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Development of Advanced Diesel Particulate Filtration (DPF) Systems

(ANL/Corning/Caterpillar CRADA)

May 20, 2009

DOE Annual Merit Review & Peer Evaluation Meeting

Project ID: ace_22_lee

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Office of Vehicle Technologies

This presentation does not contain any proprietary or confidential information

Overview

Timeline

- Start: Oct 2007
- Finish: Dec 2010
- 25% Finished

Budget

- Total Project funding
  - DOE: $1,450K
  - Industry sponsors: $1,450K
- Funding received in FY08
  - $400K
- Funding received in FY09
  - $400K

Barriers

- Increased back pressure and fuel penalty
- Effective regeneration strategy to reduce input energy and deal with low exhaust temperature
- Durability of the system, including filter materials
- Sensor technology

Partners

- Corning and Caterpillar
- Univ. of Wisconsin
- NGK and Iljin Electric

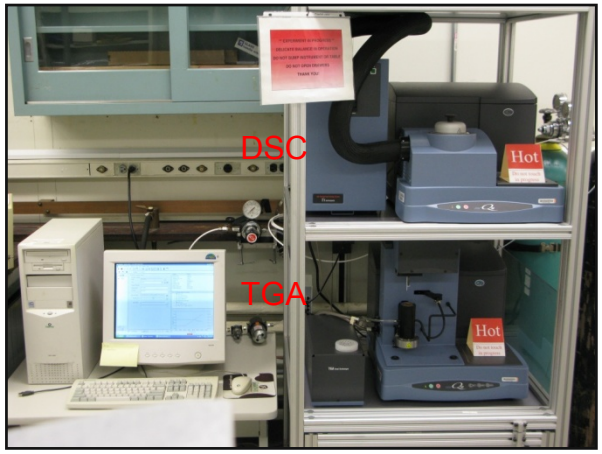
Objectives and Milestone (Year 2)

- Evaluate/improve filtration efficiencies and pressure drops at different engine operating conditions (till Aug.)
- Develop technologies to measure/monitor the mass of PM emissions in DPF membranes and detect filter failure (till Oct.)
- Effects of catalytic coating on membrane micro-structures, pressure drop, and filtration efficiency (July – Dec.)
- Evaluate oxidation rates and heat release of PM emissions collected as a function of engine operating condition and soluble organic fraction (till Dec.)

