Experimental study on the PM emission characteristics of filter failure conditions

Chun B. Lee, Kwang C. Oh. Jong H. Kim. Kyoung B. Lee. Deok J. Kim. Chun H. Lee

Director of Diesel Hybrid System R&D Center, Korea Automotive Technology Institute (KATECH)

Several problems with exhaust gas emitted by diesel engine must be solved. Especially particulate matter (PM) is the major concerns. To reduce emission of diesel soot, diesel particulate filter (DPF) has become widely known as an indispensable after-treatment component of the purification of the PM in the diesel exhaust gas. DPF is damaging by various forms such as whitening and crack due to controlled or uncontrolled regeneration and uncertain reasons, and there is no clear criterion to judge the cracked filter. So, we hope to classify the degree of filter crack using the particle emission characteristics. Filtration efficiency of PN for cracked filter is varying from time to time, it is showing a big differences by the test number. But, some failure shows no difference of PM filtration efficiency with fresh filter. In this study, we hope to find two objectives. First, it is find the reduction efficiency of PM mass & number for fresh and cracked filters. Second, we standardize the crack level of filter.

This study was conducted by two different engines (Euro-I, Euro-IV) and four samples having different unknown levels of crack (4 samples – Fresh / Sample A / Sample B / Sample C).

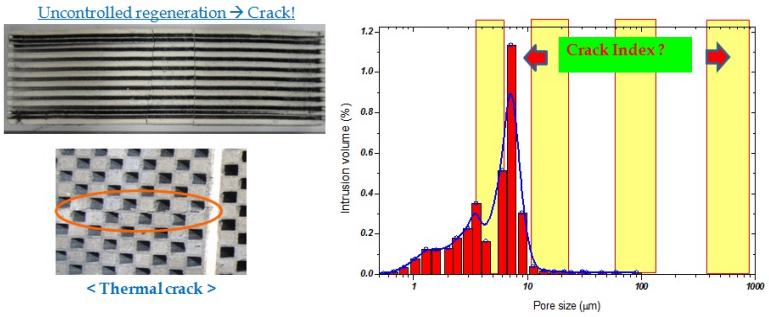

Fig.1 How do the cracked filters classify?

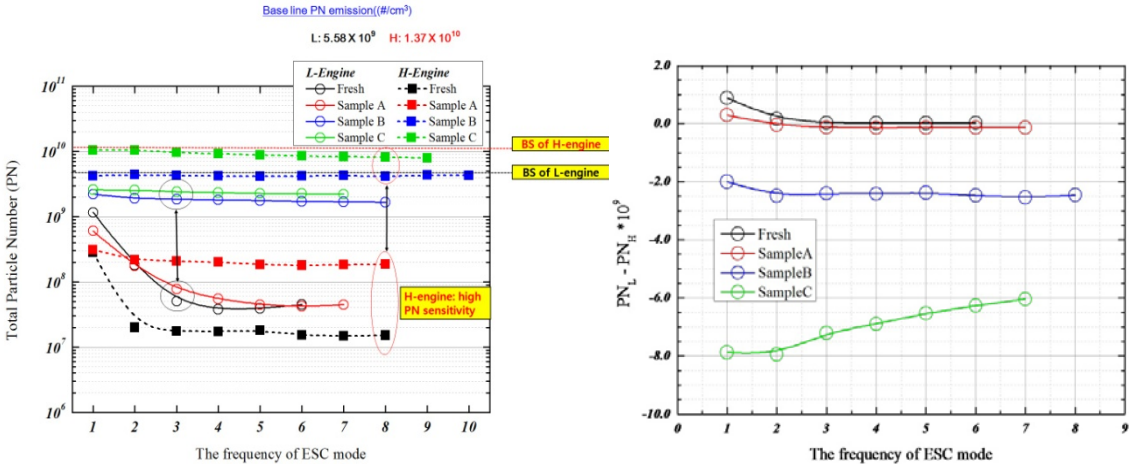

Fig.2 The experimental results of this study (various cracked filters)

In this study, the experimental results of cracked filters are as follows.

In terms of PN reduction rate of filter, the difference of PN reduction rate and number according to the level of crack shows more stable and clear difference than PM variation. Therefore, PN is more appropriate variable than PM mass to classify the level of filter crack. In addition, the difference of PN according to the engine (PN_L-PN_H) shows stable and a bigger difference according to the level of filter defects. Thus, by using the index of PN_L-PN_H, we can classify the crack level of the unknown filters. In future work, we classify the level of crack by morphology study through the 3D tomography, etc., and find the numerical correlation between PN and PM with the crack morphology.

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Chun B. Lee

Director of Diesel_Hybrid System

R&D Center(cblee@katech.re.kr)

KATECH KOREA AUTOMOTIVE TECHNOLOGY INSTITUTE

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Background?

-DPF Crack is occurred by the several kinds of causes; whitening and crack due to controlled or uncontrolled regeneration and uncertain reasons.

-There is no quantitative standards to classify the DPF Failures

- Filtration efficiency of cracked filter is varying from time to time, it is showing a big differences by the test number.

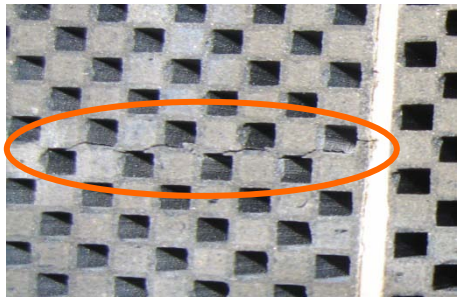
- Some failure shows no difference of PM filtration efficiency with fresh filter.

-How can we classify the status of cracked filter ?

