04)

Application

- Retrofit
- OEM
- Diesel generator
- Construction engines and vehicles
- Ship and locomotive engine
MLF - High Technology Potential

- Solution to Nano-particle PM reduction due to diffusion filtration mechanism
- Economical and durability free filter system, sustainable to rapid and intense heating
- Various functional catalysts, applicable to each layer of MLF
- Design flexibility for various shape, efficiency and size
- Engineering potential for various applications such as locomotives and ship

Working with HMC (Hyundai Motor Company) for OEM

MLF

Catalyst + Post-Injection

Reduction to small size with Continuous regeneration

Closest position to engine

HC-SCR + Plasma

→ Dual PM/NOx reduction system for retrofit
DPF retrofit market in Korea

- Starting on Jan. 2005
- Market size for DPF/DOC : ~1,200 million(USD) till 2012 (50% from Gov.)
- 150,000Km or 3 yr. Warranty
- Bus and trucks with high PM and (or) low temperature (~Euro-II)
- Expected DPF system price for 12L engine : ~about $6,500 (USD)

DPF Maker in Korea with products (2004. 8)

- CATech Inc. (Active type DPF)
- SK (CRT type DPF)
Thank you very much!

CATech Inc. is looking for the best partner for Europe DPF market,...