A new SiC-based DPF for the Automotive Industry

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TYK Corporation
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- Introduction
- Our Main Innovation
  - Special sintering process on SiC-DPF
- Evaluation on the New Filter
  - Engine Bench Testing
  - Initial filtration efficiency
- Analysis on the Microstructure of Filter Wall
- VERT VFT1 report
- Conclusion
The TYK 's SiC-DPF


The new technology enables the controlling of porosity and pore size distribution of the filter material with comparatively high flexibility, and the cost reduction as compared with the normal sintering process.
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**Our Main Innovation**

**TYK material’s sintering reaction**

Sintering Model (Diagrammatical view)

- **SiC grain**
- **Si₃N₄**
- **Graphite**

Sintering at high temperature

**Si₃N₄ + 3C → 3SiC + 2N₂**

Base SiC grains are connected by synthetic SiC

- Possible to sinter at lower temperature, so excessive grain growth
- Possible to make small size pore and sharp pore distrib
Pore size control technology

Pore Size (μm) vs. Pore Volume (mL/g) graph.

Images showing different pore structures.
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## Properties of DPF Test Samples

Table 1. Properties of DPF Test Samples

<table>
<thead>
<tr>
<th></th>
<th>Filter-A (Developed)</th>
<th>Filter-B (Commercial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell Density / cpsi</td>
<td>169</td>
<td>178</td>
</tr>
<tr>
<td>Wall thickness / mm</td>
<td>0.38</td>
<td>0.36</td>
</tr>
<tr>
<td>Porosity / Vol%</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td>Mean Pore Size / μm</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Bending Strength / MPa *</td>
<td>9.8</td>
<td>7.6</td>
</tr>
<tr>
<td>Initial Pressure Drop / kPa**</td>
<td>4.7</td>
<td>4.6</td>
</tr>
</tbody>
</table>

* Size: 2cell × 3 cell × 40mm,  Span: 30mm,  Load speed: 0.5mm/min
** Size: D5.66inch × L6inch,  Air flow: 9.5Nm³/min
**Pore size distribution**

Fig.1: Pore size distribution of DPF test sample measured by mercury porosimetry
Fig. 2: X-ray diffraction
Engine Bench (TYK R&D)

Engine: NISSAN QD32 Diesel (KG-VWGE24)
OHV 4 cylinder 3.153(L)
N/A
Max. Power: 72kW/3200rpm
Max. Torque: 216Nm/2000rpm
Fuel Injector Pomp: Bosch
**Drop To Idle Test (DTIT)**

**Sample description**

<table>
<thead>
<tr>
<th></th>
<th>Filter A</th>
<th>Filter B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell Density (cpsi)</td>
<td>169</td>
<td>178</td>
</tr>
<tr>
<td>Wall Thickness (mil)</td>
<td>15.0</td>
<td>14.2</td>
</tr>
<tr>
<td>Porosity (%)</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td>Mean Pore Size (um)</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Size</td>
<td>5.66 ” – 6”</td>
<td>5.66 ” – 6”</td>
</tr>
<tr>
<td>Exhaust end surface</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
</tbody>
</table>
Drop To Idle Test (DTIT)

Fig. 4: Drop to Idle test
Table 2. Summary of DTIT Result

<table>
<thead>
<tr>
<th></th>
<th>Max temperature/°C</th>
<th>Combustion efficiency</th>
<th>Weight/g</th>
<th>Crack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter-A (Developed)</td>
<td>880</td>
<td>78</td>
<td>3040</td>
<td>no</td>
</tr>
<tr>
<td>Filter-B (Commercial)</td>
<td>900</td>
<td>69</td>
<td>2818</td>
<td>no</td>
</tr>
</tbody>
</table>

※Weight: Initial DPF involve canning weight

Fig. 5: DTIT Chart of Filter-A

Fig. 6: DTIT Chart of Filter-B
Pressure Drop v.s. Soot Load

![Graph showing the relationship between Pressure Drop and Soot Load for Filters A and B.](image)

**Axes:**
- **Soot Load / g/L**
- **Pressure Drop / KI**

**Legend:**
- **Filter-A** (green circles)
- **Filter-B** (blue diamonds)
Filtration Efficiency Test

Exhaust duct

Surplus exhaust

EEPS
(Engine Exhaust Particle Sizer: TSI Model 3090)
Initial filtration efficiency

Fig. 7: Total concentration of particle which leaked from the outlet side of DPF in the initial 2 minutes.

