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Advanced Materials and Regeneration Control for Cost-Effective and Low-Backpressure DPF Systems in On-Road and Off-Road Heavy-Duty Applications

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Presentation outline

1. Background & Objectives

- 1-1) Global emission regulation and DPF requirements
- 1-2) Filter material options & challenges
- 1-3) Potential for SML improvement with Cordierite

2. Experimental Methods

3. Experimental Results

- 3-1) DTI durability test results (Cd vs SiC)
- 3-2) Regeneration efficiency test results
- 3-3) DTI durability test results
(impact of Flow rate/coating/porosity)

4. Summary

Global emission regulation and DPF requirements

Global Regulatory Trends

- India :
PN10 requirements, Tighter NOx limits
- Japan :
Potential tightening in future
(PN10 and RDE implementation ?)
- EU & China :
PN10 requirements, stringent RDE requirement
- North America :
NOx limits progressively tightened

DPF requirements

- Thermo-mechanical durability
- SML
- Filtration efficiency
- Pressure drop
- Aftertreatment system cost

*SML (Soot mass limit) : Maximum soot load DPF can survive an active regeneration event without loss of integrity

...And CO2 emission/Fuel economy standards

DPF requires multi-dimensional optimization:

material / pore structure / cell geometry must all be considered simultaneously across **diverse applications and regional requirements.**

1. Background & Objectives

Substrate Material Options & Challenges

Selecting the right filter material is a critical decision in DPF system design

Material property	Cordierite (Cd)	Aluminum Titanate (AT)	Silicon Carbide (SiC)
Structure	Monolith	Monolith	Segmented
Material Density (non-porous) [kg/m ³]	2510	3400	3240
CTE at 23-1000 °C [ppm/K]	<1.0	<1.0	4.5
Thermal Conductivity ^{*)} (non-porous) [W/mK]	~1.0	~1.0	10-20 ^{**)}
Specific Heat Capacity ^{*)} (non-porous) [J/m ³ K]	2.79	3.60	3.63
DPF Cost Index	Low	Medium	High

^{*)} at 500 °C ^{**)} Dependent upon bonding type

SiC

- High CTE → needs segmentation
- High heat capacity
- High thermal conductivity
- Highest manufacturing cost

AT

- High heat capacity
- Low CTE
- Medium manufacturing cost

Cordierite

- Lower heat capacity
- Lowest cost

Cordierite can achieve **SML equivalent to SiC under regeneration condition optimization** while delivering **significant cost savings.**

1. Background & Objectives

Potential for SML improvement with Cordierite

Focus of study:

Demonstrate the possibility that Cordierite DPF can achieve SML equivalent to SiC through an optimized regeneration condition.

Approach: **Lowering inlet target temperature for active regeneration**

Active regeneration can be achieved with lower target inlet temp. because of lower heat capacity

Check point:

- ① **DTI survivability** at worst case scenario
- ② **Regeneration efficiency** check

Other factors driving SML Improvement:

- 1. **Higher exhaust flow rate** during idle (better heat convection)
- 2. Use **bare DPF** (save coating cost)
- 3. **Lower porosity** combined with thinner web thickness (lower dP)

SML Evaluation Method: Drop-To-Idle (DTI) & regeneration efficiency

Test engine & system

Displacement	3.0 L
Engine Type	4-cylinder, EGR+SCR
Power Output	~85HP
Aftertreatment	DOC → DPF (5.4 L) → SCR/ASC

- ◆ **Regeneration condition of reference system using SiC DPF**
 - DPF target inlet temp:
640 °C for SiC / 585 °C for Cordierite considering lower heat capacity
 - Target soot load: 5.0 g/L
 - Exhaust flow during idle : 85 kg/h
- ◆ **Maximum DPF temp**
DPF bed temp $\leq 900^{\circ}\text{C}$