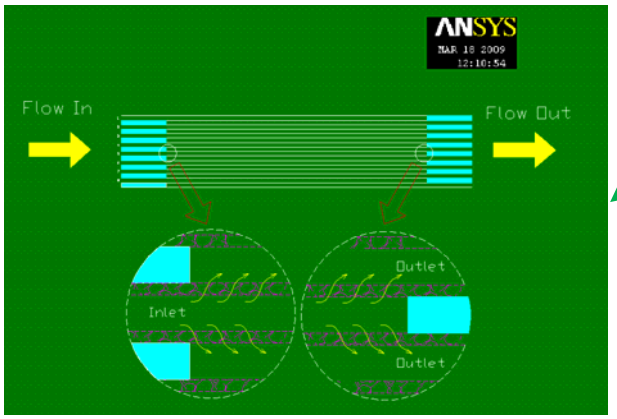
Approach

Filtration, regeneration in a thermal reactor with *μ*-imaging

Caterpillar C7 Diesel



Oxidation, heat release with TGA, DSC

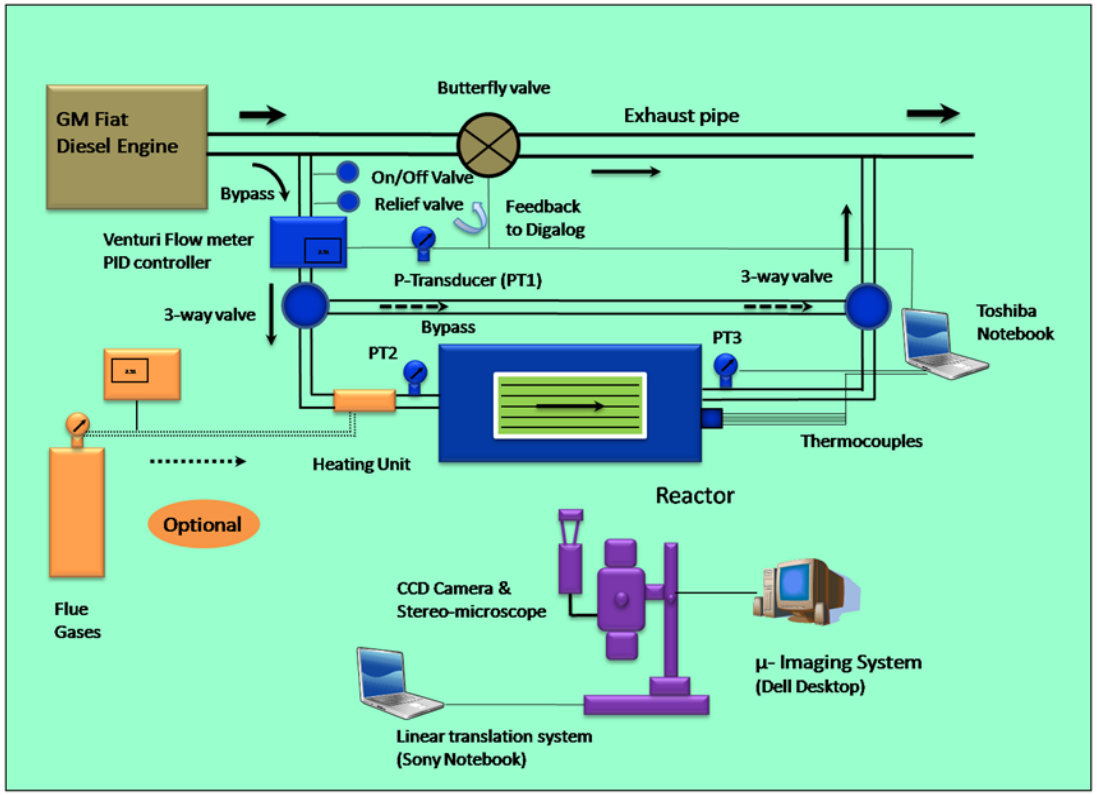


Numerical modeling

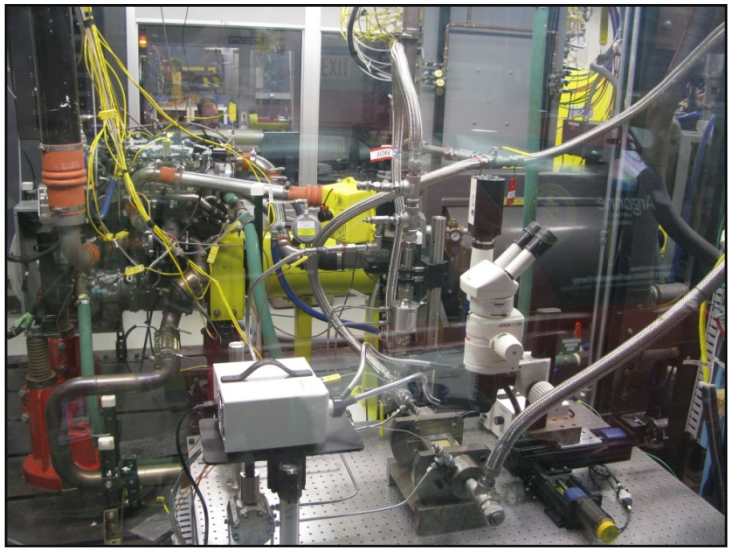
Filtration efficiency, PM mass withTEOM

