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Analysis of Aged Diesel Particulate Filter and Ash Components with Physicochemical Validation

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Introduction

DPF should be equipped after Euro-5 emissions regulations. As DPF equipped vehicles were driven for a long time, aged DPF has been clogged by ash components.

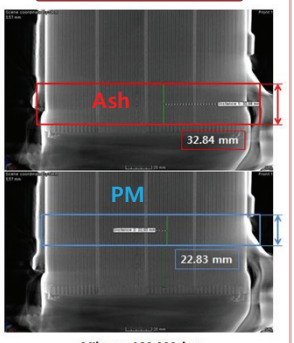
Previous research found out that ash components are mainly derived from engine lubricant. For decreasing ash creation, ash in DPF should be figured out what components it has and how they bonded.

Objectives

- Using various X-ray based equipment to figure out ash atomic components and its bond
- Morphological analysis of real-world driving aged DPF and its ash
- Effects of SAPS in engine oil to 100 hours engine aged DPF
- Establishing the analysis process of aged DPF and PM
  - ▶Understanding the effect of ash creation and DPF

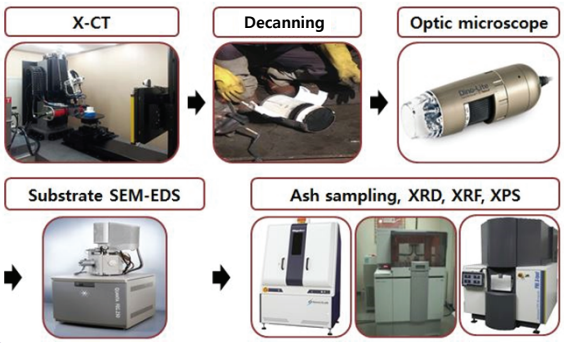
Method and Results – Ash and aged DPF analysis process

X-CT

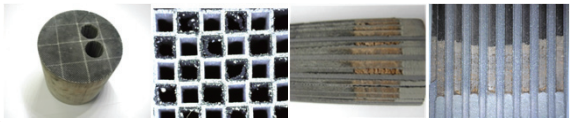


Mileage 189,000 km

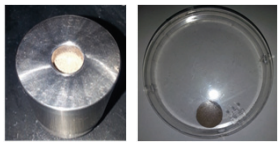
DPF Analysis process



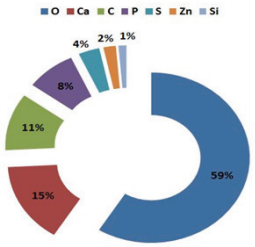
Optical microscope



Ash sampling

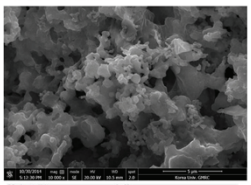


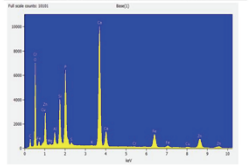
XPS Analysis



SEM-EDS Analysis

Aged DPF at Position 1

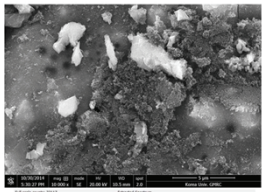


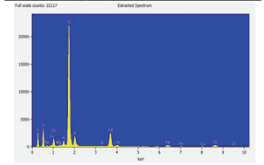


1. Ash Position

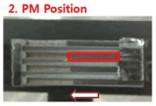
Element Line	Weight %	Weight % Error	Atom %	Atom % Error
C K	3.50	± 0.06	7.16	± 0.13
O K	37.30	± 0.97	57.33	± 1.48
Mg K	0.09	± 0.03	0.09	± 0.03
Al K	1.36	± 0.04	1.24	± 0.04
Si K	5.12	± 0.06	4.49	± 0.05
P K	9.30	± 0.09	7.38	± 0.07
S K	0.25	± 0.02	0.19	± 0.01
K K	0.04	± 0.02	0.03	± 0.01
Ca K	22.78	± 0.12	13.97	± 0.07
Cr K	0.11	± 0.03	0.05	± 0.01
Fe K	7.54	± 0.13	3.32	± 0.06
Cu K	0.84	± 0.08	0.32	± 0.03
Zn K	11.76	± 0.27	4.42	± 0.10
Total	100.00		100.00	

