Thermal Shock Risk of DPF for Indian Market Application

P20231102,3-ECMA

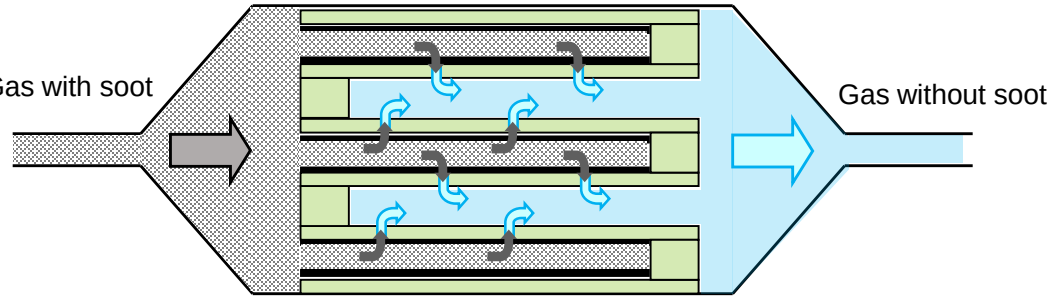
Emission regulation and voice of DPF system

	'17	'18	'19	'20	'21	'22	'23	'24	'25	'26
EU	EUVI **PN regulated**		EUVI d,e **PN regulated under RDE**							
IND	BS IV **(No PN regulation)**		BS VI Phase1 **PN regulated**				BSVI Phase2 **PN Regulated under RDE**			

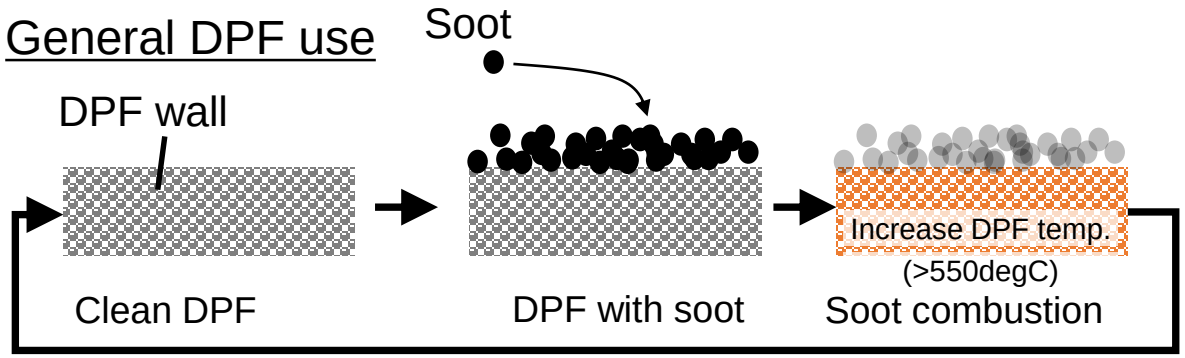
*OEM, Maintenance/Cleaning company, End-user

☐ Diesel car needs DPF system

PN/PM filtration by DPF



General DPF use



Market * voice of DPF system in India

-No polluted (with soot) exhaust gas = clean air☺

-Diesel car available with meeting regulation ☺

-High DPF regeneration frequency than expected☹

-Need service regeneration due to over soot load☹

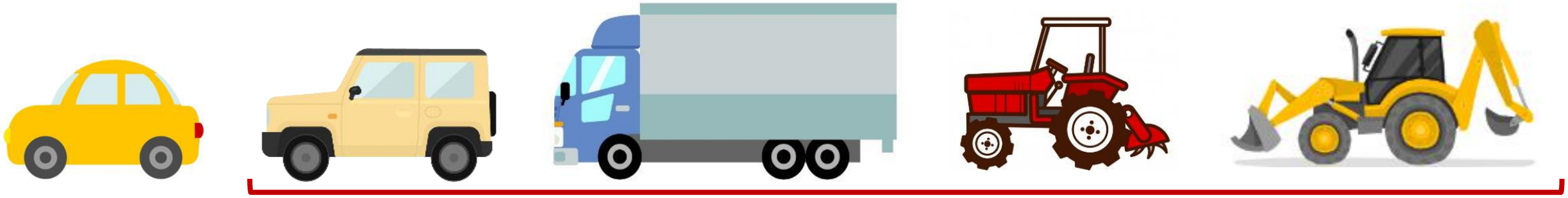
-Damaged DPF replacement needed after high thermal shock caused by over loaded soot regeneration ☹

In spite DPF system is mature technology in the world, challenges still remain at regeneration

■Necessity of DPF robustness in the market

On-road vehicle | **Non-road vehicle**

PC | LCV | HCV | Tractor | CEV



Working vehicle

If DPF trouble happen due to low robustness design , vehicle doesn't perform normally, and have to stop until parts are changed* in a worst case. ***Additional cost**

Passenger car : There are substitute public transportation (Train, Bus, Taxi, Ship and Air-plain)

Working vehicle : No substitute measure → Work has to stop.

→High influence against end users

- ✓ **High robustness DPF is needed and IBIDEN can contribute to it by R-SiC DPF**
- ✓ **It can also contribute end-users' satisfaction.**

Reality of Indian use

Cool ATS state (Idle~low speed)

On-road vehicle
(Regulation on going)

- Heavy traffic jam often occurs in India, and vehicles kept longtime under idle/low speed.

Non-road vehicle
(Regulation from TremV)

(Example)

- Pumping water (Long time idle/low load)
- Warm up (Long time idle)
- Waiting for dump truck (Long time idle)

One of the phenomenon behind regeneration troubles

Diesel basic ATS

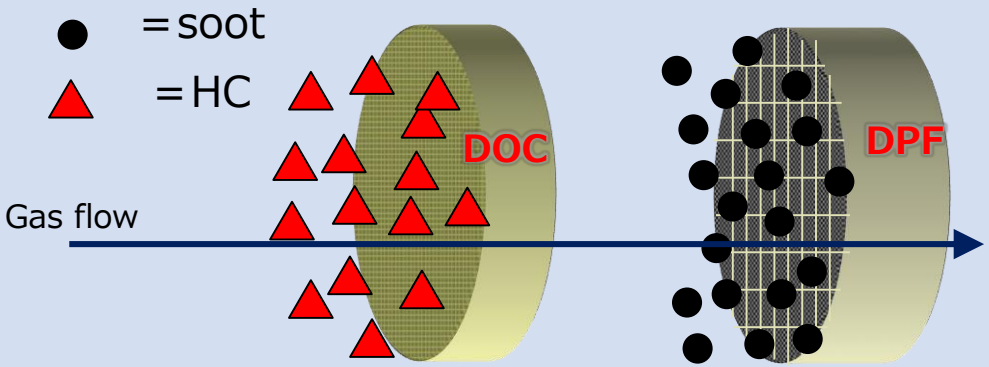
Main function	**Purification (CO,NO,HC)**	**Filtration (Soot)**	**Purification (NOx)**

Idle / low speed (Low gas temp.)