Technical Accomplishments

- **Experimental Setup**



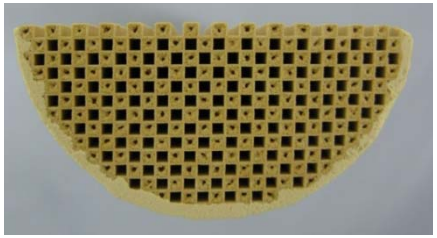
Schematic



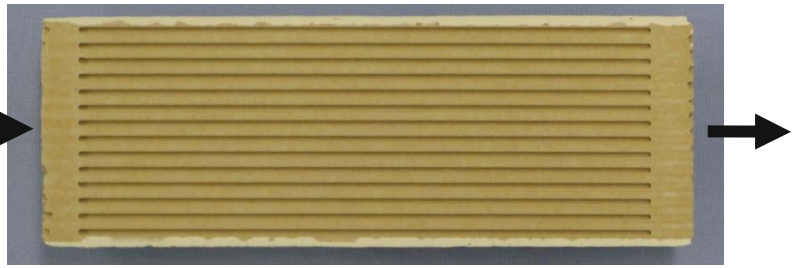
Connected to GM 1.7L diesel

Pressure drop in clean DPF membranes varies with total surface area available for filtration

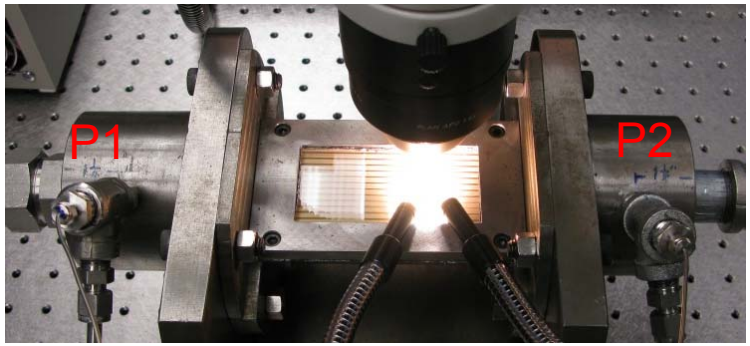
Φ2”xL6”



