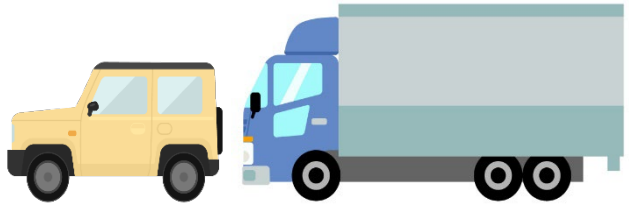
Need for Robust design of DPF for Non-Road Engines

■Leanings from other markets globally

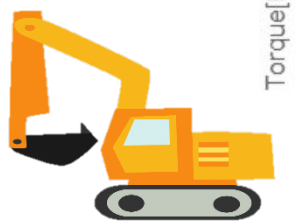
On-road vehicle

(Function ; Transfer of human/products)



Non-road vehicle

(Function ; **Work**)



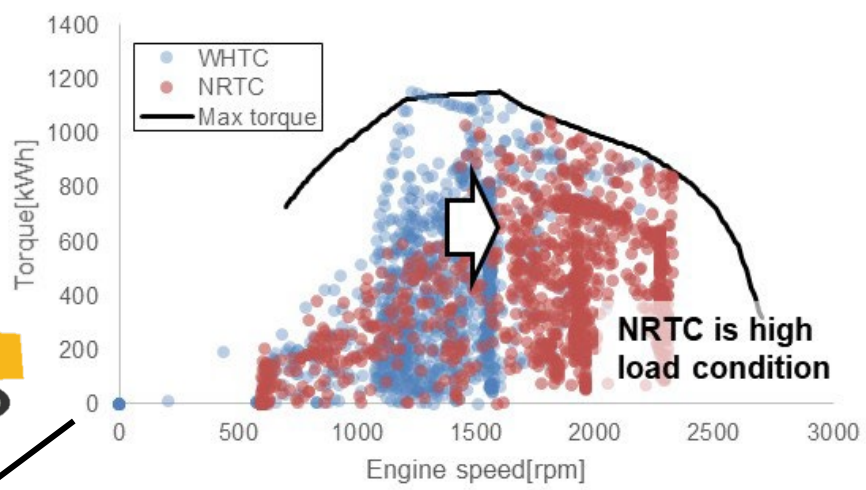


Fig. Engine map comparison b/w WHTC(OR) and NRTC(NR)

Road

◆ Vehicle runs based on traffic condition , area.

◆ Traffic condition is less

1: PN leaks easily due to high load

Requirement for DPF : High filtration performance

2: Higher Oil consumption

-> Ash* amount is higher than on-road vehicle for the same in use hours

Requirement for DPF : Low back pressure with Ash (or long ash cleaning interval)

Use

◆ Used under traffic rules

-> Less extreme condition

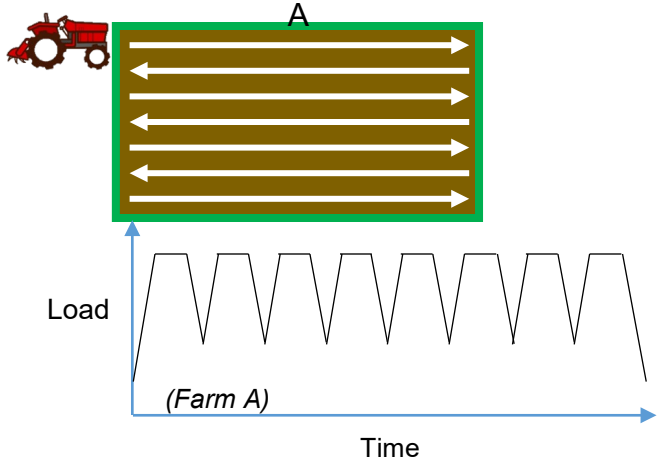
◆ Depends on customer education and decision including maintenance / type of oil and fuel etc

Requirement for DPF : High robustness considered with worst condition**

Example) Customer use condition variation

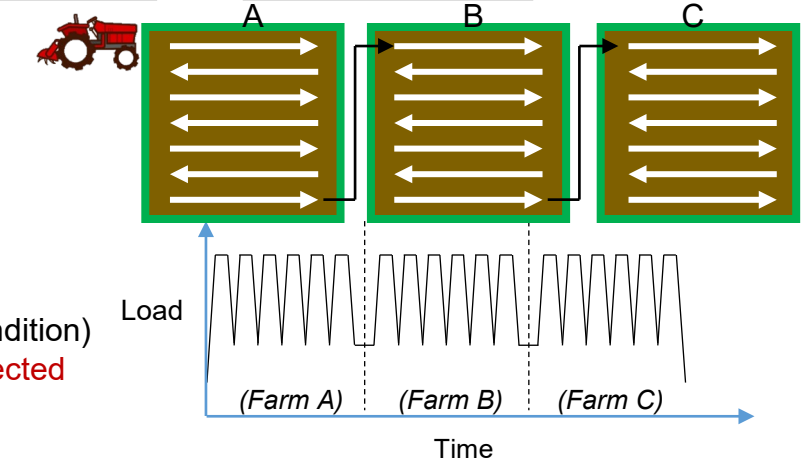
- ✓ In case tractor works in small size farm, the loading condition is transient (not stable condition) ,it implies passive RG is less than expected and more Active RG is needed.
- ✓ Higher robustness substrate :R-SiC can help in these deviations of working parameters.