Oxidation/Purification will be prevented

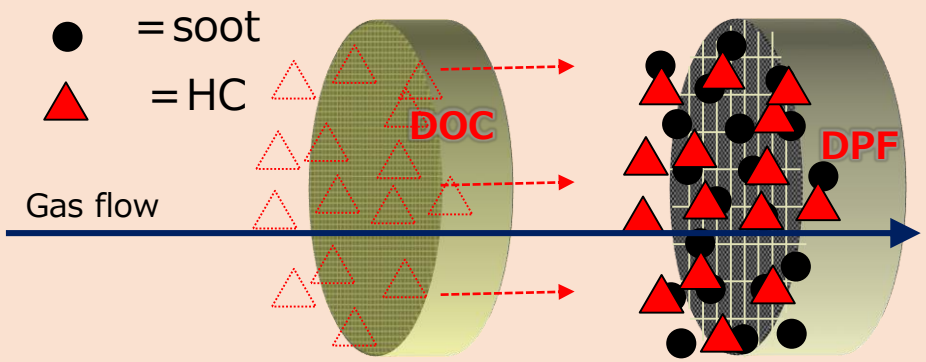
Soot regeneration will be prevented
➡Over soot load

Cool ATS (Idle~low speed)



Repeat
Stop & Go

Heated ATS (≥Middle speed*)



✓ **HC will be supplied from DOC to DPF**
➡HC oxidation will cause exotherm

HC desorption amount on DOC at idle condition

Table test condition

Engine/ATS	Passenger car
Idle time	0hr, 4hrs
HC desorption temperature	From 150degC to 400degC

Test flow

Pre-treatment: Clean DOC @ gas temperature 600degC

↓

Test start: No idle & 4hrs idle treatment

↓

Increase temperature by post injection for HC desorption

↓

Measure HC desorption amount by gas analyzer while increasing temperature from 150degC to 400degC

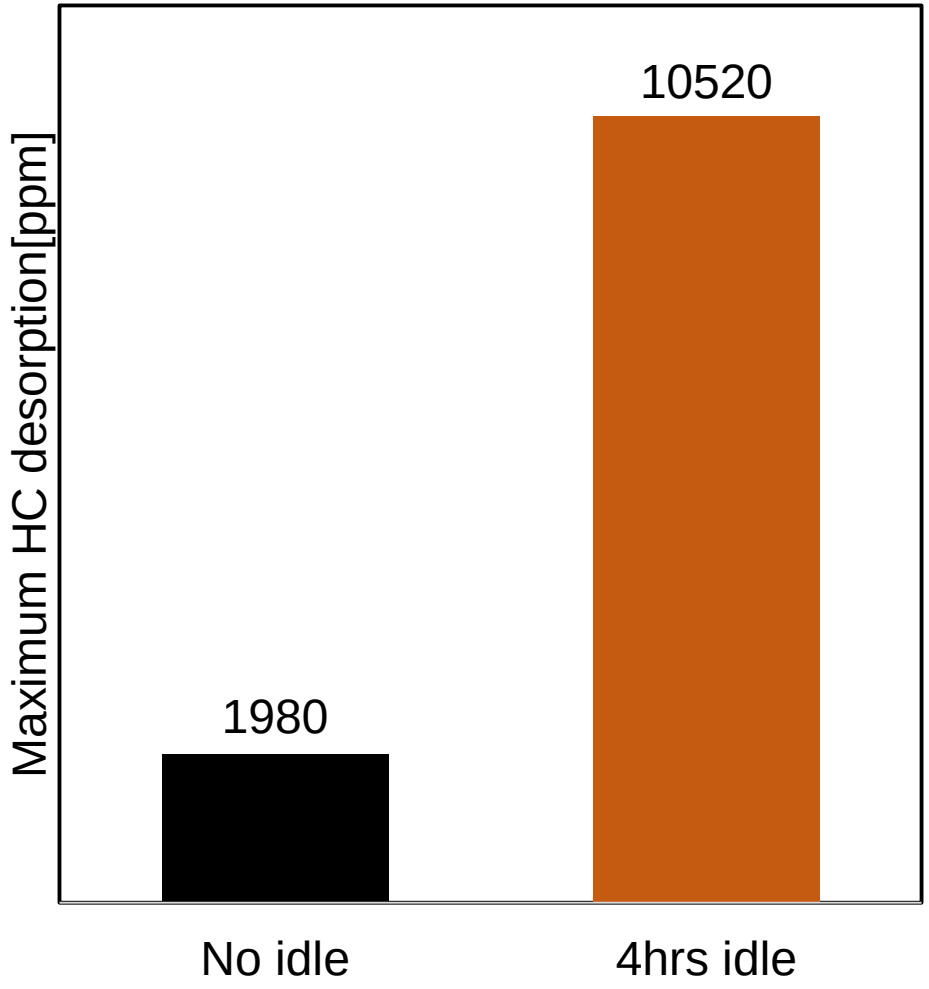


Fig. Maximum HC desorption amount from DOC

Influence of HC desorption from DOC during DTI test

- ✓ R-SiC showed 2~3g/L higher soot mass limit even though wall thickness of R-SiC was thinner than that of Cord.
- ✓ When comparing SML with 4hrs idle and without idle, 4hrs idle condition had shown lower SML.
- ✓ When comparing SML with 350degC and 620degC DTI temp., 350degC had shown lower SML despite that normal DTI temperature is usually ≥600degC

Table DTI* test condition

Test DPF	-Market Cord. (9/300) -R-SiC (Thin wall type)
Pre-Idle	0hr (w/o Idle), 4hrs
DTI trigger temp.	350degC, 620degC
Ramp up	Post injection

*Drop-to-idle: Abnormal regeneration caused by supplying high-concentration oxygen to the DPF when the vehicle is in an idle state with the accelerator off during forced regeneration while driving.