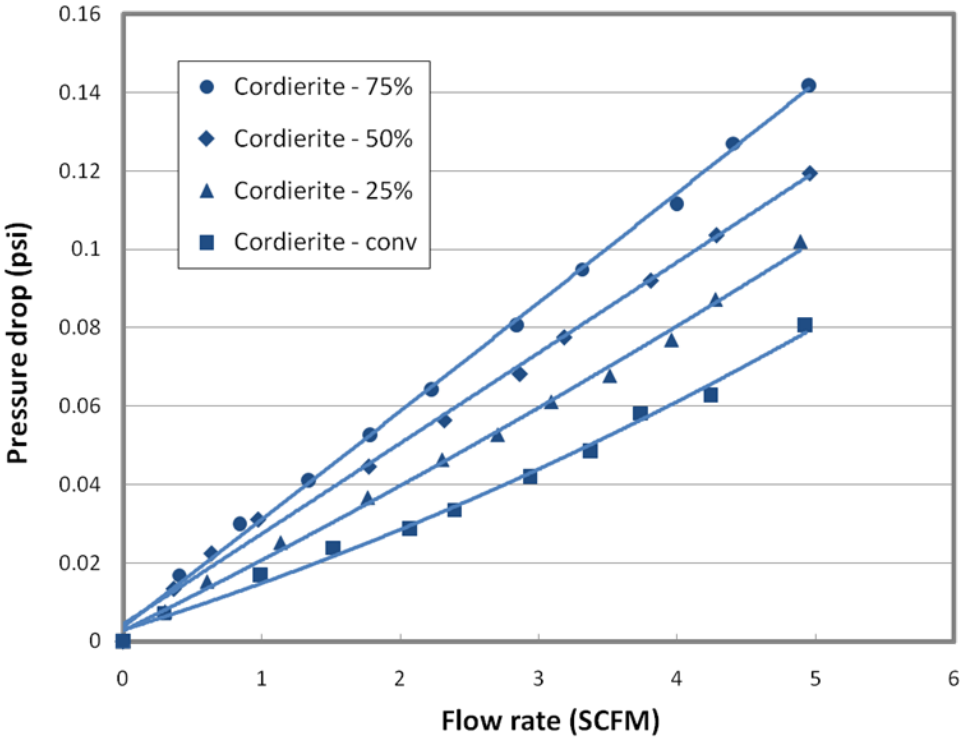
Air



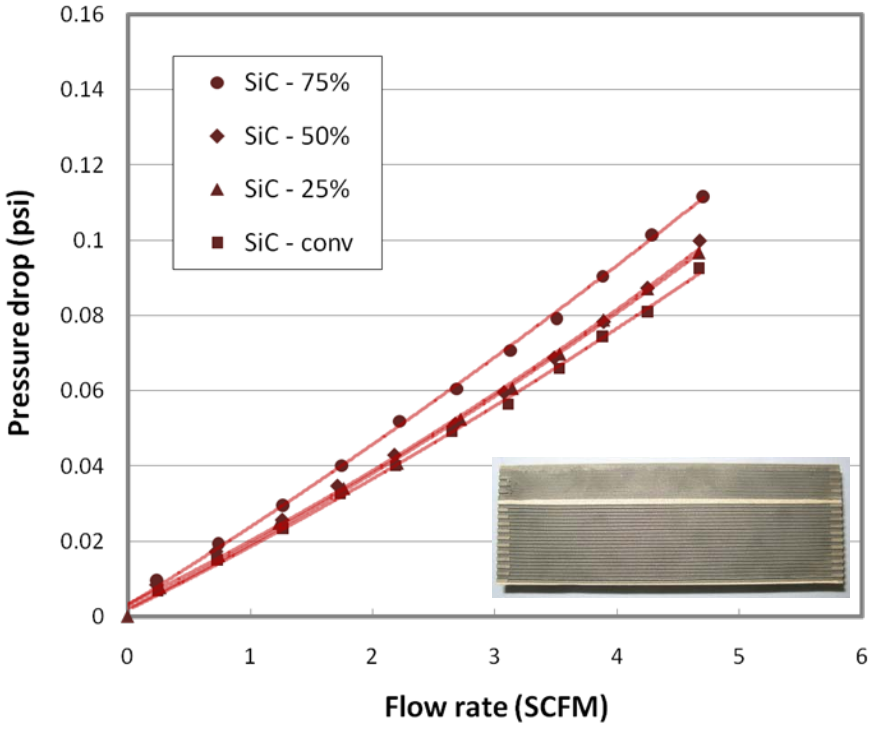
Half-sectioned Cordierite Membrane

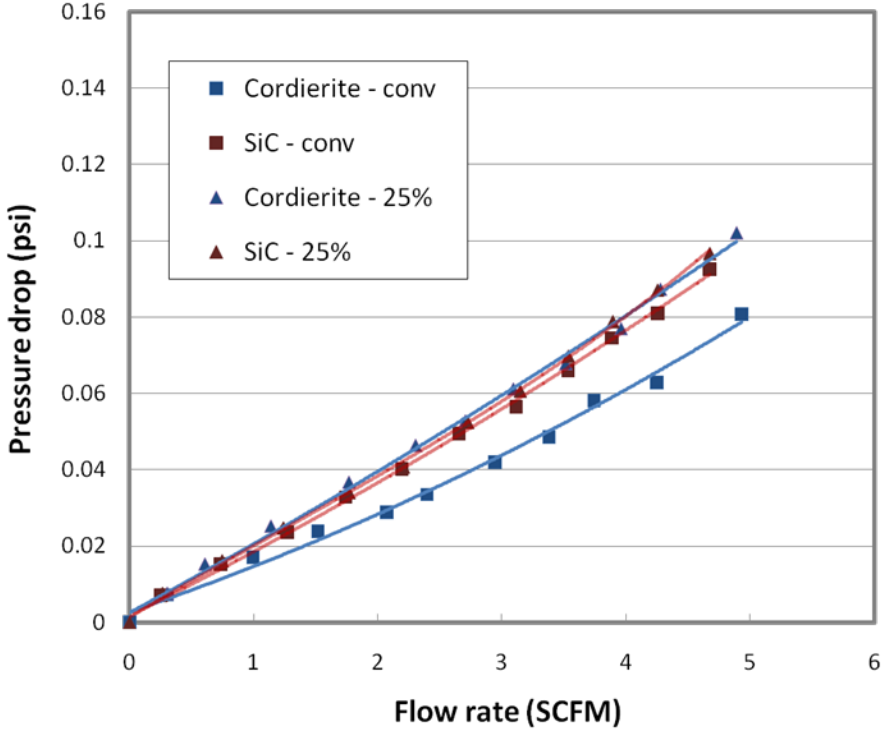


Pressure measurement in flow reactor



Pressure drop in conventional Cordierite membrane