Small tractor x Small farm

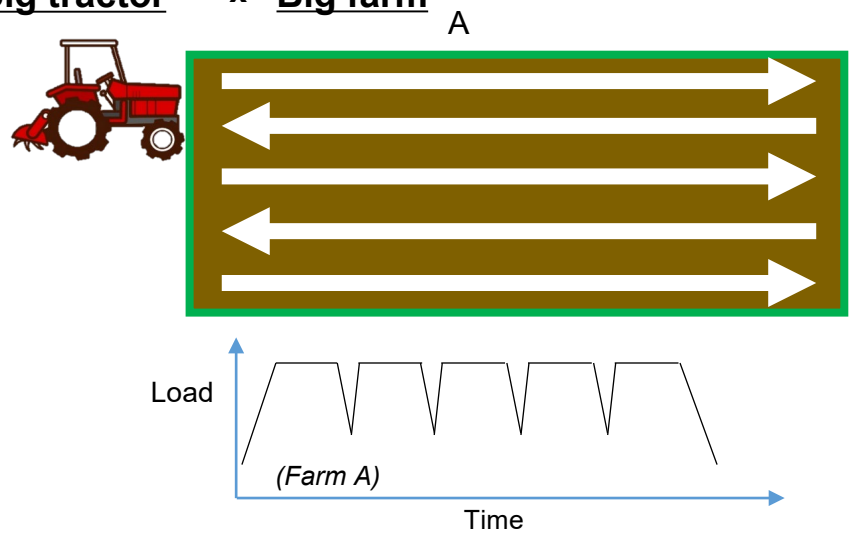


More transient(Not stable condition)
->Less passive RG than expected

Small tractor x More Small farm

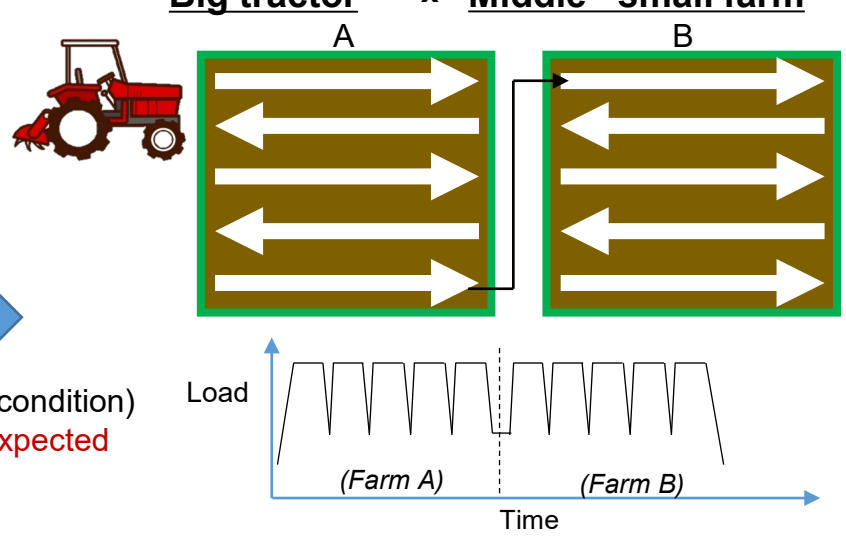


Big tractor x Big farm



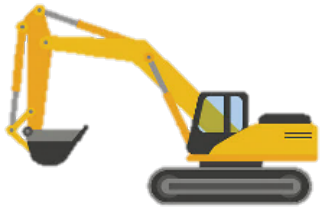
More transient(Not stable condition)
->Less passive RG than expected