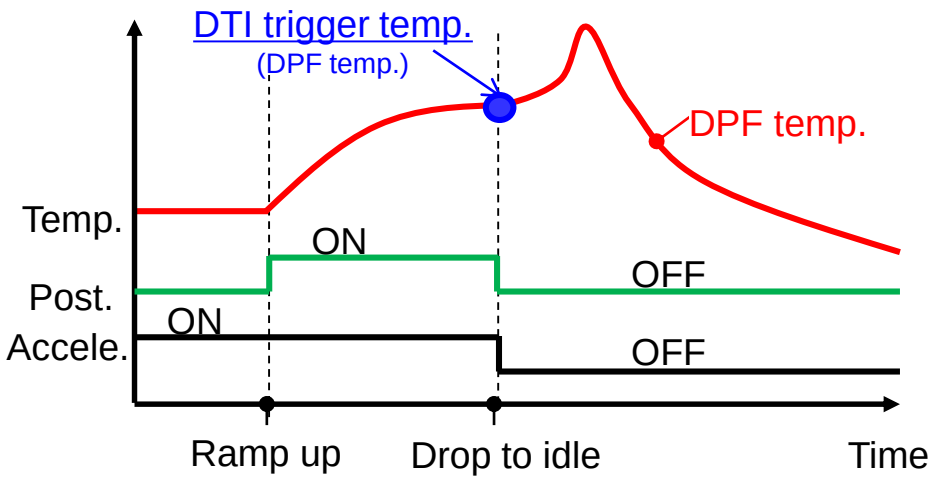


Fig. DTI test protocol

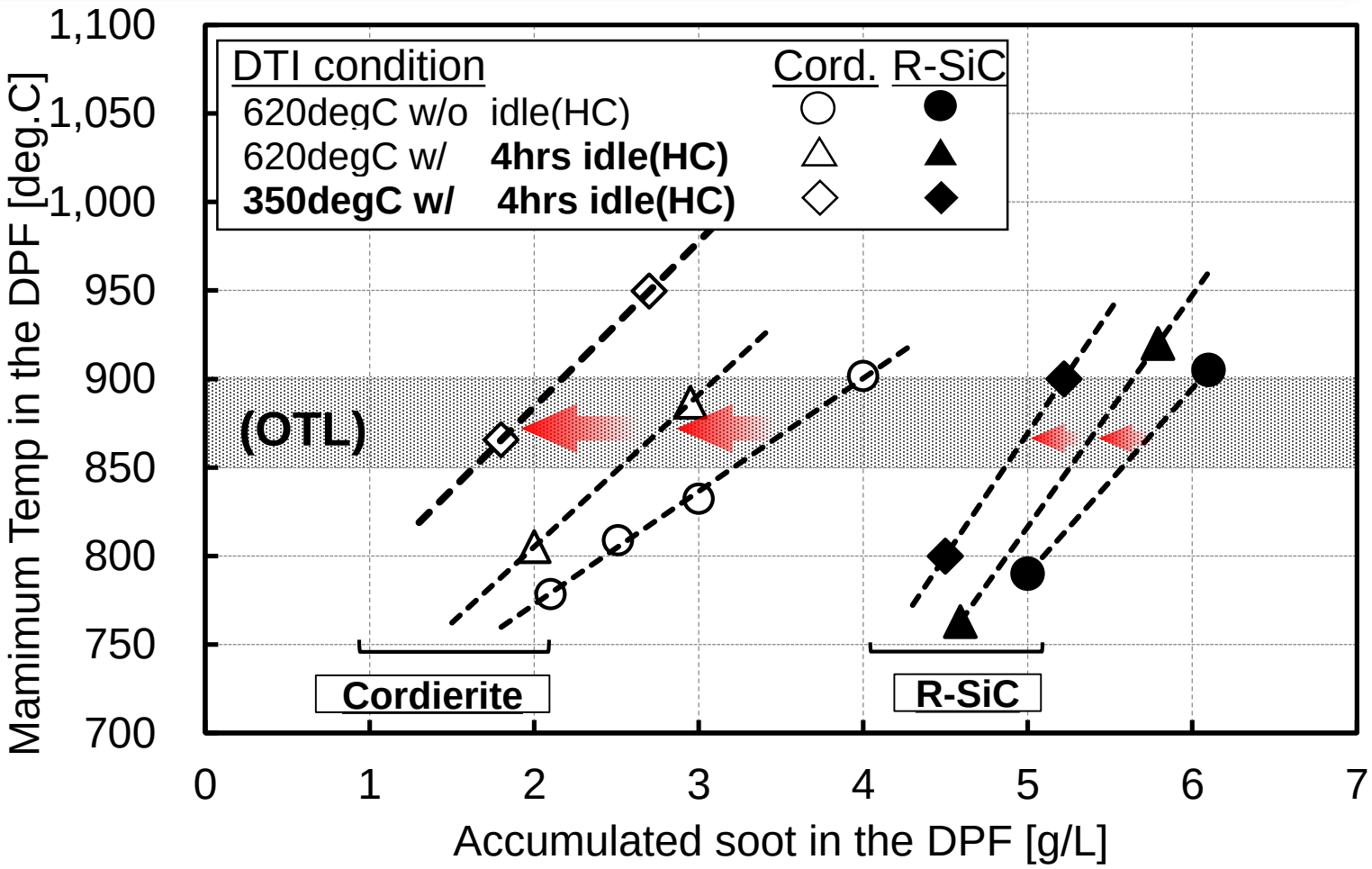


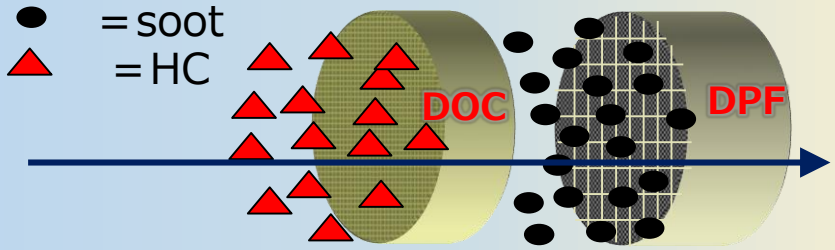
Fig. Maximum temperature in the DPF when DTI occurred

■ Influence of HC desorption and trigger temperature against DTI

Assumed mechanism

Long Idle ~ low speed

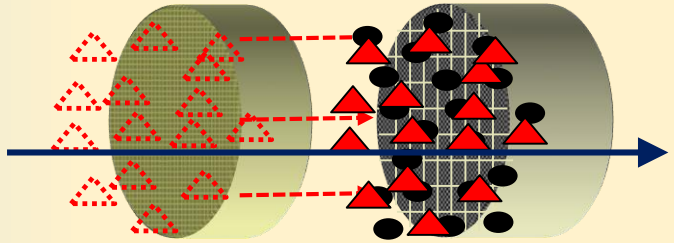
(≤150degC)