is lower than that in competitive product, but higher with increased filtration areas

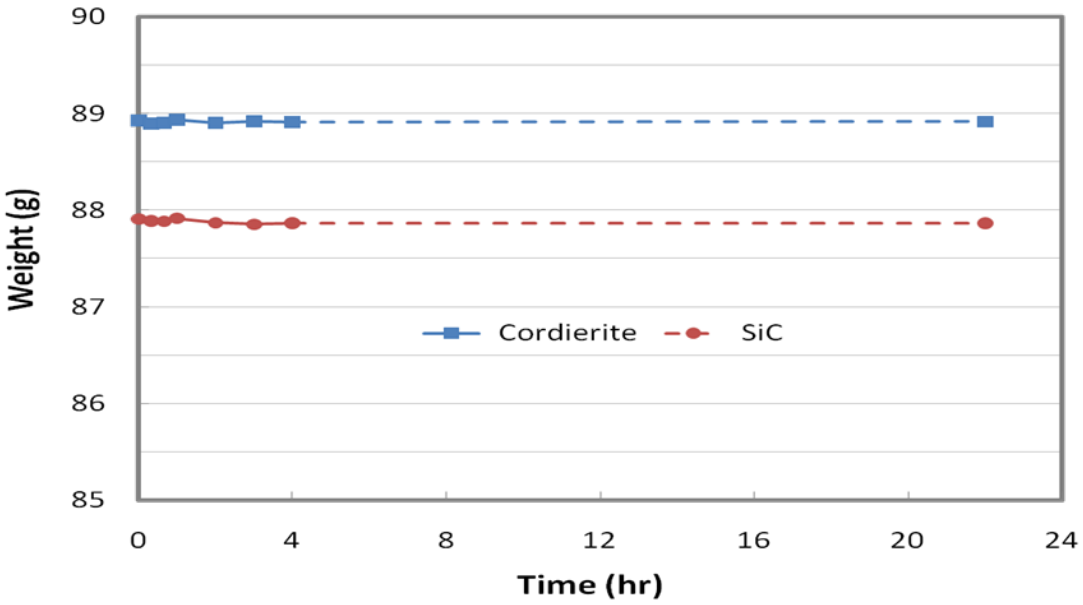




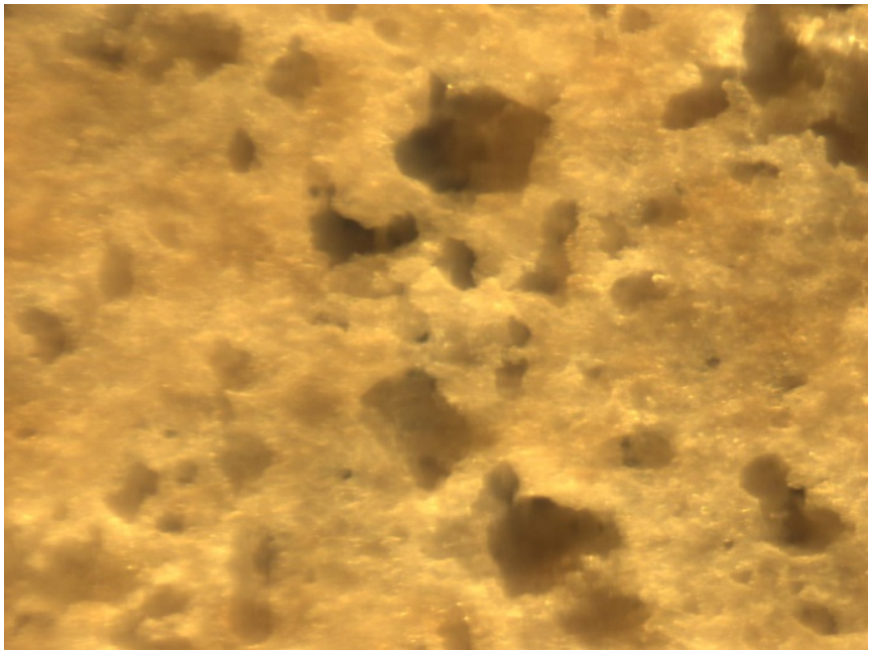
- Cordierite membranes are suggested to increase the filtration area up to 25%.