-Should we monitor the PN rather than PM to decide the reuse of filter?

Class	Test No W ESC	PM_MASS(g/kwh)	PM_Reduction(%)
Cracked filter	H3_old_01	0.056	64
	H3_old_02	0.042	73
	H3_old_03	0.029	81
	H3_old_04	0.018	89
	H3_old_05	0.022	86
	H3_old_06	0.017	89
Fresh filter	H3_NEW_01	0.008	95
	H3_NEW_02	0.007	96
	H3_NEW_03	0.008	94

< Whitening failure >



< Thermal crack >

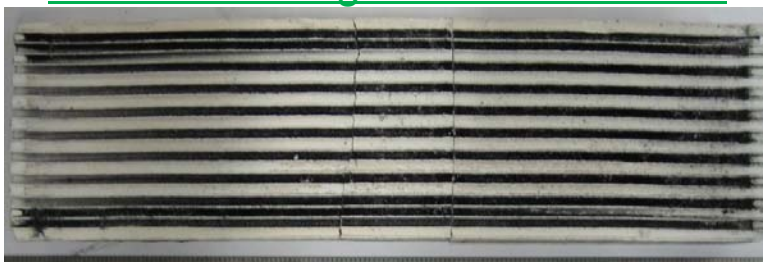
< Ring + multipoint Crack >

Purpose of study

In this Study, we hope to find

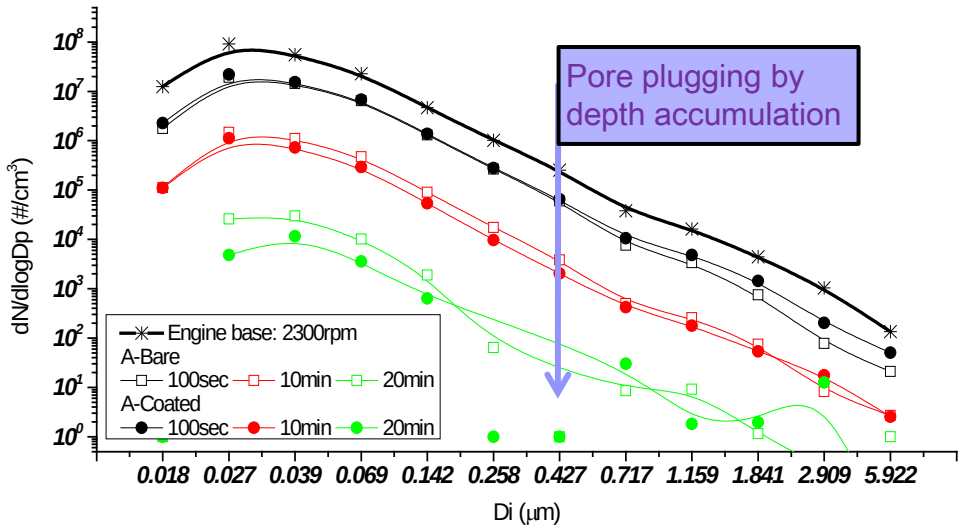
1. Reduction efficiency of PM & PN of fresh and cracked filters
2. How can we standardize the level of filter crack!

Uncontrolled regeneration → Crack!



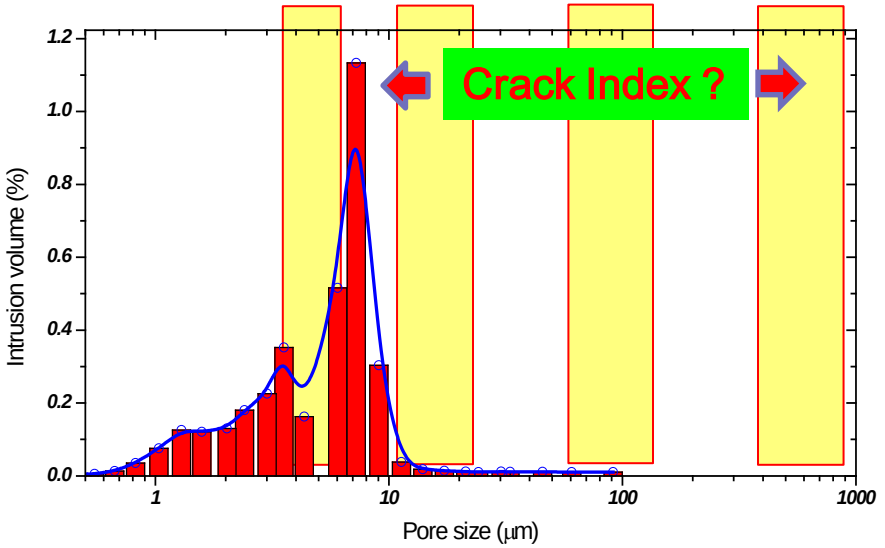
PN emission a.t. the loading time

PN emission of cleaned filter depends on the pore plugging by accumulation duration(10s,10/20min).