Big tractor x Middle ~small farm



Example)End user character variation for each vehicle type

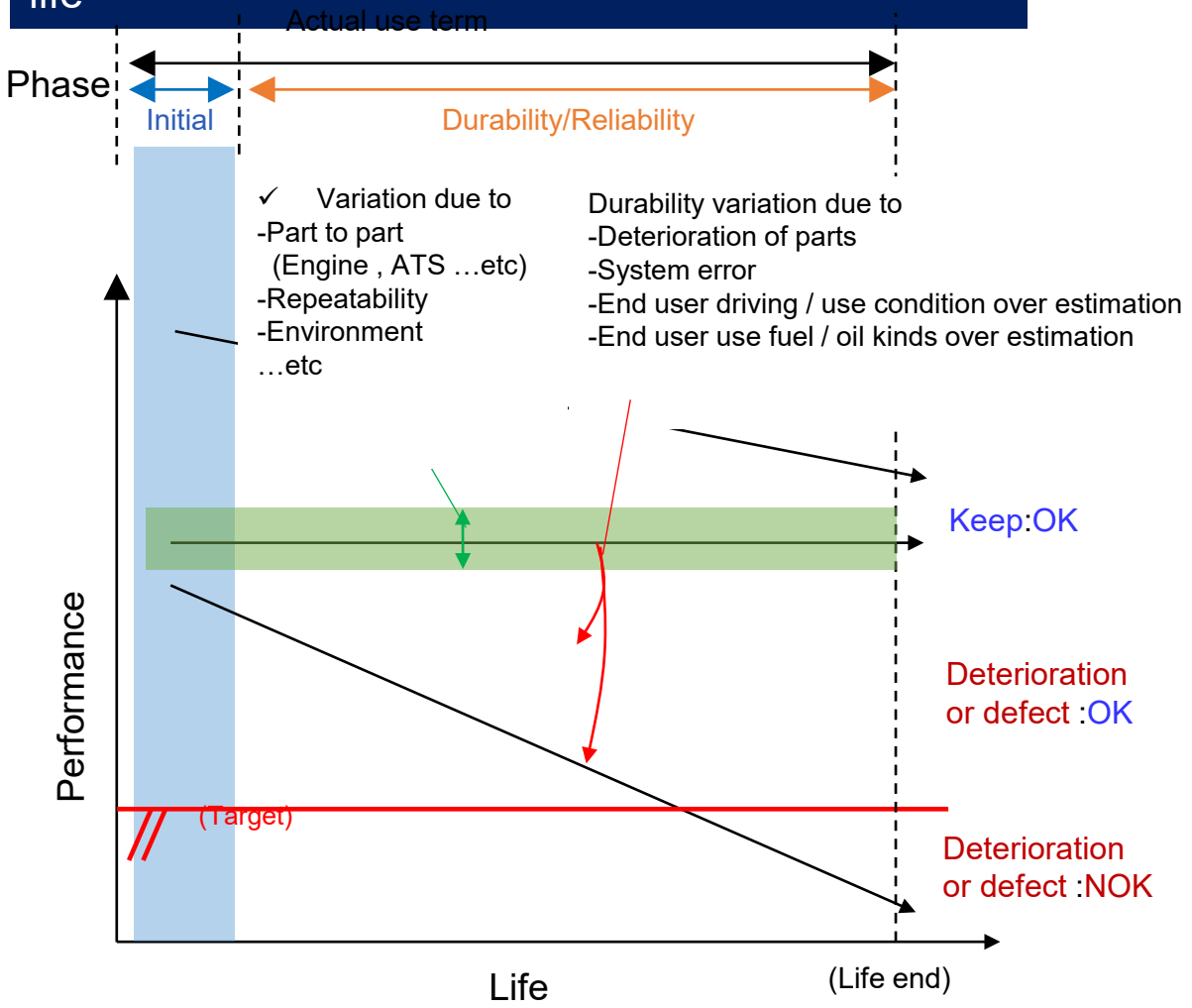
Table End user character for each vehicle type

Vehicle type	Passenger car(OR), AGRV(NR)	Medium/Heavy duty(OR) , CEV(NR)
	 	 
Main End User	Individual person* / small group* / Company   	Big group / Company  
Care (Maintenance)	*Depend on end user judgement -> Care/maintenance is less (Continue to use without care)	Care / regular maintenance is conducted depends on company