□ DOC adsorbed majority of HC

Intermediate ramp-up

(350degC)

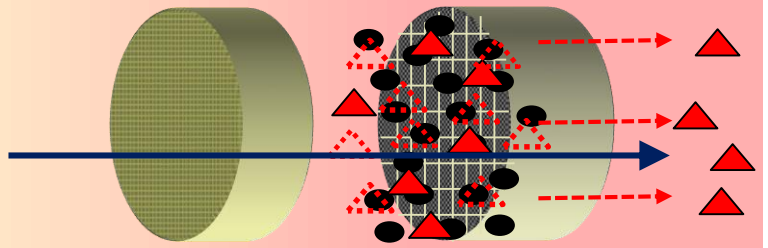


□ HC desorbed from DOC

□ DPF adsorbed HC from DOC

Ramp-upped

(600degC)



□ DPF started HC desorption

Exotherm energy source	Soot	Soot + much HC Exotherm temp of HC : ≈350degC	Soot + small HC

✓ **Most of the substances that cause exothermic reactions are on DPF**

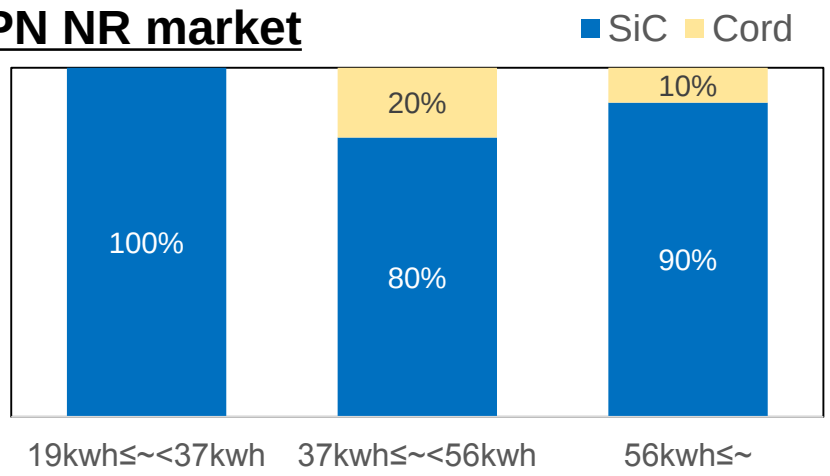
◆ **All diesel vehicles(PC,LCV,HCV) are under similar situation in India**

✓ **High robustness DPF is needed and IBIDEN can contribute to it by R-SiC* DPF**

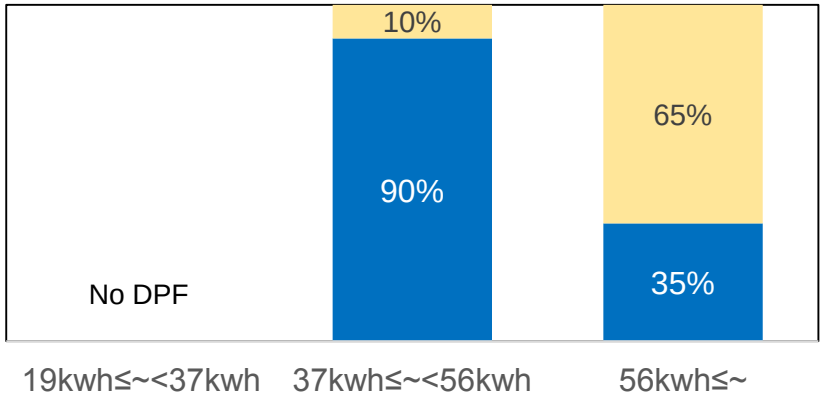
*** Has high thermal conductivity, high heat capacity as thermal robustness**

DPF type in NR Asian market and customer voice of R-SiC user

JPN NR market



China NR market



■ SiC is mainly used in small~middle engine

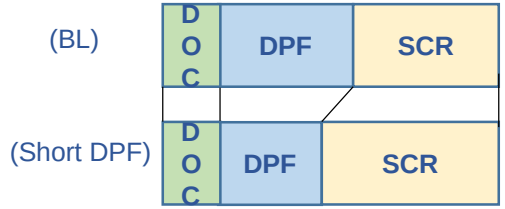
Fig. DPF substrate selection in power category*

*JPN/CHN NR OEMs(Major player of Small ~ middle size engine)
CICEIA , OEM info. and IBIDEN assumption data

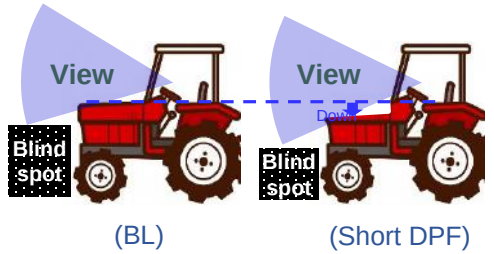
Customer voice (R-SiC benefit)

Company A

R-SiC enables low dP and high robustness→ Filter volume reduction possible!



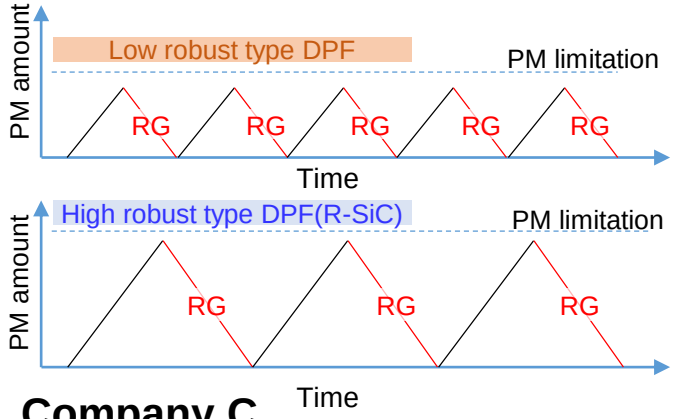
Increasing other component

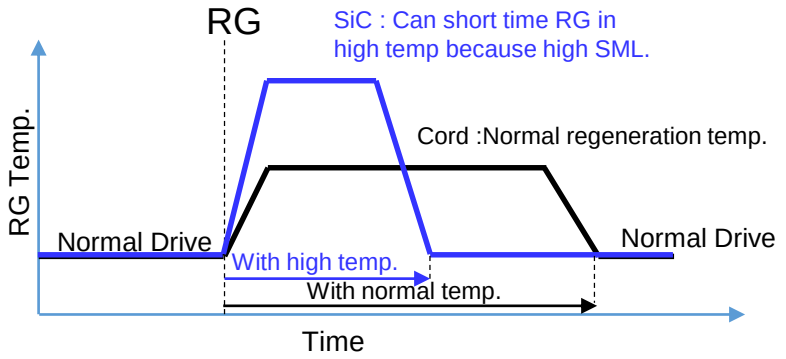


Small DPF can expand field of view for safety

Company B

R-SiC can reduce regeneration frequency, time, and fuel consumption!