SML Evaluation Method: Drop-To-Idle (DTI) & regeneration efficiency

Test engine & system

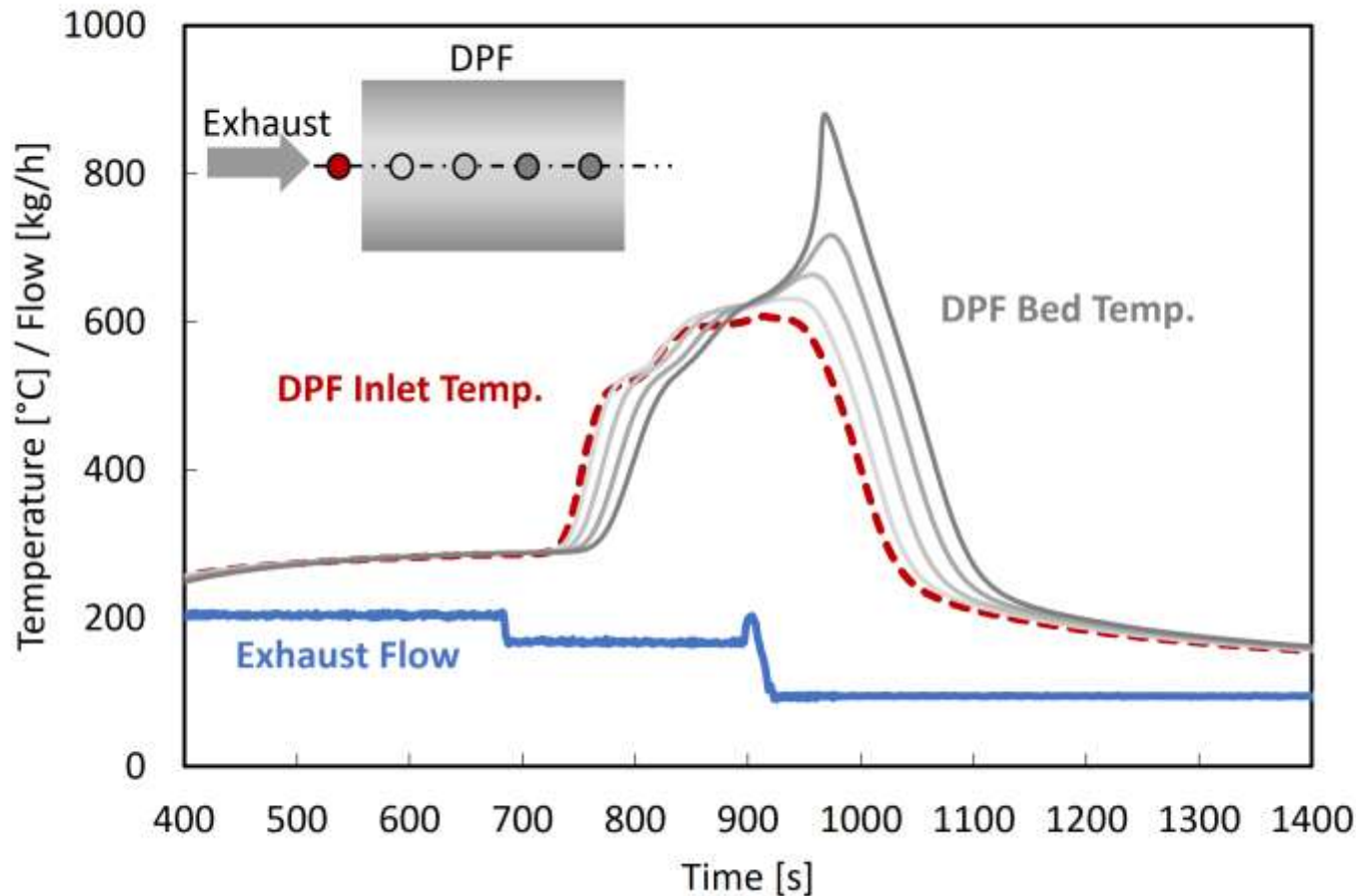
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 - Exhaust flow during idle : 85 kg/h
- ◆ **Maximum DPF temp**
DPF bed temp ≤ 900°C

Regeneration Survivability Evaluation Matrix

<p>Gap between actual vs model</p> 		control variability	
		Target DPF Inlet Temp. -20 °C (Lower tolerance)	Target DPF Inlet Temp. +20 °C (Upper tolerance)
			
Target SML -1.5 g/l (Lower tolerance)		Safe	Safe
Target SML +1.5 g/l (Upper tolerance)		Soot building-up risk Regeneration Efficiency Check over full regeneration	Worst case DPF Survivability (DTI) Risk Check

DTI Test Profile (Cordierite DPF, Soot Load = 6 g/L)