(W/O Filter 3.7E+07)
Concentration and size distribution of leaked particle.

Fig. 8: Concentration and size distribution (Filter-A)

Fig. 9: Concentration and size distribution (Filter-B)
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Microstructure of Filter Wall

SEM Photos:
After the initial 2 minutes filtration

Gas flow direction

Filter-A

Filter-B

Fig.10&11: SEM of DPF-wall surface and cross section
Microstructure of Filter Wall

X-ray CT 3-Dimensions image on the fresh filters

Filter-A
400×400×200 μm

Filter-B
400×400×200 μm
Microstructure of Filter Wall

Depth Filtration

Sieving (Cake Filtration)
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## Filter

<table>
<thead>
<tr>
<th>Main dimensions</th>
<th>(\varphi 143.8\text{mm} \times L 254\text{mm} (4L) \times 3\text{pcs} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell number</td>
<td>169\text{cps}i</td>
</tr>
<tr>
<td>Wall thickness</td>
<td>16\text{mil (0.4mm)}</td>
</tr>
<tr>
<td>Porosity</td>
<td>42%</td>
</tr>
</tbody>
</table>

## Engine

<table>
<thead>
<tr>
<th>Engine type</th>
<th>D 924TI-E A2 by Liebherr SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement</td>
<td>6,64 L</td>
</tr>
<tr>
<td>Rated power output</td>
<td>137 kW</td>
</tr>
<tr>
<td>Maximum torque</td>
<td>760 Nm at 1200...1400 rpm</td>
</tr>
</tbody>
</table>

## Trapping efficiencies of counts 20nm-320nm

<table>
<thead>
<tr>
<th>Particle size</th>
<th>Particle number before filter</th>
<th>Particle number after filter</th>
<th>Filtration efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>nm</td>
<td>cm(^{-3})</td>
<td>cm(^{-3})</td>
<td>%</td>
</tr>
<tr>
<td><strong>Before regeneration</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrated</td>
<td>6,917,749</td>
<td>996</td>
<td>99.986</td>
</tr>
<tr>
<td>20-40</td>
<td>965,032</td>
<td>343</td>
<td>99.964</td>
</tr>
<tr>
<td>40-80</td>
<td>2,408,606</td>
<td>166</td>
<td>99.993</td>
</tr>
<tr>
<td>80-160</td>
<td>2,580,243</td>
<td>377</td>
<td>99.985</td>
</tr>
<tr>
<td>160-320</td>
<td>963,869</td>
<td>110</td>
<td>99.989</td>
</tr>
<tr>
<td><strong>After regeneration</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrated</td>
<td>6,577,985</td>
<td>1,223</td>
<td>99.982</td>
</tr>
<tr>
<td>20-40</td>
<td>732,458</td>
<td>163</td>
<td>99.978</td>
</tr>
<tr>
<td>40-80</td>
<td>2,179,589</td>
<td>352</td>
<td>99.985</td>
</tr>
<tr>
<td>80-160</td>
<td>2,557,854</td>
<td>416</td>
<td>99.984</td>
</tr>
<tr>
<td>160-320</td>
<td>1,108,084</td>
<td>292</td>
<td>99.974</td>
</tr>
</tbody>
</table>
Conclusion

- The newly developed SiC-based filter which are brought about from the special sintering process has high purity crystal phase.
- This new filter shows preferable tendency of properties for regeneration and robustness having lower peak temperature and higher combustion efficiency.
- The new filter has an uniform pore structure on the wall surface and complicated flow-pass structure inside the wall.
- Therefore, it shows superior initial filtration efficiency compared to commercial product.
Thank you for your attention!

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