Company C

R-SiC can unify system and reduce development cost with enough safety margin!

Engine	Calibration	Other	DPF	
			Cord	R-SiC
A	1:Torque peak@ 1500 rpm		Type A	Type A
	2:Torque peak@ 2200 rpm			
	3:Torque peak@ 2800 rpm		Type B	
	4:Torque peak@ 2200 rpm	With Turbo	Type C	

Thank you for your attention.

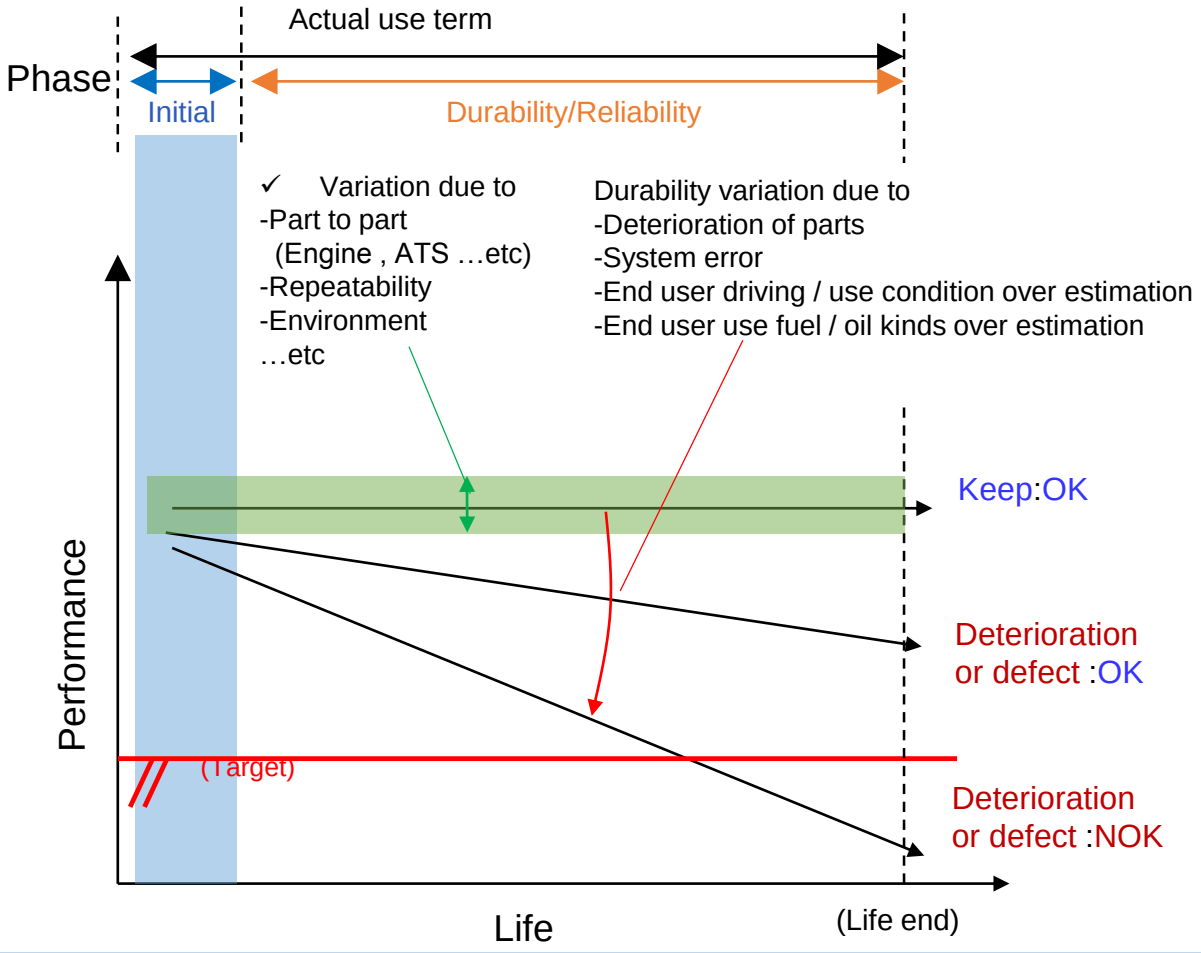
Let us support you more !!

IBIDEN Co., Ltd.

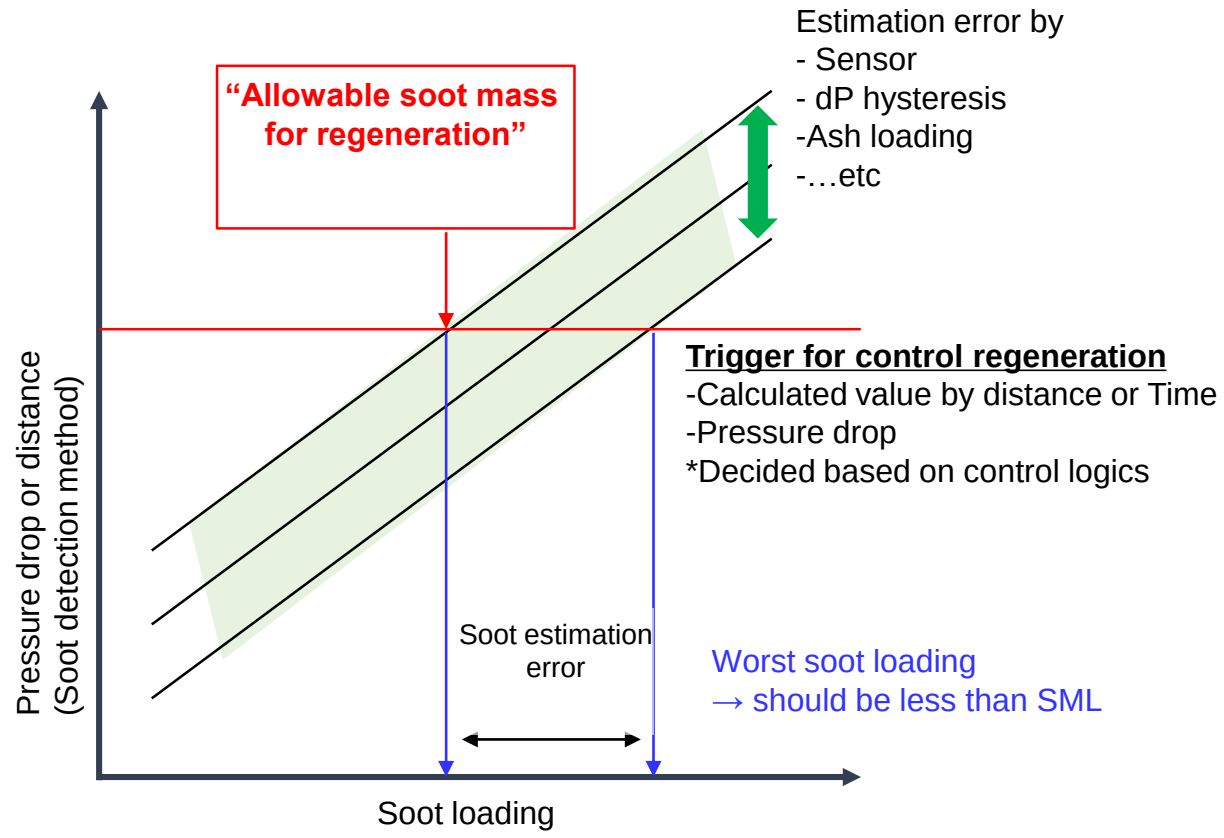
Fundamental safety design way considered with market use