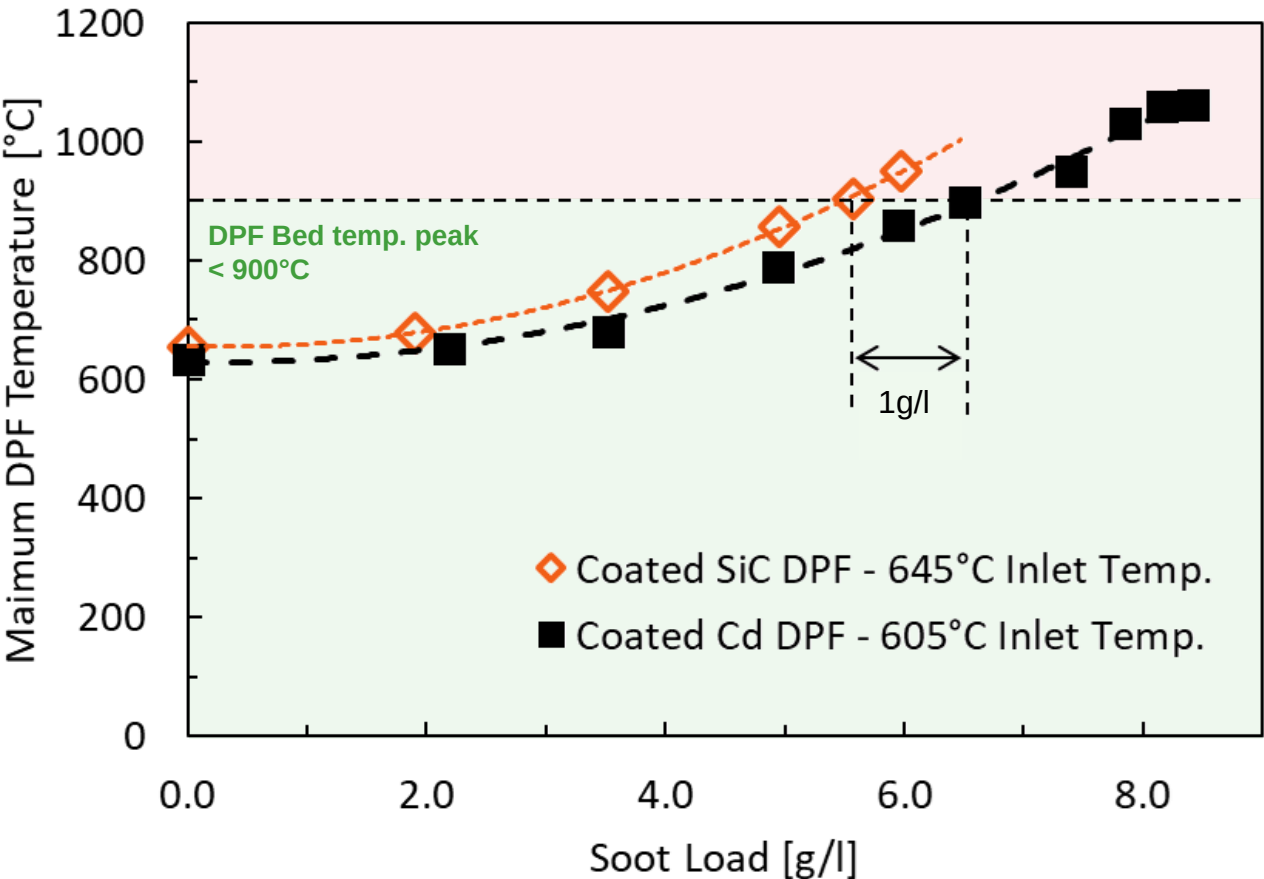
Test Sequence

- ① Soot loading phase
- ② Heating-up Phase
Exhaust temp raised stepwise
- ③ DTI Event
Engine drops to idle once inlet temp. achieves to the target test condition ($605^{\circ}\text{C} = 585 + 20^{\circ}\text{C}$)
- ④ Assessment
DPF bed temp. elevates with reduced convective cooling and higher oxygen availability
DPF Bed temp. peak $< 900^{\circ}\text{C} \rightarrow \text{PASS}$

3. Experimental Results

①DTI durability test results

Maximum DPF temperature during DTI test



	Target DPF Inlet Temp. -20 °C (Lower tolerance)	Target DPF Inlet Temp. +20 °C (Upper tolerance)
Target SML -1.5 g/l (Lower tolerance)	Safe	Safe
Target SML +1.5 g/l (Upper tolerance)	Soot building-up risk Regeneration Efficiency Check over full regeneration	Worst case DPF Survivability (DTI) Risk Check