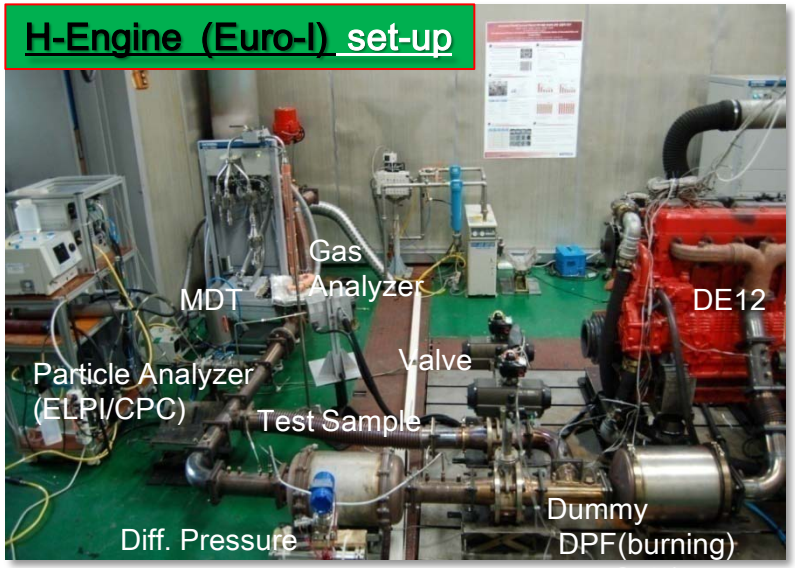
How to classify the index of crack?

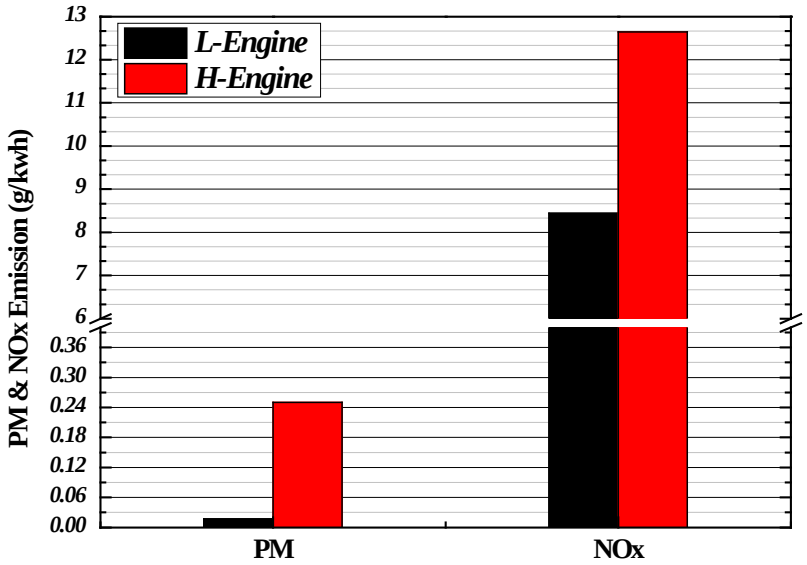
Pore size distribution versus representative index of filter crack?



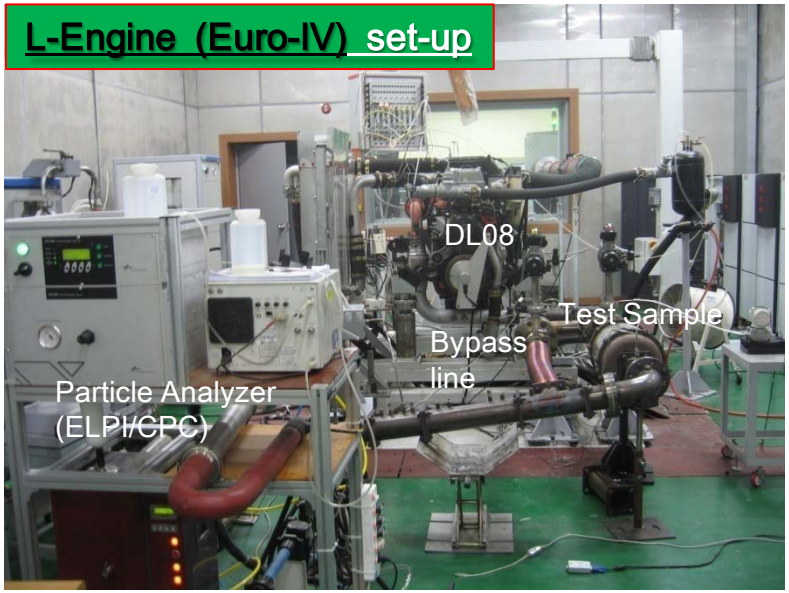
Experimental Setup

H-Engine (Euro-I) set-up





L-Engine (Euro-IV) set-up

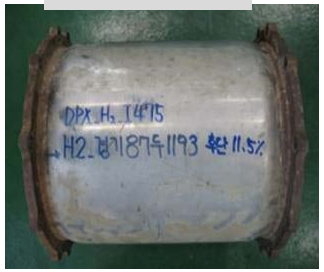


Test Procedure

1. DPF Cleaning/preconditioning @ 1500rpm /750Nm
   - Treatment Temp. for cleaning : 550 °C
   - EXH gas flow rate: 490 kg/hr
2. Engine warm-up and conditioning with Bypass Path
3. Turn to the Test Path to preserve the test condition of DPF
4. Repeat test of ESC mode : measuring average PM efficiency and total PN per ESC test cycle