✓ Parts is used for a long time in market, so to design stage includes performance from market release to life-end, and should be considered safety margin for lots deviation.

Parts performance from market release to life-end



Regen control(SML) with safety regen for a lot of deviation



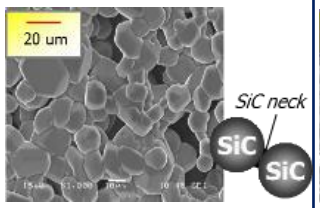
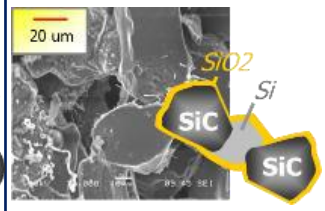
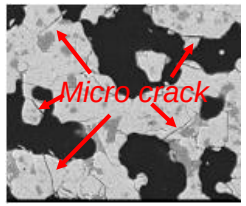
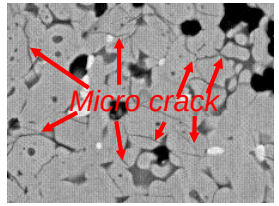
To design system with safety margin contributes reducing OEM's after service and increasing end user satisfaction

Characteristic of DPF Substrate (Benefit of R-SiC)

- R-SiC's high heat capacity and thermal conductivity contributes to DPF thermal robustness to provide regeneration repeatability and higher maximum regen soot load amount.
- Sharp pore distribution contributes on PM filtration performance.

Table Comparison of material

*Reference value

Item		IBIDEN R-SiC	Si-SiC	Cordierite	AT
SEM					
Material		Pure SiC	SiC, Si, SiO_2	MgO,Al2O_3,SiO_2	Al_2TiO_5 +α(Si,Sr,Ca,Mg)
k : Wall thermal conductivity[W/mK]	for High SML ,High RG ratio	**50***	17*	1*	1.5*
Pore distribution	for High filtration	**Sharp**	Broad	Broad	Broad

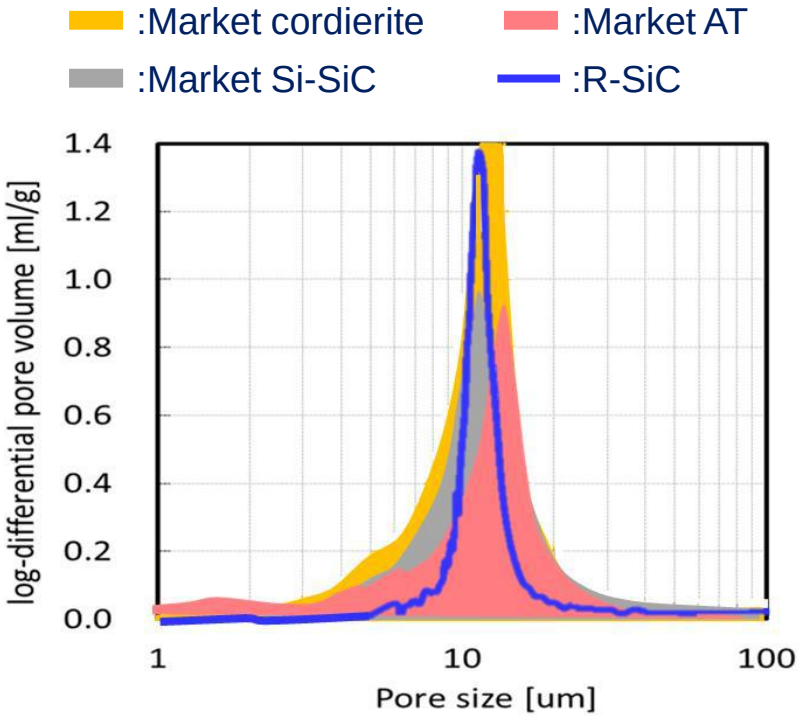


Fig. Comparison of pore size distribution

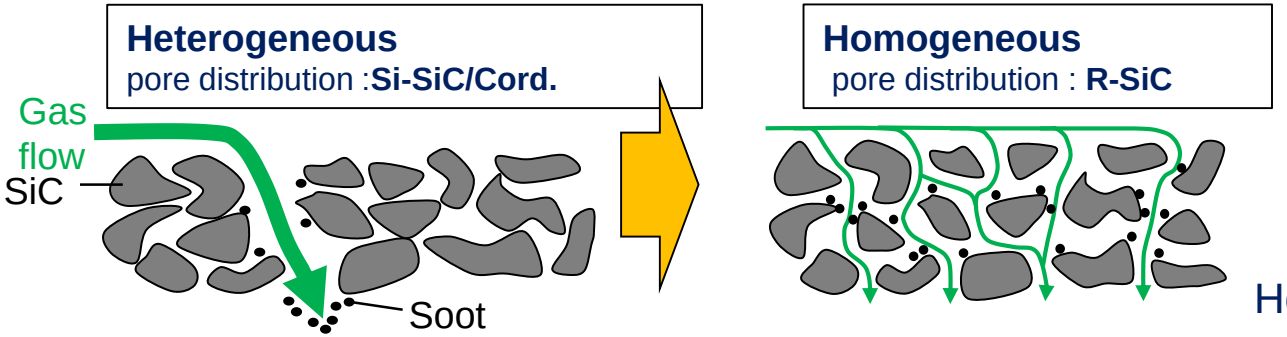


Fig. The image of gas flow uniformity of different pore distribution

Homogenization of gas

⇒High Filtration Efficiency

Appendix
Other deviation element should be considered for DPF

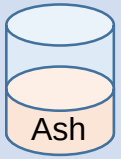
■ Ref.)Performance deterioration by i.g.:Ash

✓ Soot burned ash deposits on the filter step by step in use, and affect impact for performance
1:Ash decreases effective DPF volume and makes regeneration interval short .
2:Ash is composed by some material and it gives damage for substrate

Ash affection to SML

Example
DPF size : D6.77x6"L (Volume: 3.5L)
In case require SML is 14g/F(4g/L).

