DPF System S-Cube (S³ : Soot Solving System)
- MLF Volumetric Filtration and Active Regeneration

New Generation in Diesel Particulate Filter

In-Gweon Lim
CATech Inc.
(Clean Air Technology)
www.CATech.co.kr

Dept. of Mechanical Eng.
Myong-Ji Univ.
KOREA

Japan Certification (2004. 1.)
KT Mark Award (2004. 6.)
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)

- Address: San 38-2, Nam-dong, Yong-In, Kyunggi-do, 449-728, Korea
- URL: www.CATech.co.kr
- E-Mail: iglim@catech.co.kr
- Tel/Fax: +82-31-336-6436 / +82-31-336-6434
Facts on structured ceramic monolith filters

Structured Ceramic monolith filter

Typical Active DPF system
(Fig. from DieselNet)

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

$S^3$ (S-Cube : Soot Solving System)

Japan Certified (2004. 1.)

KT Mark Award (2004. 6.)

Excellent Korean Technology
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: \( \sim 12.5 \ \mu m \)
- filter thickness: \( \sim 0.7 \ \text{mm} \)

\[ \Delta P \propto \text{mainly due to PM filtration} \]
\[ \text{Steep increase with high PM filtration} \]

---

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

\[ \Delta P \propto \text{mainly due to filter structure} \]
\[ \text{Slow increase even with high PM filtration} \]
MLF - Filtration Efficiency

Overall Filter Efficiency \~ \frac{Layer \ Thickness(L)}{Pore \ Size \ (D_f)} 
\~ Filtration by Interception + Filtration by Diffusion

Interception \~ \text{Particle Size} (d_p) 

\begin{align*}
&\text{Surface filtration} \quad \leftrightarrow \quad \text{Mainly filtration by interception} \\
&\text{MLF filtration} \quad \leftrightarrow \quad \text{Filtration by both interception and diffusion}
\end{align*}

As the size of PM is reduced, it can be guessed that

\rightarrow \text{Filtration by Diffusion will be enhanced even with present MLF filter.}
\rightarrow \text{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

- Engine
- Switch box
- Control Box
- ECU
- Fuel Tank
- Battery
- Fuel
- Engine Signal
Regeneration
- at engine stop
- 220vAC External power
- ~6.0 Kwh (60 min.)
**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.
- Pressure, $P$, increases with PM loading during real road driving.
- Mass of filtered PM, $Ms$, 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**

Temp. at filter inlet is controlled with fuel pump duty.

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

<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 D-13 mode: (PM 91 % ↓)

<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>

Japan 10・15 mode: (PM 85 % ↓)

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.
# Product portfolio (Aug. 2004)

<table>
<thead>
<tr>
<th>Categorized by regeneration method</th>
</tr>
</thead>
<tbody>
<tr>
<td>• DPF system with In-line burner – exported to Japan retrofit market</td>
</tr>
<tr>
<td>• DPF system with electric heater regeneration (external electric power)</td>
</tr>
<tr>
<td>• DPF filter only on vehicle + external hot gas supplier (available in Dec. ’04)</td>
</tr>
</tbody>
</table>

## 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

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 best partner for Europe DPF market,....