DPF robustness	**Requirement is much more.** **(Need robustness for avoiding customer complaints due to failure , and in order to reduce after care support by OEM)**	Requirement is needed. **(Need robustness for avoiding customer complaints due to failure , and in order to reduce after care support by OEM)**

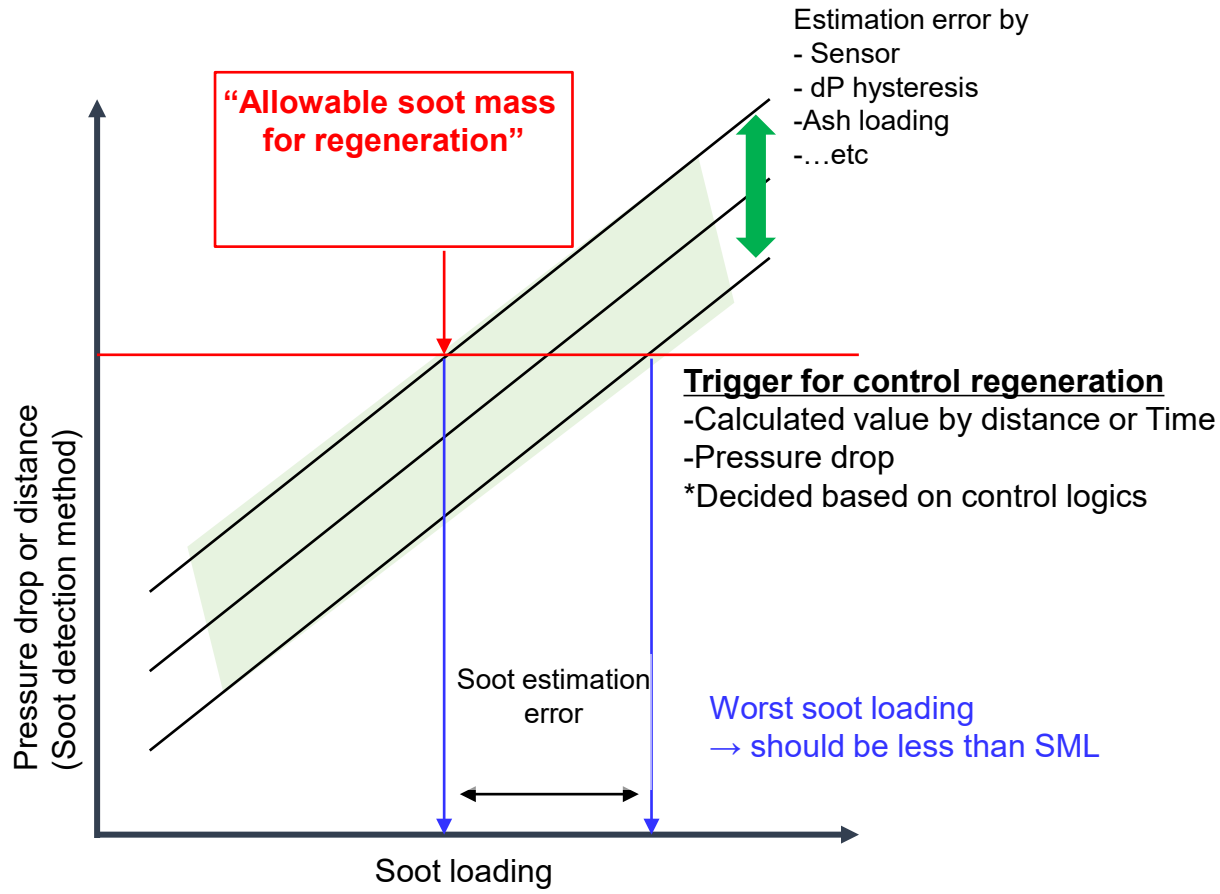
■ Robust design for actual use condition