(Target inlet temp: 585 °C, Target soot load: 5.0 g/L)

Cordierite has **lower bulk density** than SiC



Lower required inlet temp to trigger regeneration (40 °C lower than SiC)



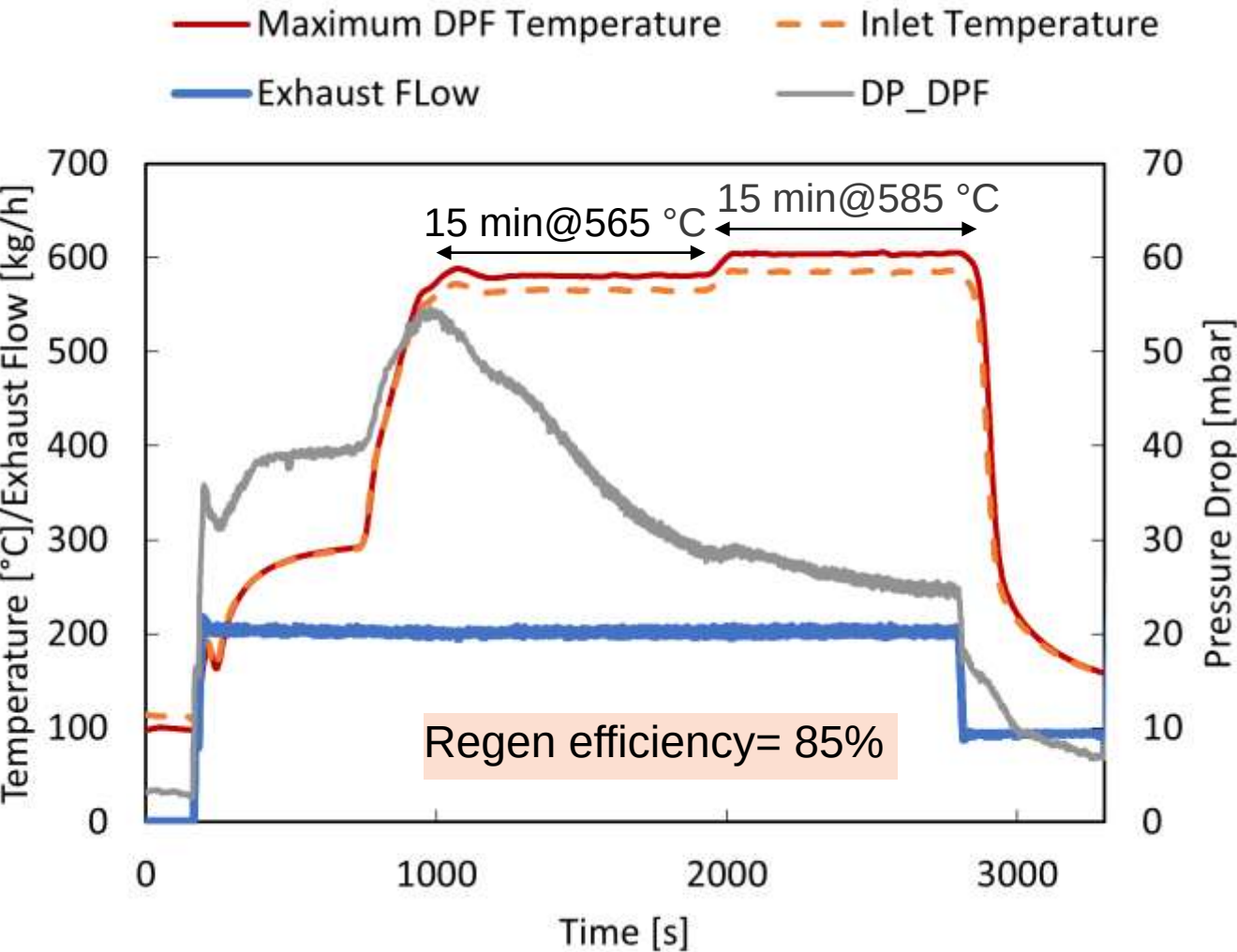
① **Better SML** (improvement in SML ~1g/L)