Porosity, pore size, surface area and thermal durability

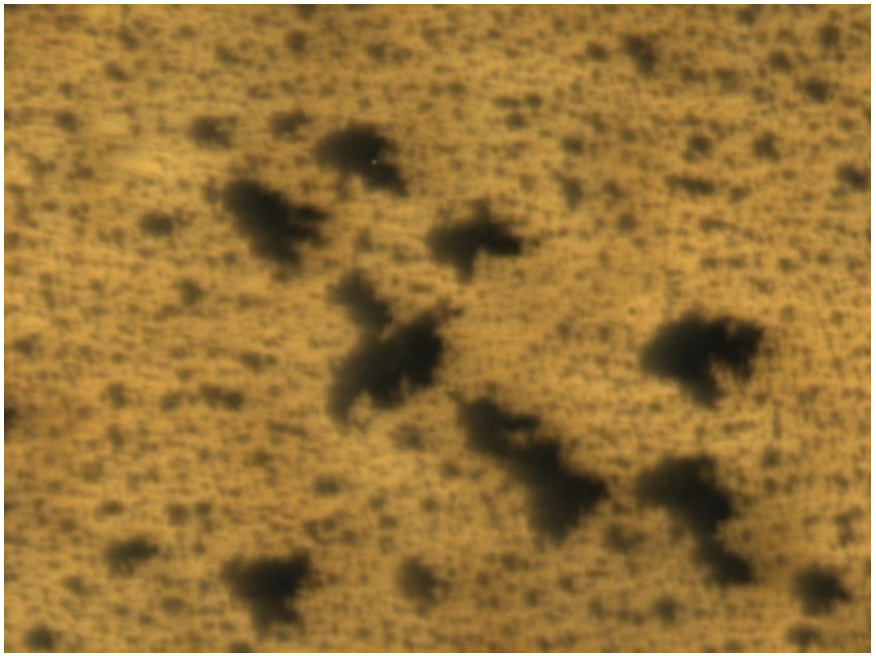
- Measurements of porosity, pore size, and surface area of uncatalyzed Cordierite membranes (to be available at presentation).
- Thermal durability test of clean membranes showed no mass change with time.
  - Furnace operating temperature: 200 °C continuous
  - Total heating time: 22 hours.