Aged DPF at Position 2



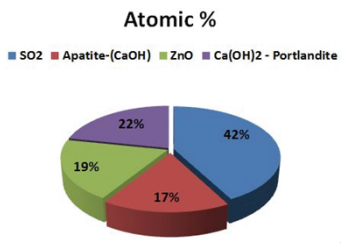


2. PM Position



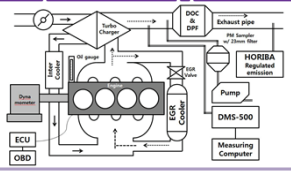
Element Line	Weight %	Weight % Error	Atom %	Atom % Error
C K	20.98	± 0.19	35.36	± 0.33
P K	3.90	± 0.05	2.55	± 0.03
Mg K	0.04	± 0.02	0.03	± 0.02
Al K	1.15	± 0.04	0.87	± 0.03
Si K	32.69	± 0.13	23.56	± 0.10
Ca K	7.38	± 0.07	3.73	± 0.04
K K	0.12	± 0.02	0.06	± 0.01
O K	24.33	± 0.26	30.79	± 0.33
Zn K	6.02	± 0.24	1.86	± 0.08
Cu K	1.01	± 0.08	0.32	± 0.03
Zn K	2.37	± 0.11	0.86	± 0.04
Total	100.00		100.00	

XRD Analysis



Method and Results – Aged engine mode test

Experimental Apparatus

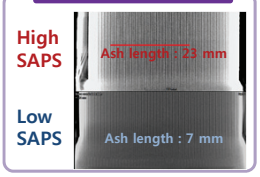


DPF aging engine test mode

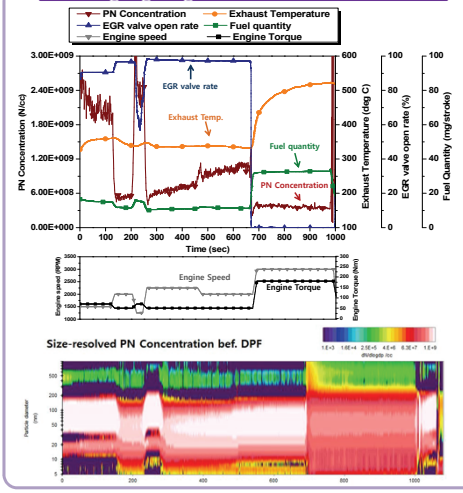
(Ramp-Time) : 15 sec

Mode Num.	Engine Speed (RPM)	Engine Load (Nm)	Duration (sec)
1	1500	65	120
2	2000	45	60
3	1250	65	45
4	2250	45	180
5	2000	45	180
6	3000	180	300

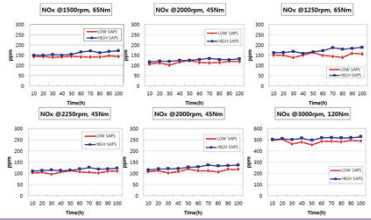
X-CT



DPF aging engine test mode - Emission



DPF aging engine test mode – NOx emission



DPF aging engine test mode – Engine oil specification

Contents		Low SAPs Base	Low SAPs 100hr	High SAPs Base	High SAPs 100hr
Kinematic Viscosity	40°C	71.16	69.72	66.85	61.69
	100°C	11.82	11.68	11.17	10.44
Viscosity index	-	162	163	160	159
Pour point (°C)	-	-39	-39	-39	-39
TAN (mgKOH)	-	4.9	5.1	2.9	3.1
TBN (mgKOH)	-	6.1	5.9	7.8	7.3
Metallic component (mg/kg)	Ca	1679	1691	2113	1947
	Mg	12	16	210	220
	P	851	911	1157	1022
	Si	3.89	60.34	7.29	18.55
	Fe	1.09	18.52	1.07	10.28
	Zn	880	959	1245	1193
	Ba	0.27	0.44	0.08	0.00
	Cu	0.17	1.50	0.20	1.10
Sulfur (%)	Sulfur	0.21	0.22	0.32	0.30
Sulfate Ash (wt %)	-	0.86	0.89	1.2	1.9

Conclusion & Ongoing work

- Establishment of DPF analysis process
- Validations of various X-ray based equipment such as XRD, XPS to find out components and its chemical bond of PM (Soot + Ash) and aged DPFs have been identified
- Portion of Zn, P and Ca come from engine oil in PM sampling from loaded on DPF was over 60%
- High SAPS engine oil has longer ash length than low SAPS engine oil
- Longer DPF aging engine test with EGR fouling testing set to find out how engine oil additive effect on fouling

Acknowledgements

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