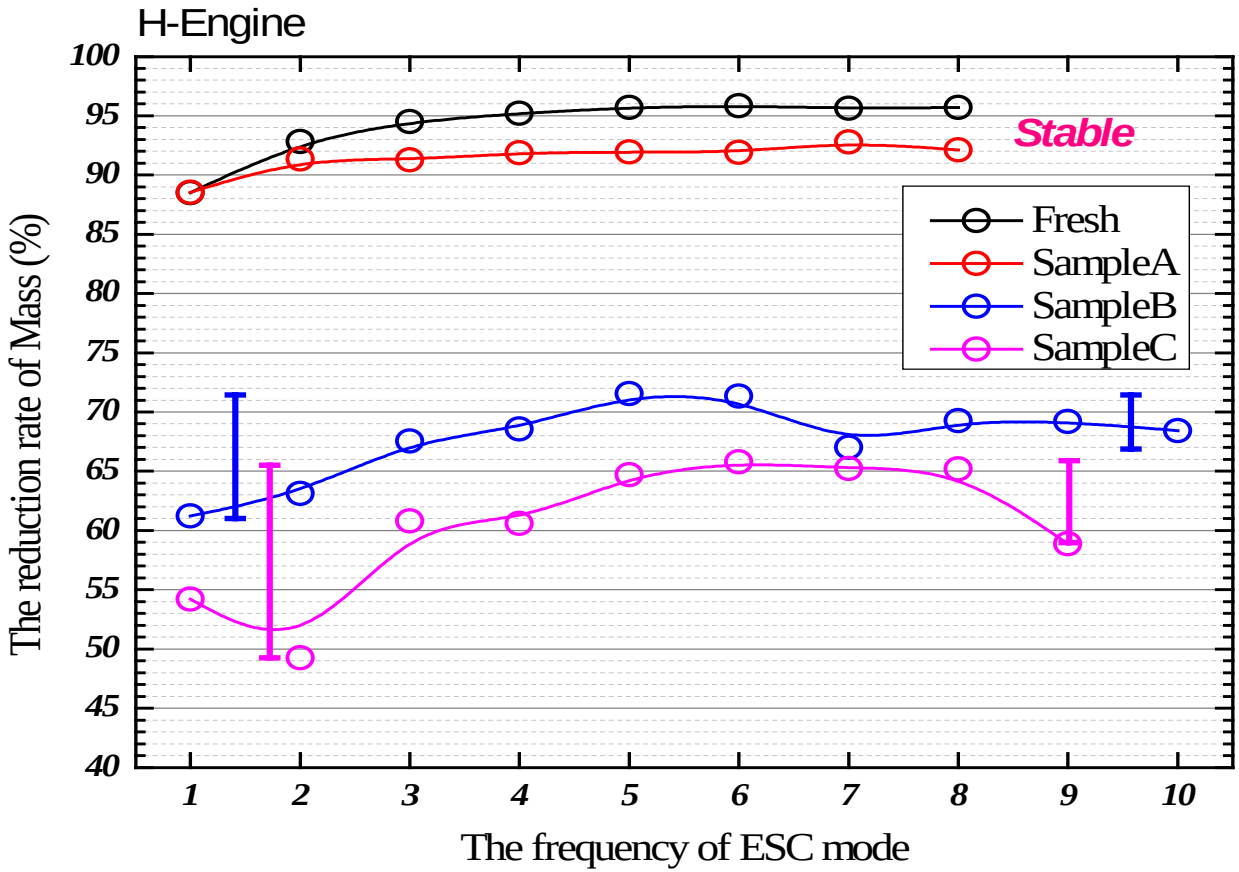
Test Filters

- Filters: used for Seoul city bus ran a fixed route/same duty
- Level of crack : Fresh < Sample A < Sample B < Sample C

	Fresh	130,000 km	180,000 km	170,000 km
Front Side				
Rear Side				
	Fresh sample	Sample A	Sample B	Sample C

Result and Discussion

Result and discussion(1/6)



1. Fresh and Sample A @ H-engine

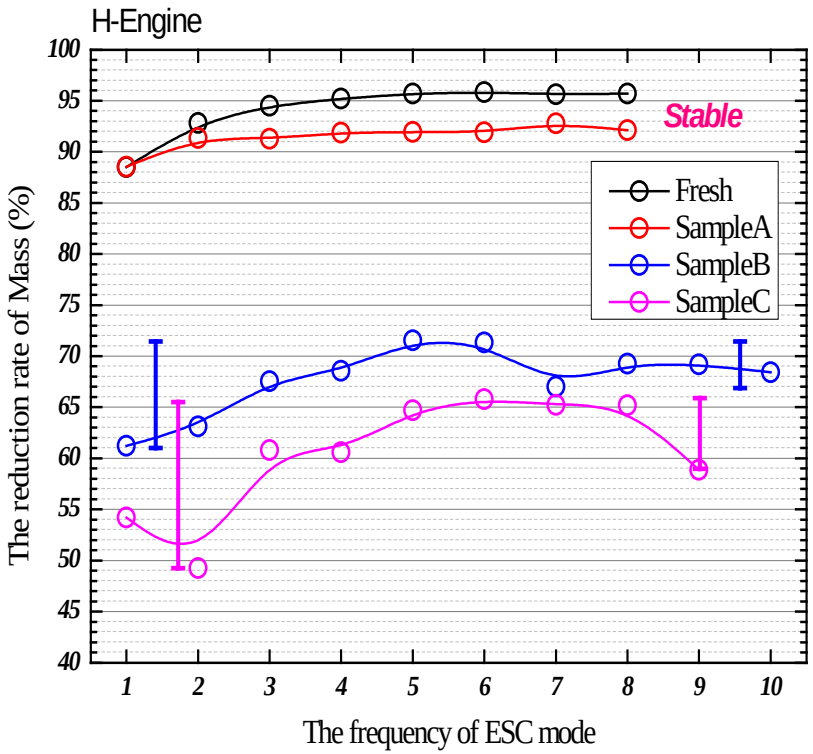
   - PM reduction rate is stable and the difference of PM reduction rate is clear