Micro video-images revealed details of PM filtration processes in membrane



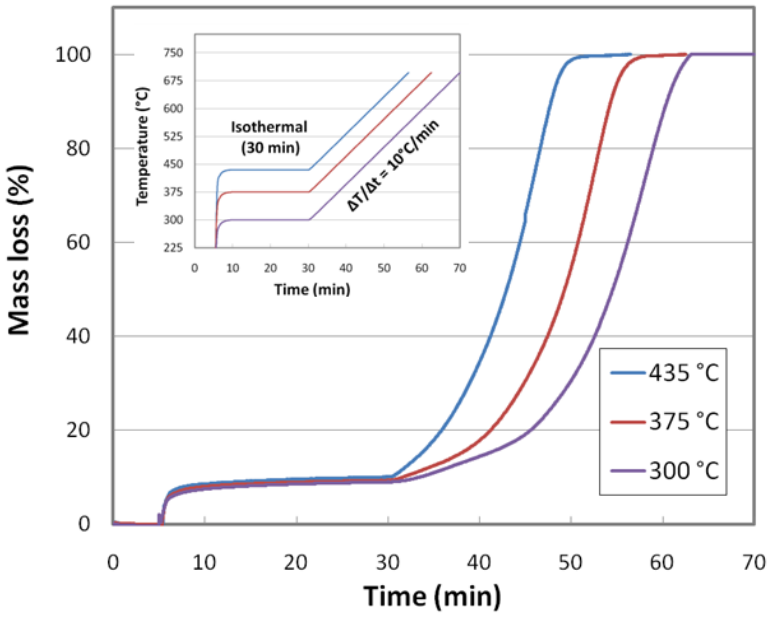
Before filtration

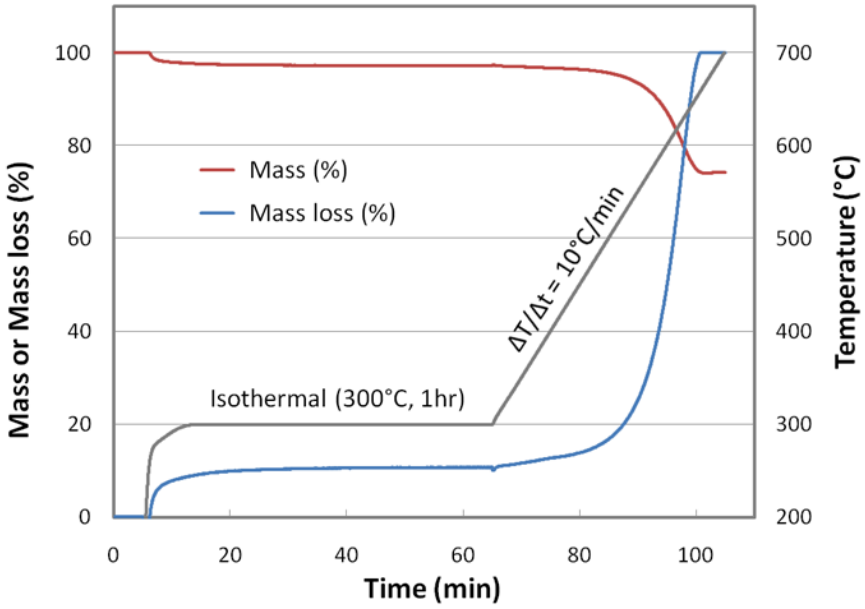


20 min after filtration

Inflow Channel

TGA provided accurate measurements of soot oxidation rate, along with capability in measuring soluble organics





- A heating temperature of 300 °C was determined to control the amount of soluble organics.
- Maximum oxidation rate appeared to be *12.1 %/min* in mass.
- TGA revealed approximately 10% of PM mass consists of soluble organics.