✓ Parts are used in the market for a long time, hence the DPF has to perform from market release to end of life with safety margin for lots deviation.

Parts performance from market release to end of life

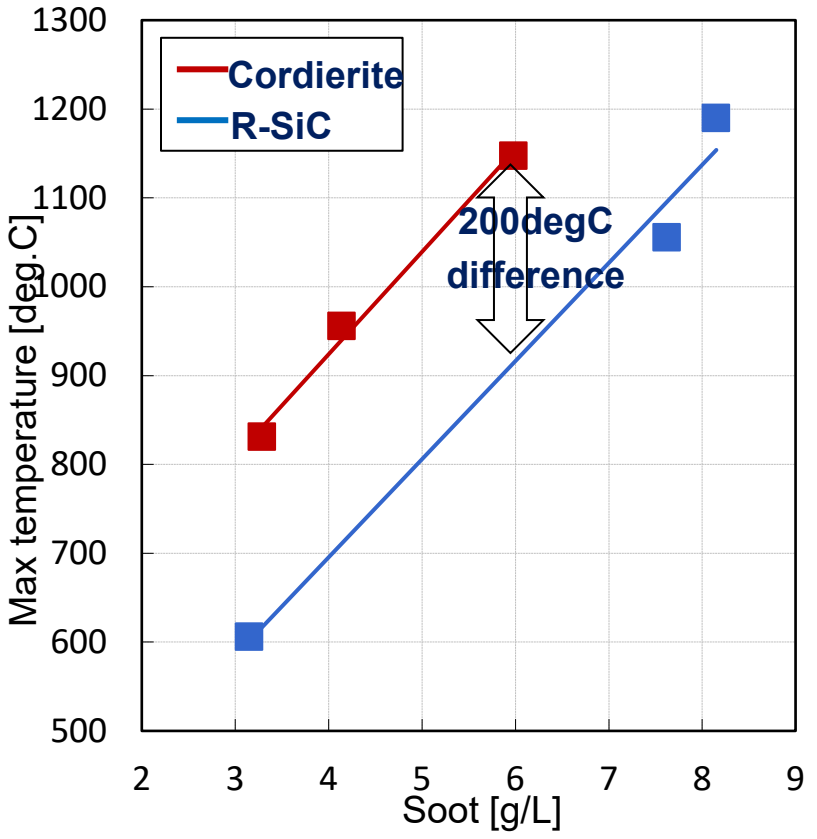


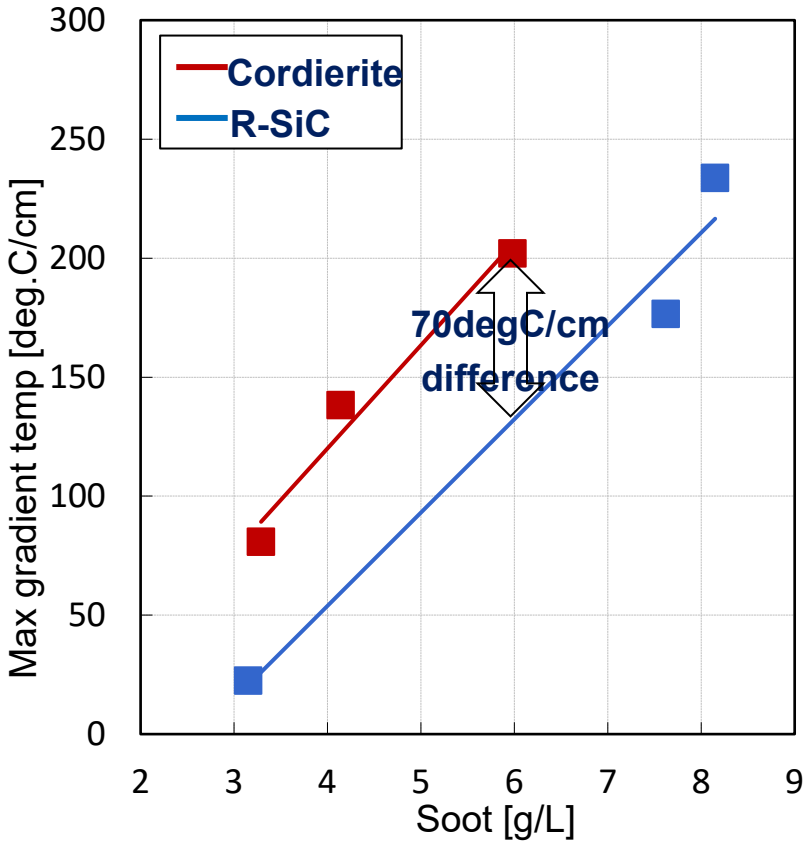
Regen control(SML) with safety regen for a lot of deviation



Example)Ash deposition effect for soot mass limit

- ✓ R-SiC has higher soot mass limit than Cordierite.
- ✓ Advantage soot mass limit can be used for reduced effective area by ash deposition.





Example
DPF size : D6.77x6"L (Volume: 3.5L)
In case require SML is 3g/L(10.5g/F).

Table SML comparison

Material		R-SiC	Cord.
SML/Litter		6g/L	(3g/L)
Fresh : No ash	(Effective volume) 3.5L	18g/F :+100%*	10.5g/F :+0%*
Deposit ash filled 50% of filter after durability	1.75L	10.5g/F :+0%*	5.3g/F :-50%* ->1.5g/L

*Advantage percentage for target SML

Blue : Clear Red : Not clear for Target SML

Fig. Maximum temperature during Drop-to-idle test with different soot load

■ Example)Considering back pressure on actual use

- ✓ Back pressure with soot has some deviation in actual use.
- ✓ R-SiC has higher repeatability for back pressure hysteresis

Fig. Test flow

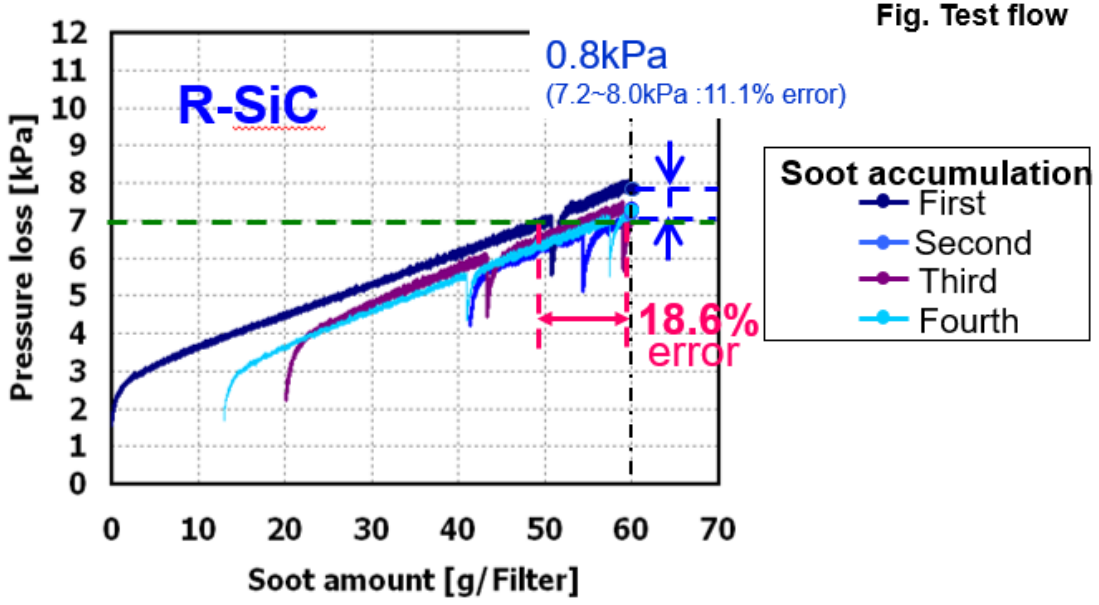


Fig. Pressure loss during soot accumulation and regeneration (300/7)