Table SML comparison

Material			R-SiC Thin wall type	Cord. 9/300
SML/Litter			6g/L	(4g/L)
Fresh : No ash		(Effective volume) 3.5L	18g/F :+100%* (Margin)	14.0g/F :+0%* (No margin)
Durability ash 30% of filter after durability		2.45L	14.7g/F :+5%*	9.8g/F :-30%*

*Advantage percentage for target SML
Blue : Clear Red : Not clear for Target SML

Ash affection to substrate material

✓ R-SiC has high chemical resistance

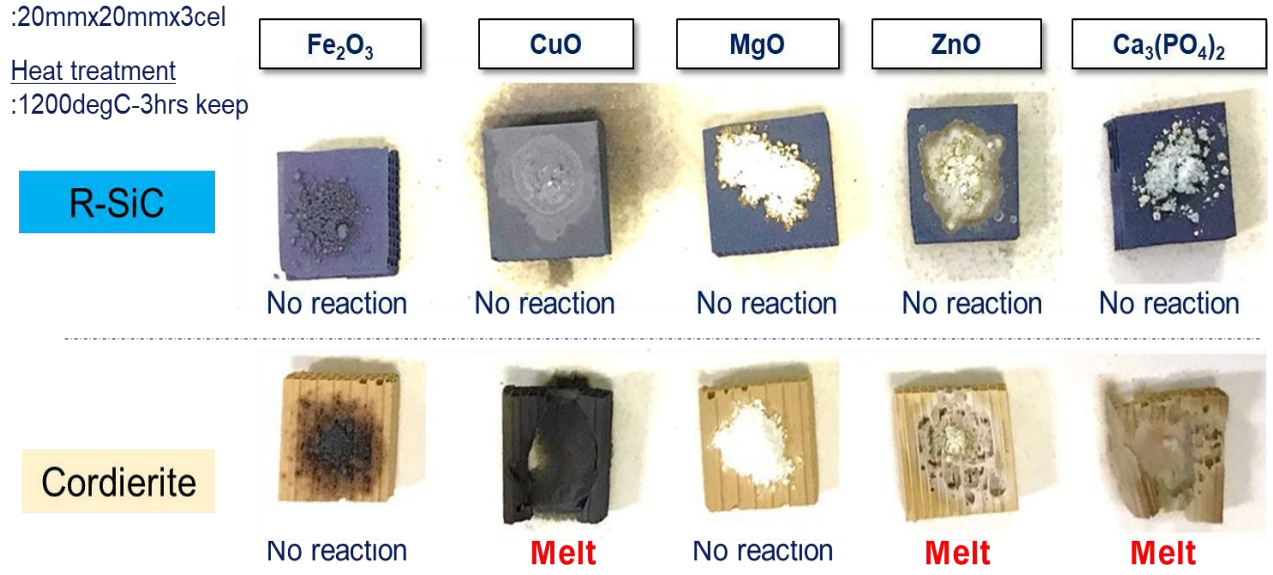


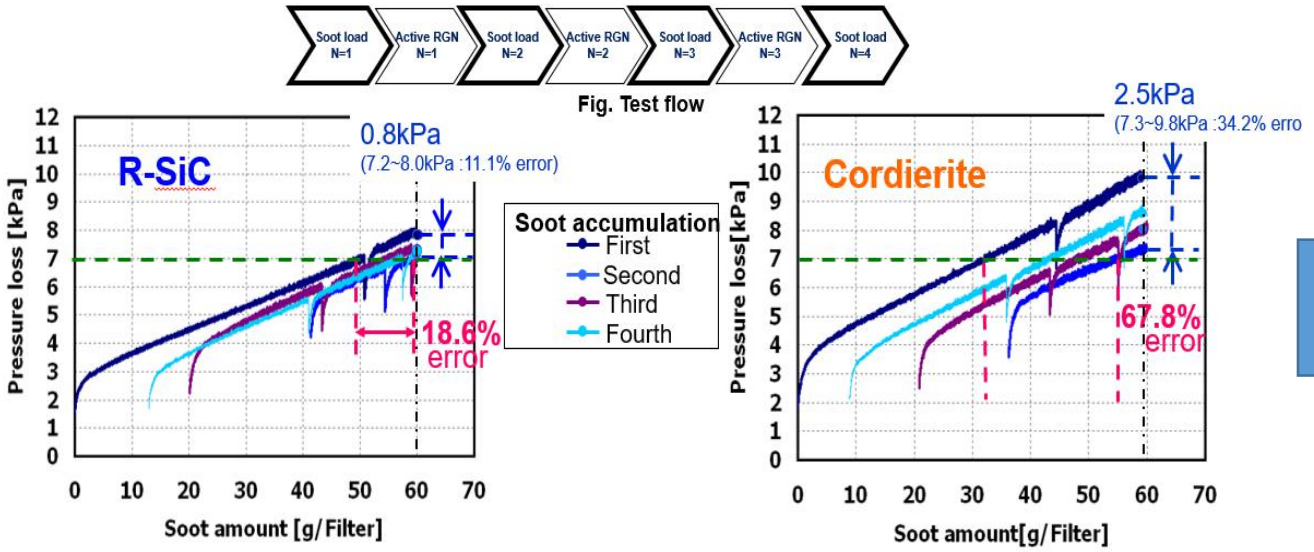
Fig. Chemical reaction test results

->broken filter , PN leak

■ Ref.) SML design considered with deviation

- ✓ Filtrated soot is deposited in the filter , and soot amount is detected by back pressure in generally.
- ✓ So back pressure deviation leads to miss detection of soot amount, and which in turn over soot load as possibility.
- ✓ To have margin considered with deviation is needed for avoiding regeneration failure

dP hysteresis (soot measurement deviation)