Numerical modeling predicted detailed fluid dynamics in membrane channels

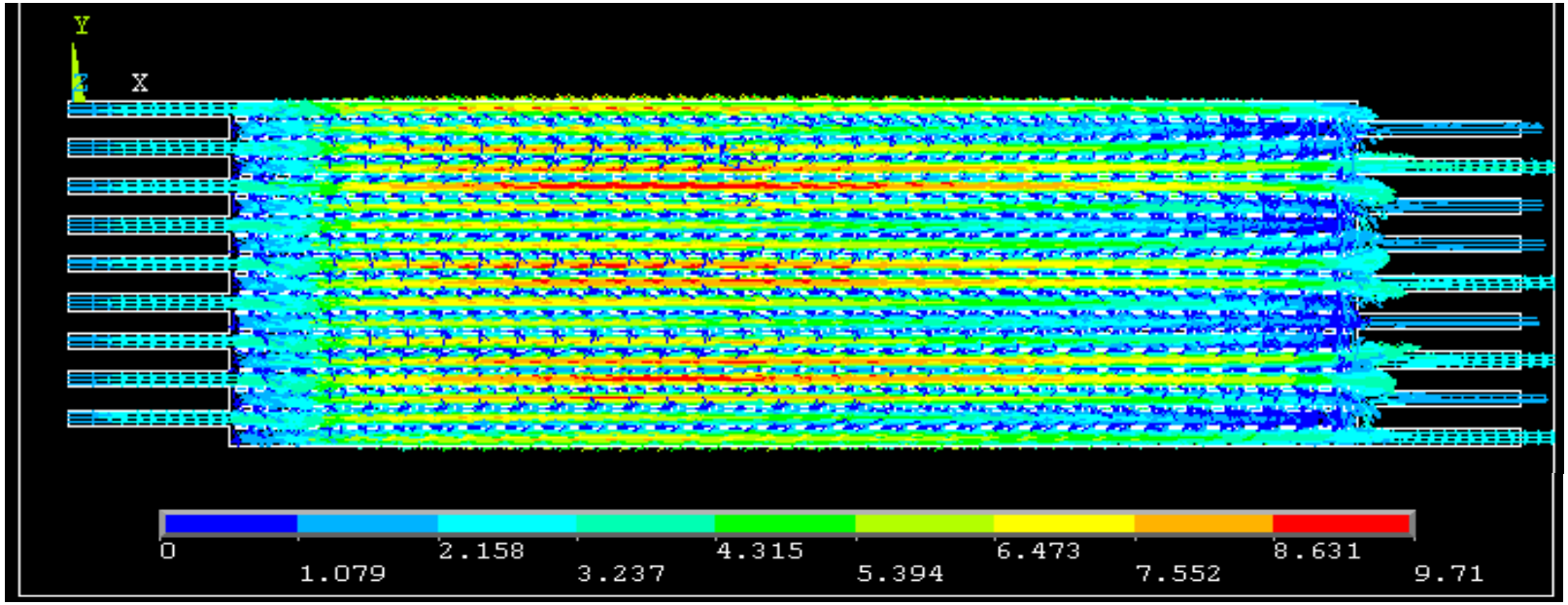
$$\frac{\partial u_i}{\partial x_i} = 0, \quad \frac{\partial u_i}{\partial x_j} = \left(-\frac{1}{\rho}\right)\frac{\partial p}{\partial x_i} + \upsilon \Delta u_i$$

u_i : Flow velocity υ : Kinematic viscosity

p : Pressure Δ : Laplace operator

ρ : Density i : Standard index notation

21% porosity; 60 pores/wall; 200μ x 400μ pore size; 400μ wall thickness; **2mm x 152.4mm channel size**; 18 total channels; **2 m/s inlet air**; No-slip condition; 1 x 10^6 iterations



Future Work

FY09

- Evaluation of PM filtration efficiencies with conventional/modified membranes at various engine operating conditions.
- Catalytic coating of membranes and measurement of physical properties and filtration properties.
- Justification of the non-dimensional parameter with engine exhaust emissions at various engine conditions.
- Measurement of soot oxidation rates and heat release as a function of engine condition and SOF concentration.
- Morphology of partially oxidized soot particles and ash particles.

FY10

- Optical images of propagating reaction zone with temperature measurements during regeneration (needs to fabricate a PM ignition system).
- Evaluation of regeneration efficiencies of conventional membranes at various engine conditions.
- Analysis of gaseous emissions at the DPF exit during regeneration.
- X-ray imaging of soot deposits in a membrane (may need an additional fund).

Summary

- Pressure drop of clean Cordierite membranes was lower than SiC membranes.
- Overall, the increased filtration area increased pressure drop. The increase of surface area is suggested only up to 25%.
- Microimaging on membrane surface showed detailed filtration processes.
- TGA data revealed the amount of soluble organics in PM emissions and oxidation rates with a maximum of 12.1 %/min in mass.
- Numerical modeling showed detailed gas dynamics in membrane channels, which validated the conventional profile of soot deposit.