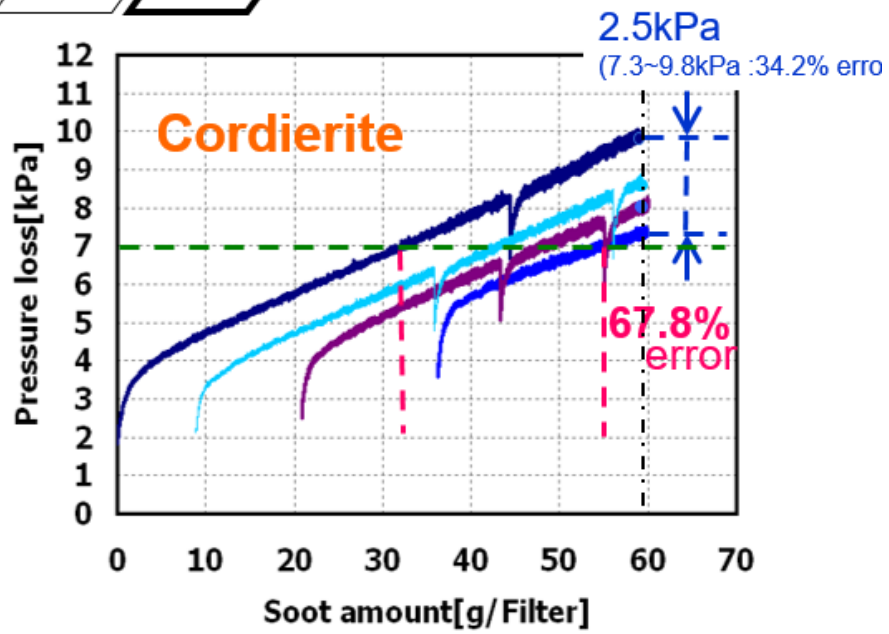


Fig. Pressure loss during soot accumulation and regeneration (Cordierite)

R-SiC

dP deviation in same soot

1st ~4th : 7.2~8.0kPa (11.1%)

2nd ~4th* : 7.2~7.6kPa (5.5%)

Cordierite

dP deviation in same soot

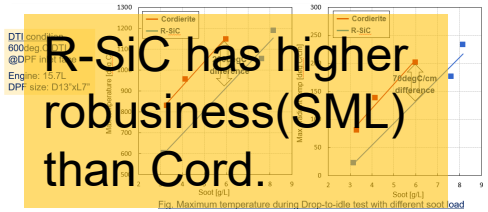
1st ~4th : 7.3~9.8kPa (34.2%)

2nd ~4th* : 7.3~8.7kPa (19.1%)

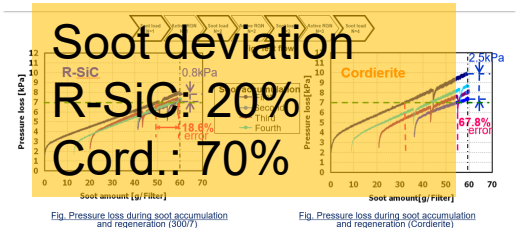
*Excluding First : Close to actual use(Soot deposit on Fresh filter)

■ Example)dP hysteresis effect for soot mass limit

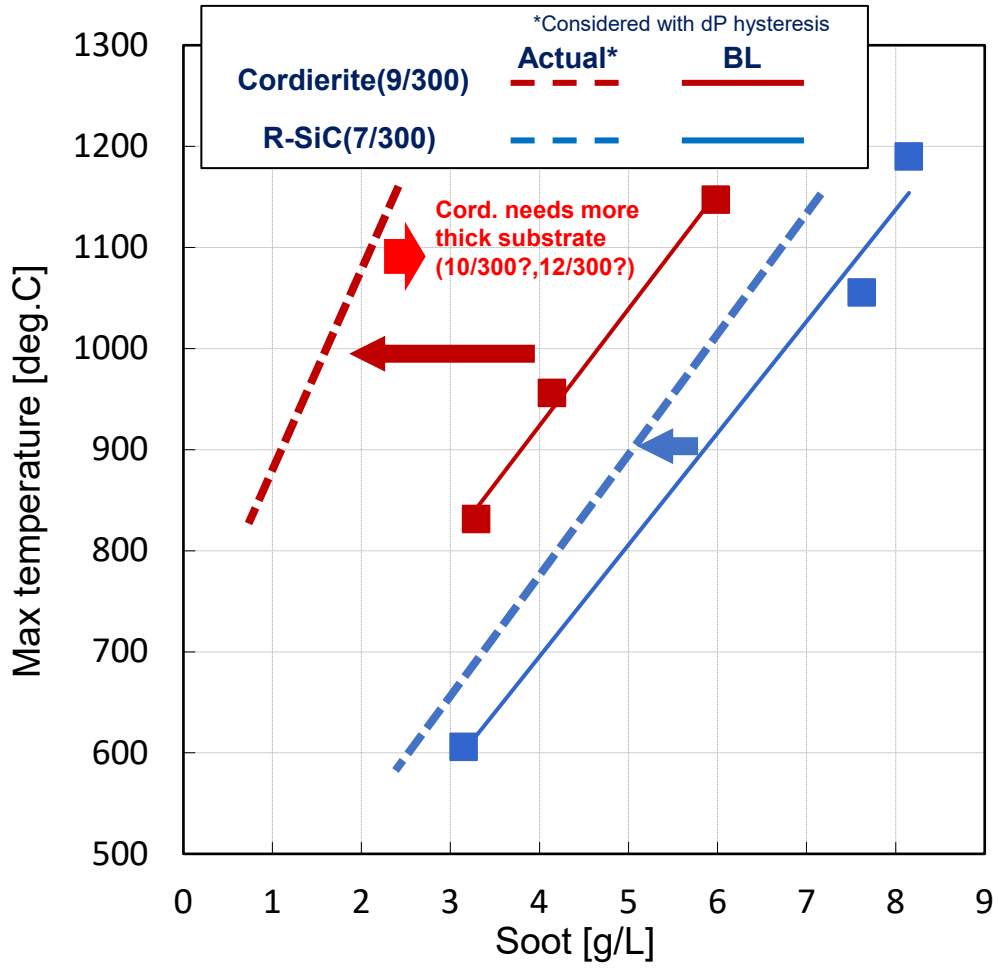
✓In case consider with dP deviation as hysteresis , there is possibility that actual soot amount is much higher than OBD/ECU value. R-SiC has better dP hysteresis and high robustness, therefore it help for control with some buffer