2. Sample B and Sample C @ H-engine

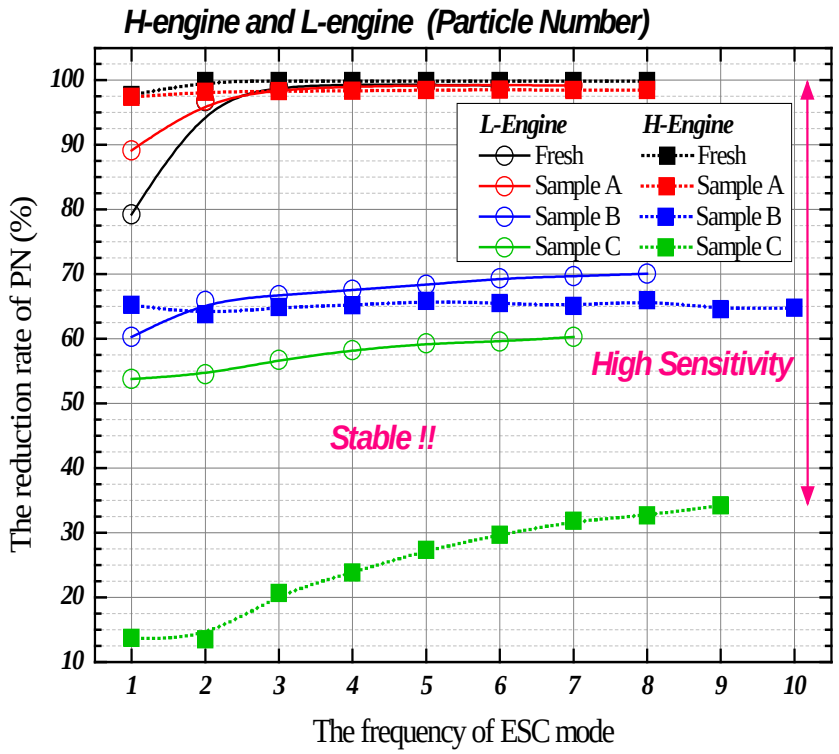
   - showing a overlapped deviation and a big fluctuation of PM reduction rate: not stable

3. Hard to evaluate the degree of filter crack by PM emission

Result and discussion(2/6)



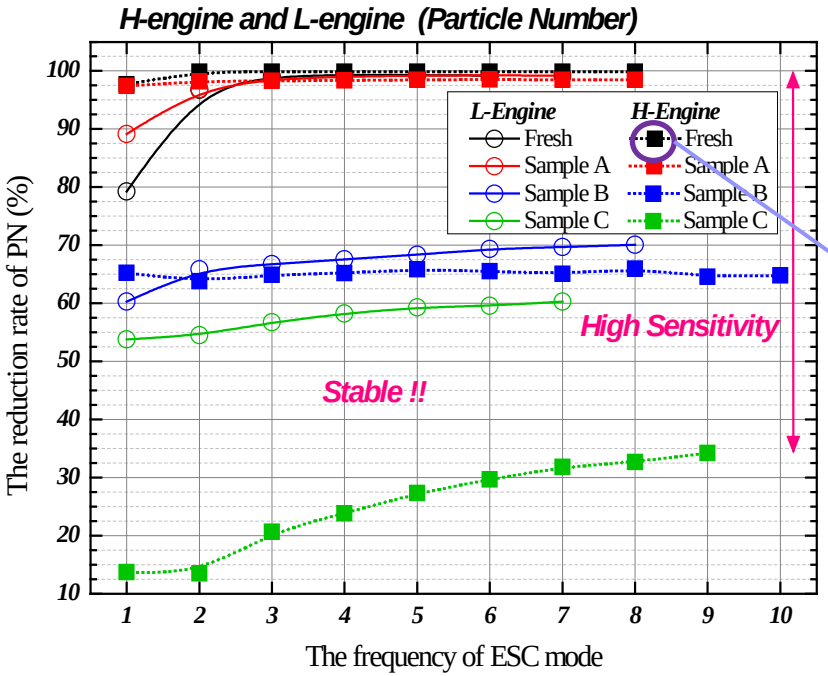
Reduction rate of PM



Reduction rate of PN

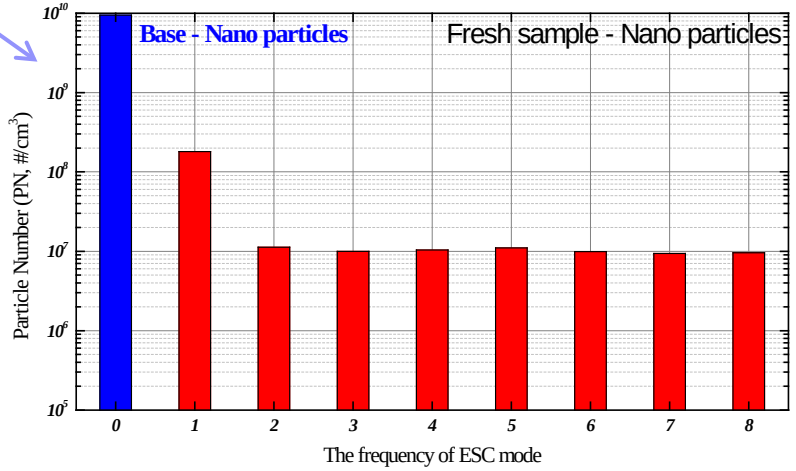
Result and discussion(3/6)