R-SiC
dP deviation in same soot
1st ~4th : 7.2~8.0kPa (11.1%)

Cordierite
dP deviation in same soot
1st ~4th : 7.3~9.8kPa (34.2%)

*Excluding First : Close to actual use(Soot deposit on Fresh filter)

dP hysteresis (soot measurement deviation)

*Considered with dP hysteresis

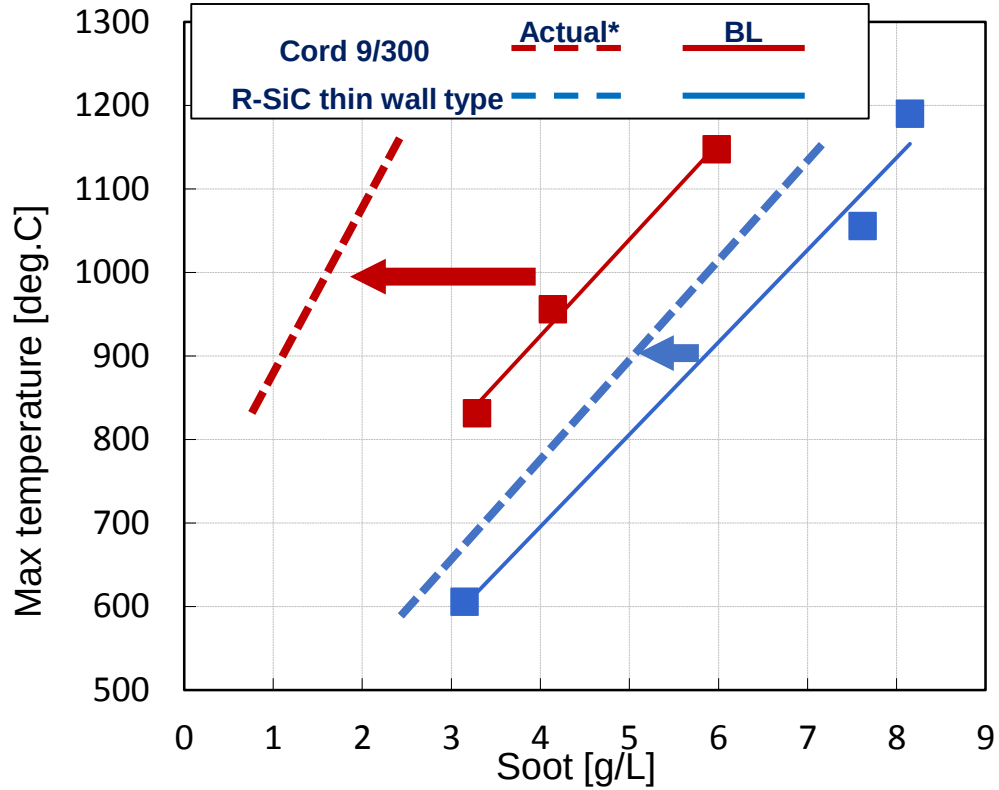


Fig. Maximum temperature on DTI test

One of the phenomenon behind regeneration trouble

Traffic Jam

◆ Heavy traffic jam often occurs in India, and vehicles kept longtime with idle/low speed.

Diesel basic ATS

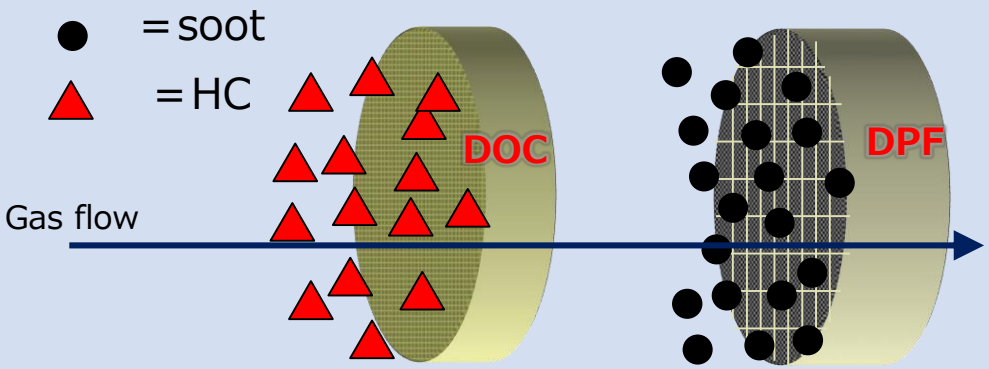
Main function	Purification (CO,NO,HC)	Filtration (Soot)	Purification (NOx)

In traffic jam (Low gas temp.)

Oxidation/Purification will be prevented

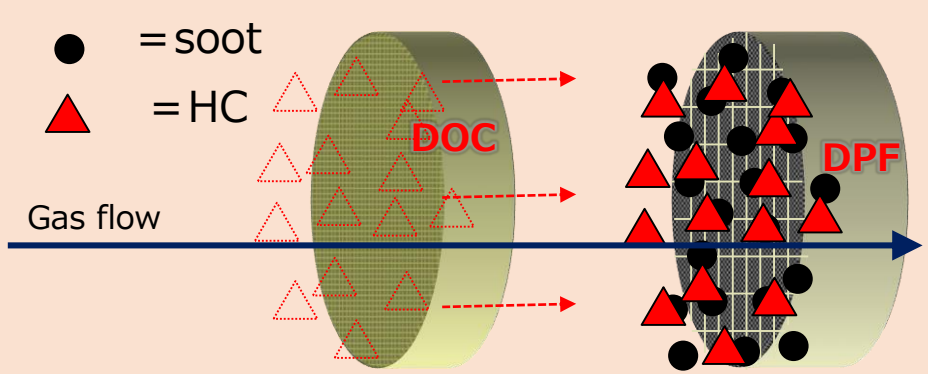
Soot regeneration will be prevented
➡Over soot load

Cool ATS (Idle~low speed)



Repeat Stop & Go

Heated ATS (≥Middle speed*)



✓ HC will be supplied from DOC to DPF
➡HC oxidation will cause exotherm

Possibility of occurrence these condition in Non-road segment

Heated ATS (≥Middle speed*)



Example

Cultivating

Digging

Basic working condition

ATS can performs

Cool ATS (Idle~low speed)



Example

Pumping water
(long time low load)

Moving/ Transfer on road
Long time idle in traffic jam

Other multi use condition

ATS performing will be prevented and similar situation(HC rich regeneration) will be occurred

✓ **Safety design system considered with multi use condition should be applied for Non-road, and R-SiC can contribute its DPF system design.**