R-SiC has higher robusiness(SML) than Cord.



Soot deviation
R-SiC: 20%
Cord.: 70%



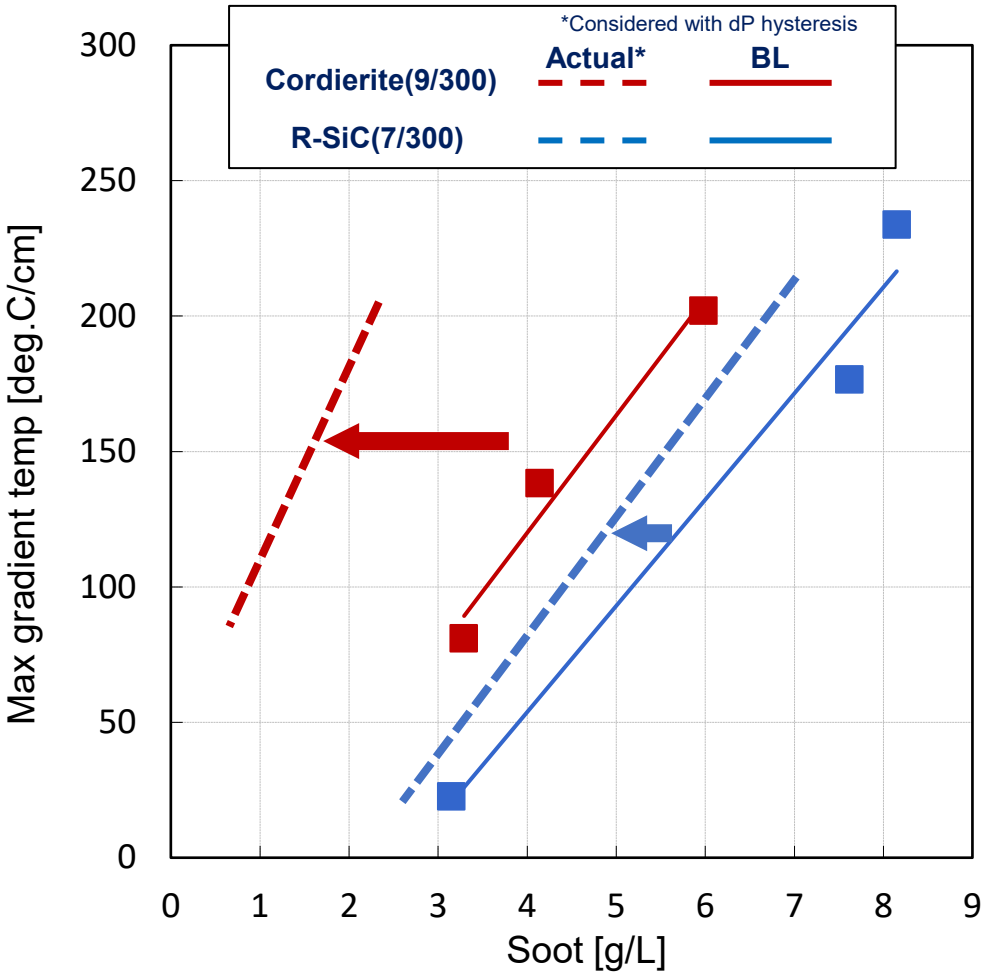


Fig. Maximum temperature during Drop-to-idle test with different soot load

Example)Chemical durability test

- ✓ Ash is deposited in the filter through soot regeneration, and there is possibility that ash reacts with the substrate and leads to defect.
- ✓ SiC has high chemical resistance and no defect.

India market Ash

Fig. Deposit ash

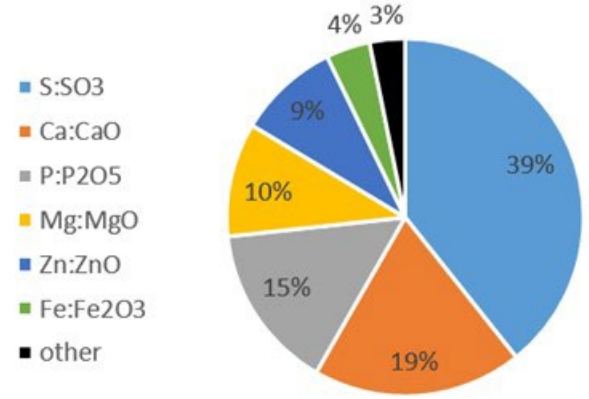


Fig. Element ratio(Oxidation based) by XRF

Test cell
:20mmx20mmx3cel

Heat treatment
:1200degC-3hrs keep

	Fe_2O_3	CuO	MgO	ZnO	$Fe_2(SO_4)_3$	$Ca_3(PO_4)_2$
R-SiC	No reaction	No reaction	No reaction	No reaction	No reaction	No reaction
Cordierite	No reaction	**Melt**	No reaction	**Melt**	No reaction	**Melt**