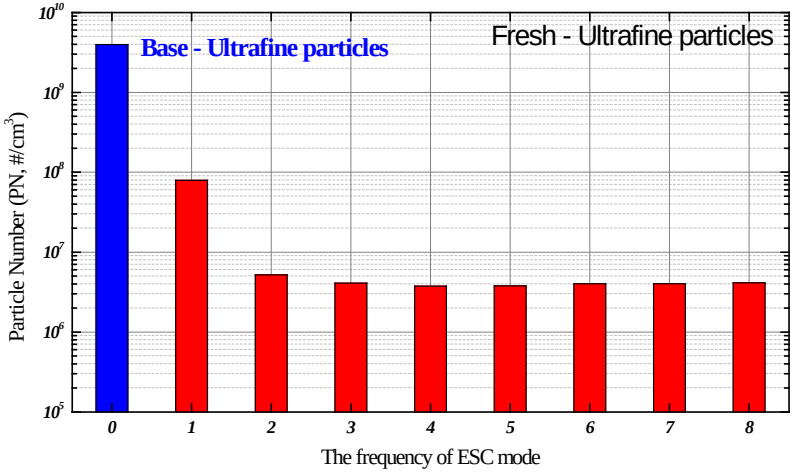
Nano Particles	Ultrafine Particles	Fine Particles	PM10
< 50nm	< 100nm	< 2.5μm	< 10 μm

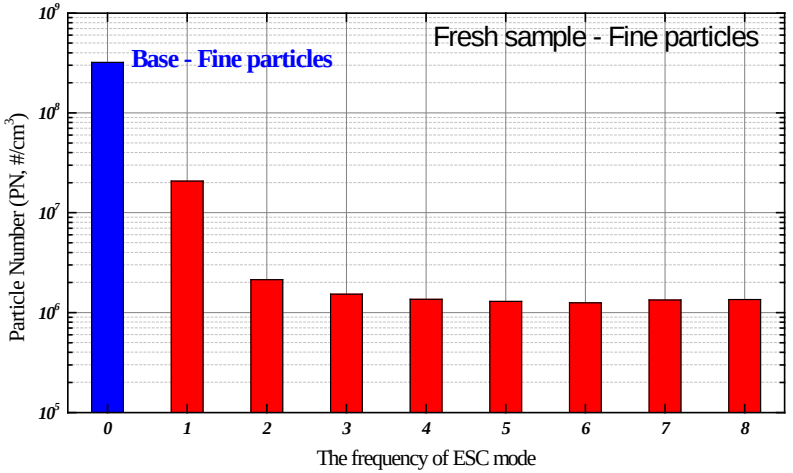


Fresh & Sample A/B/C @ H and L-engine:

- The difference of PN reduction rate is clear
- PN reduction rate is stable after one cycle run due to the depth accumulation of soot

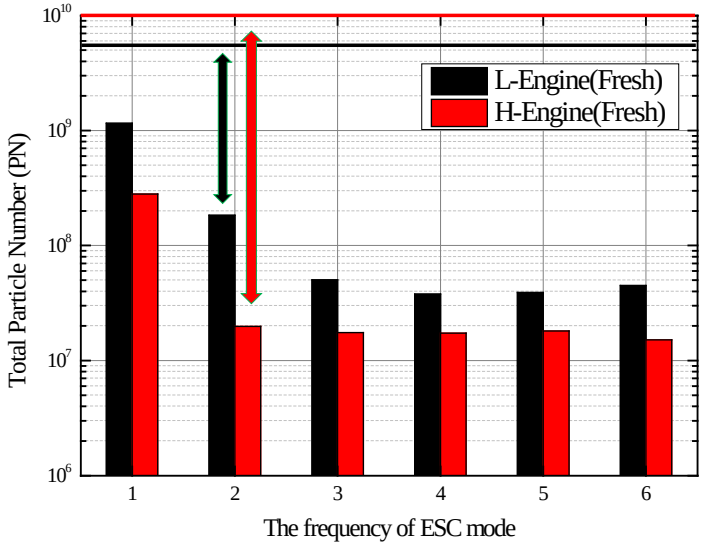




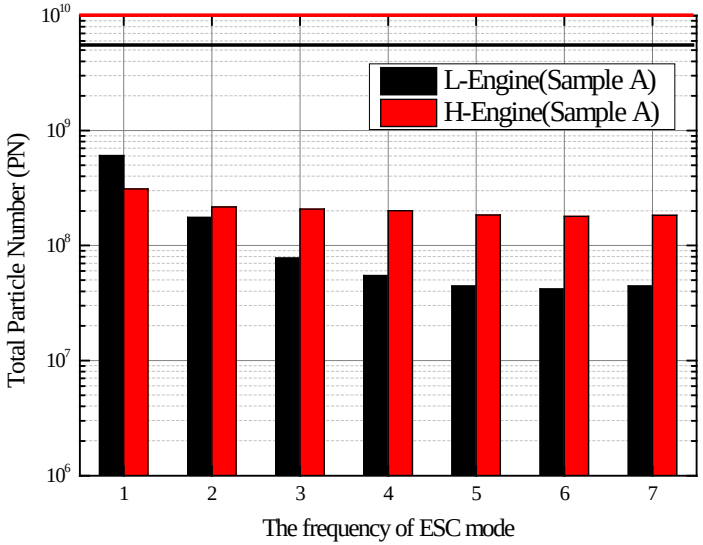


Result and discussion(4/6)