+

② **Fuel economy** can also be improved

3. Experimental Results

②Regeneration efficiency test results



	Target DPF Inlet Temp. -20 °C (Lower tolerance)	Target DPF Inlet Temp. +20 °C (Upper tolerance)
Target SML -1.5 g/l (Lower tolerance)	Safe	Safe
Target SML +1.5 g/l (Upper tolerance)	Soot building-up risk Regeneration Efficiency Check over full regeneration	Worst case DPF Survivability (DTI) Risk Check

(Target inlet temp: 585 °C, Target soot load: 5.0 g/L)

Full regeneration condition:

- Soot load: 6 g/L soot
- Target Inlet temperature: 565 °C

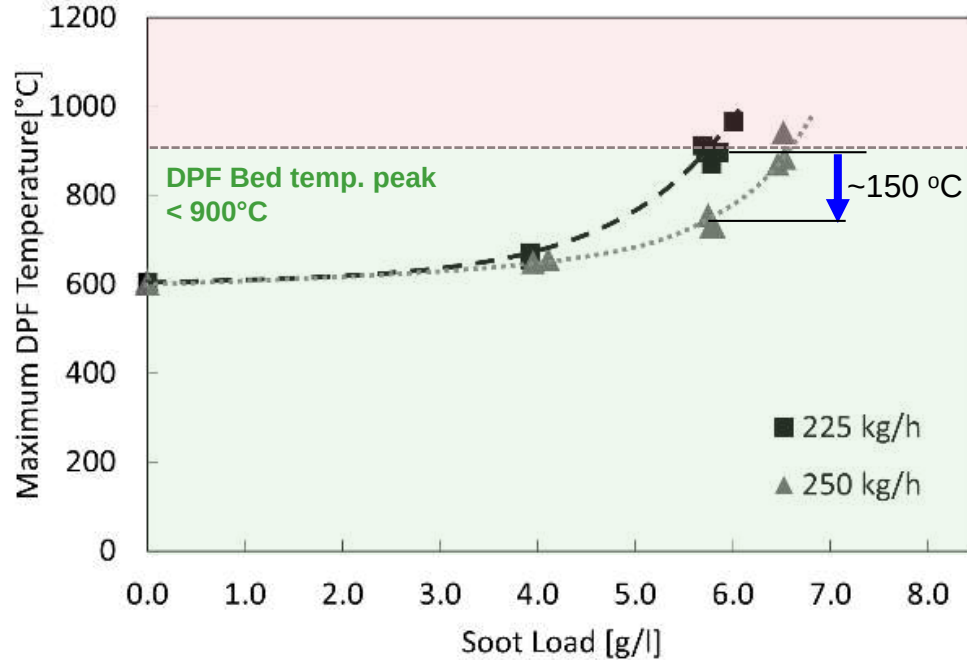


Further optimized regen strategy can help more efficient regeneration

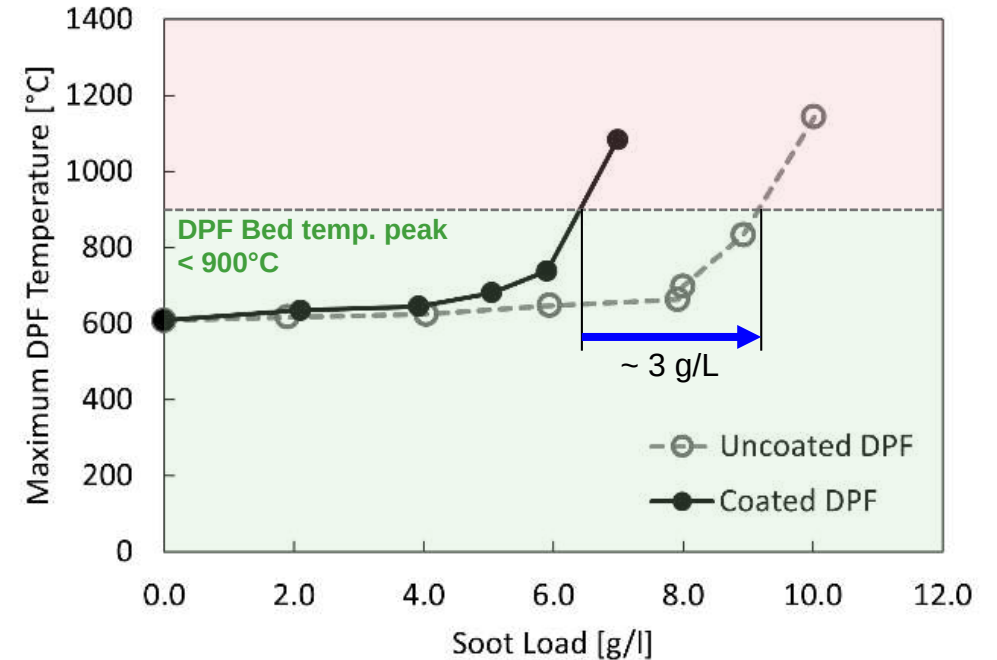
3. Experimental Results

SML Factor 1&2: Higher exhaust flow rate and bare DPF impact

Exhaust flow rate impact



Catalyst coating impact

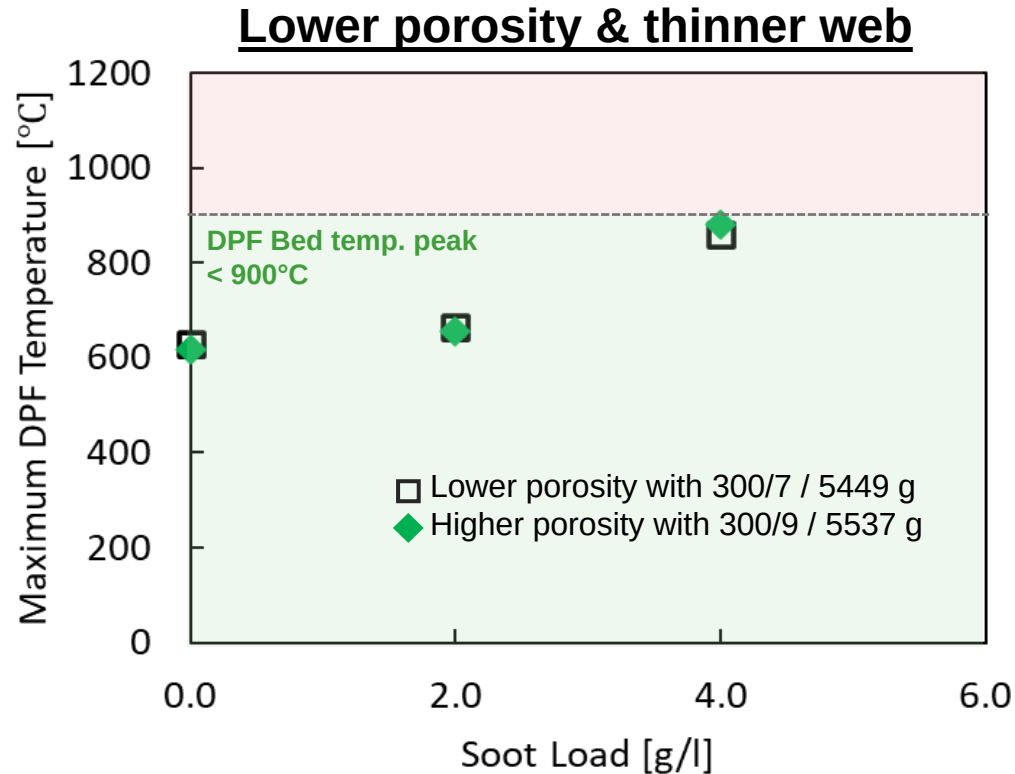


Other factors driving SML Improvement:

1. **Higher exhaust flow** rate during idle (better heat convection)
2. Use **bare DPF** (save coating cost)
3. **Lower porosity** combined with **thinner web** thickness (lower dP)

3. Experimental Results

SML Factor 3: Lower porosity combined with thinner web thickness



If the same material, lower porosity is mechanically stronger and enables to have thinner web thickness resulting in the same SML and lower dP

Other factors driving SML Improvement:

1. **Higher exhaust flow** rate during idle (better heat convection)
2. Use **bare DPF** (save coating cost)
3. **Lower porosity** combined with **thinner web** thickness (lower dP)

Summary

- **Cordierite DPF can achieve SML equivalent to SiC through an optimized regeneration condition and cost reduction.**
- ✓ Active regeneration can be achieved with **lower target inlet temperature** → Improves SML and fuel economy
- ✓ Both **DTI survivability** and **Regeneration efficiency** must be evaluated
- ✓ **Idle exhaust flow rate, coating presence, porosity, and wall thickness** are key factors influencing SML

(Next steps)

- **Further design optimization is required to meet target filtration efficiency and pressure drop**
- ✓ **Pore structure**
- ✓ **Cell design**

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