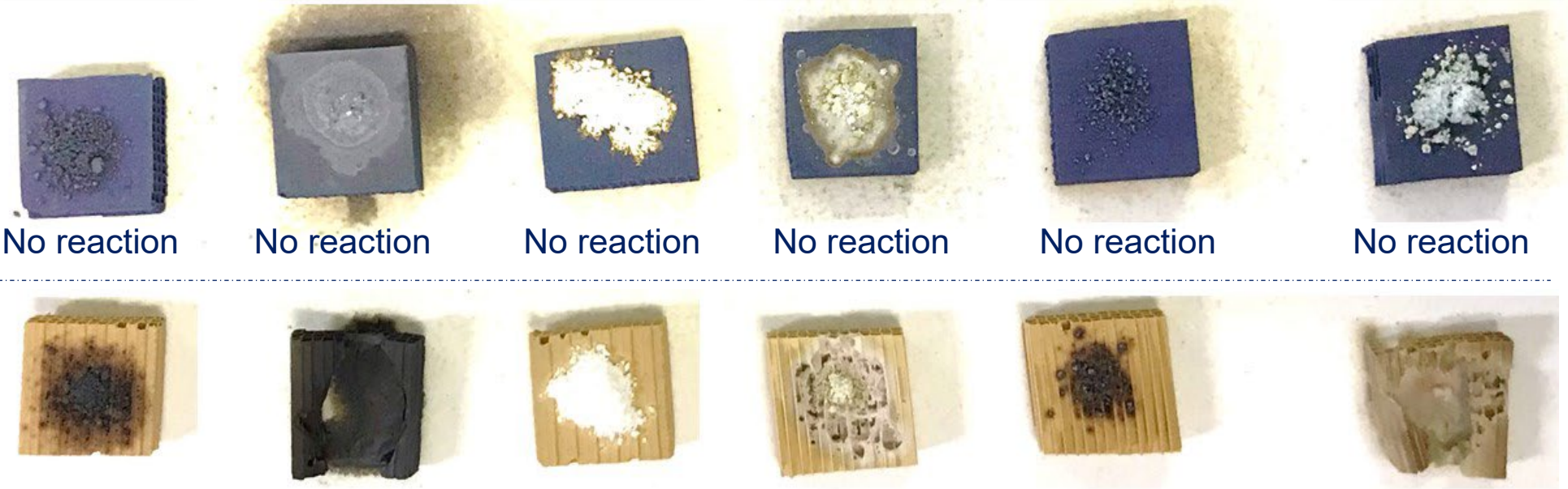


Fig. Chemical reaction test results

Size commonization

-Generally ,one engine is used with different DPFs and each calibration for each vehicle type. Especially one small engine has many iterations leading to higher cost.

-> SiC DPF has high robustness(SML) and can cover these different type of usage with single size.

Engine	Calibration	Other	DPF	
			Cord	SiC
A_30~40kwh	1:Torque peak@ 1500 rpm		Shape A	Shape A (Common)
	2:Torque peak@ 2200 rpm			
	3:Torque peak@ 2800 rpm		Shape B	
	4:Torque peak@ 2200 rpm	With Turbo	Shape C	
B_50kwh	Torque peak@ 2000 rpm	With Turbo	Shape D	

IBIDEN support for customer development

✓ IBIDEN can supply robustness substrate for meeting customer requirement , and can support development by some equipment including test cell(Engine bench)

Item				Contents	Example of contents
Technical Support	Technical support	Physical property		Fundamental properties	Bending strength, compressive strength, porosity, pore diameter, pore size distribution
		Segment		Segment evaluation	Cold-flow dP, DTI (SML), PM size distribution
		DPF	Test cell	Test with engines	PN filtration, dP, Regen. Efficiency, Uncontrolled regen., PN/PM measurement
			Vibration	Reliability test against cycles of vibration	
			Heat cycle	Reliability test against repeated thermal stress	
			Hot shake	Reliability test of vibration and thermal stress	
			Isostatic statics	Durability against canning	
			Ash accumulation	Ash loaded DPF evaluation by accumulating artificial ash	
	Analysis support	Filter analysis		Filter analysis	Size, weight, ash amount, crack detection and route cause, thermal record, internal observation
		dP simulation		[Input] DPF size, pore structure, cell structure, gas velocity, temperature, soot density, ash density [Output]dP at input condition	
		CAE	Gas flow + heat	Gas flow and thermal distribution calculation of after treatment system	
			Regeneration	Thermal behavior calculation during soot load and regeneration based on actual test	
			Filtration	Soot size distribution, DPF pore structure, soot filtration	

Thank you for your attention.

Let us support you more !!

IBIDEN Co., Ltd.