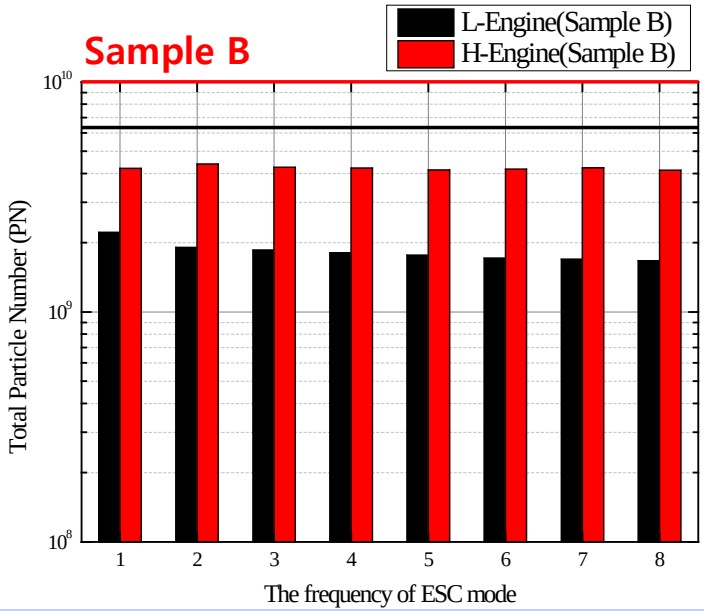
Fresh Sample



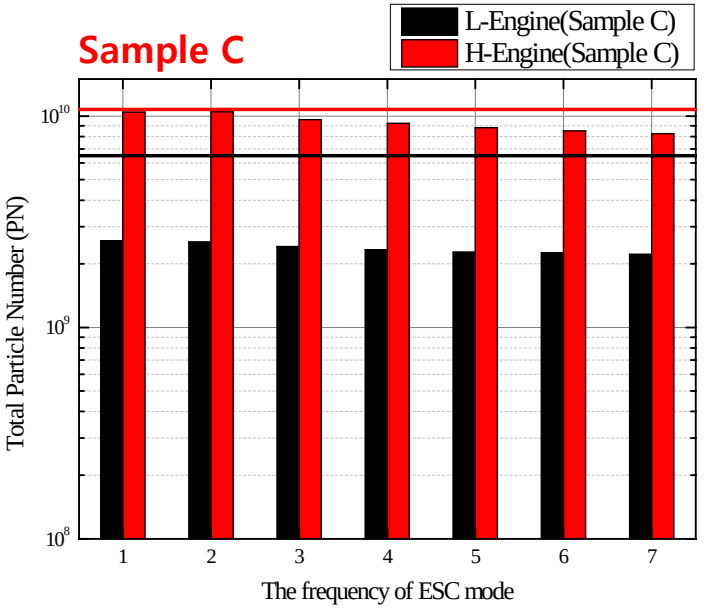
Sample A



Sample B

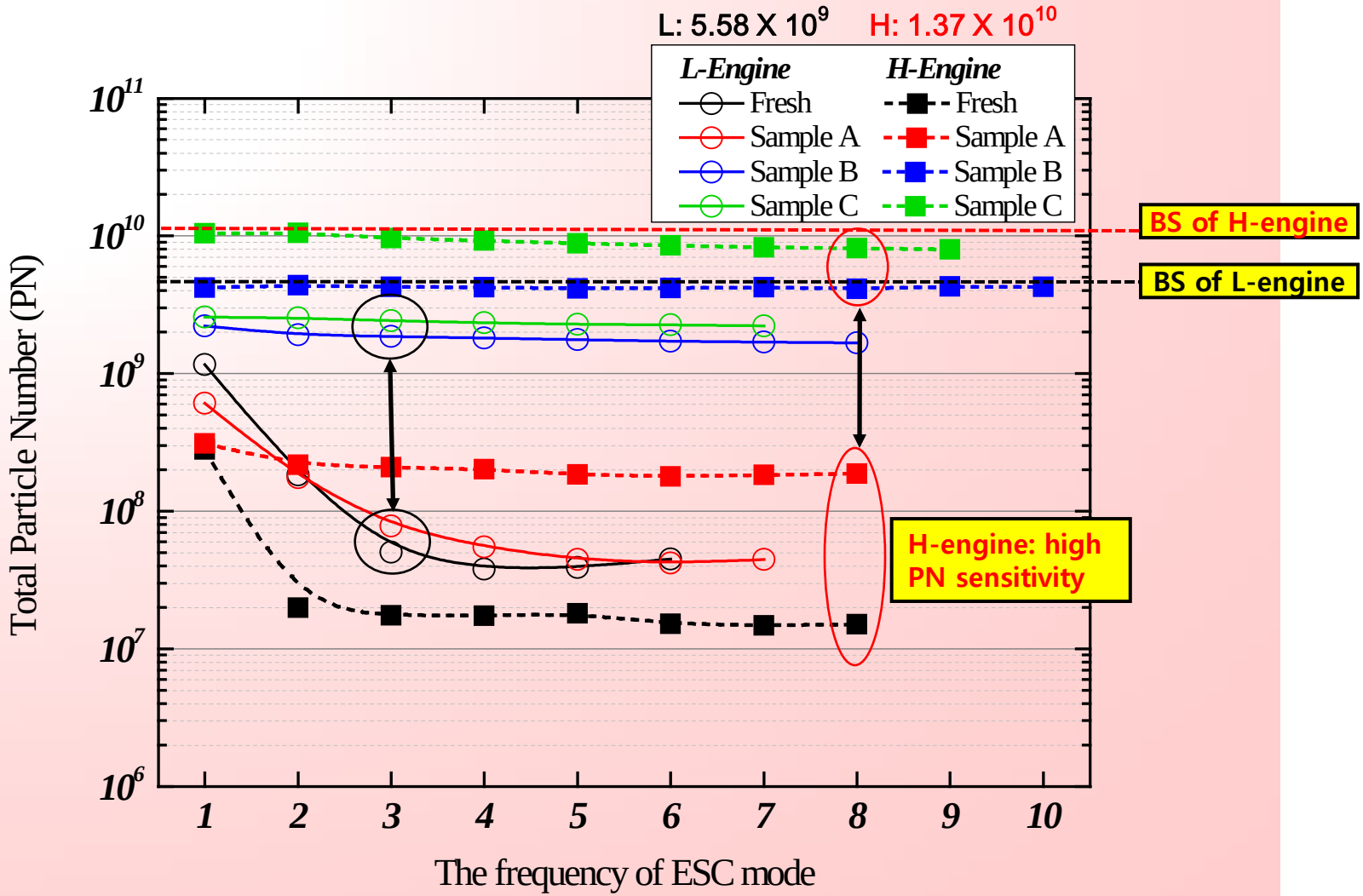


Sample C

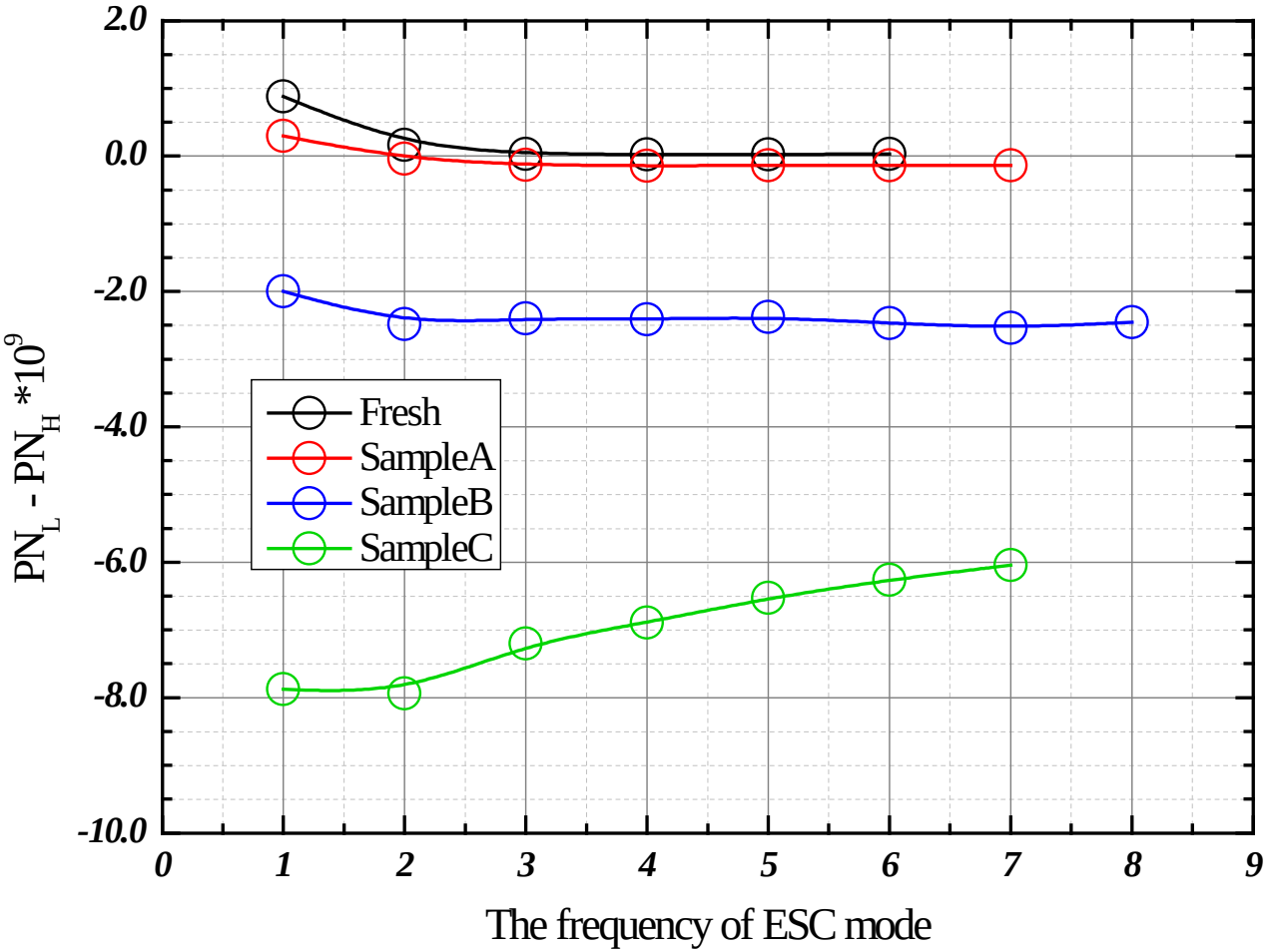


Result and discussion(5/6)

Base line PN emission((#/cm^3)



Result and discussion(6/6)



❖ **The difference of PN according to the engines(PN_L-PN_H) shows stable and a bigger difference according to the level of filter defects.**

❖ **As a same manner , Can we use PN as a stable variable to monitor the filter ?**

Summary and Work to Do

DPF is damaging by various forms and there is no clear criteria to judge the cracked filter.

So, we hope to classify the degree of filter crack using the particle emission characteristics .

This study was conducted by two different engines(EURO-I, EURO-IV) and four samples having different unknown levels of crack.

1. By PM reduction rate of filter

The difference of PM reduction rate of fresh and sample A is clear. But sample B and C shows a big fluctuation of PM reduction rate.

2. By PN reduction rate of filter

The difference of PN reduction rate according to the level of crack shows more stable and clear difference than PM variation.

☞ **So, PN is more appropriate variable than PM to classify the level of filter crack**

3. Further Work to Do !

- Classifying level of crack by morphologic study : by 3-D tomography, etc.
- Study on the relation of PN/PM with crack morphology

For Sustainable Environment & Earth !!

Thank you for your attention

감사합니다