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PERFORMANCE AND EXHAUST GAS CHARACTERISTICS ON DIESEL PARTICULATE FILTER TRAP

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ABSTRACT–Suddenly increasing numbers of automobiles result in making worse air pollution problems. In particular, the emissions from automobiles affect badly on atmosphere. Nowadays, research on catalyst converter and filter trap as a modern technology is very active because PM is designated as a major cancer material and stringent regulations on this are necessary and required. The ceramic filter is very efficient in reducing particular materials up to 80-90% and is evaluated as a very efficient after-treatment technology. However, it comes with decreased engine performance due to increased back-pressure occurred by thermal crack. In order to solve these problems, several methods are proposed such as fuel additive, electric heater and burner types. This experimental study has been conducted with equipped and unequipped a ceramic filter on a displacement 11,000cc diesel engine and compared in terms of engine performance and emission. To measure the emission, D-13 mode is applied and measured quantities of the exhaust gases, particularly in CO, HC, PM, and NOx. Therefore, this research is focused on the basic mechanism and characteristics on harmful materials generated by ceramic filter.

KEY WORDS : DPF, CO, NOx, Diesel, PM, Emission

1. INTRODUCTION

In diesel vehicle, Particulate Matters (PM) and NOx are exhausted and the PM is designated as one of major cancer materials and the regulation on exhaust gases is getting stringent.

Currently research on Diesel Particulate Filter trap (DPF) is very active in several advanced countries because it is a very unique technique reducing PM (John, 1988). DPF can be classified as filtration and regeneration technique (Yu and Shahed, 1981).

In Korea also the research has conducted in support of government since early 1990, but it is very difficult situation in commercializing due to durability of filter and high costs. However, this technique can eliminate most of PM in filter trap and in future the application of DPF is very promising as an after-treatment technique (Greevesm *et al.*, 1977).

This study is focused on the performance of electric heater, burner and fuel additive type for regeneration and they are applied to a T/C type of 11,000cc heavy-duty diesel engine.

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2. DIESEL PARTICULATE FILTER

Since the size of most of particulate matter is less than 1mm in radius, it is easy to penetrate into sinus or any other organs and stay for a long time and causes lung cancer. Therefore, DPF is called an overall system collecting carbon from emission of diesel engine and decrease exhaust gases.

DPF is a superior system in reduction of PM because it contributes to reduce 70% PM. Meanwhile, manufacturing cost is too high and the durability is low and gives problems in production. Also, as filter trap collects PM, the engine performance and fuel consumption is getting worse due to occurred back-pressure. The fundamental system of DPF constitutes filter trap, regeneration and control units

3. EXPERIMENTAL APPARATUS AND METHOD

3.1. Apparatus

The test engine is a turbocharger heavy-duty diesel engine manufactured in Korea and is aboard Korean buses and heavy-duty trucks and the specifications are shown in Table 1.

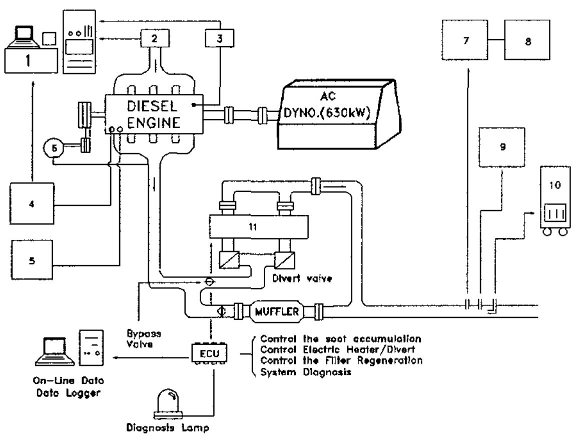
A 630 KW AC engine dynamometer, exhaust gas

Table 1. Specifications of test engine.

Items	Specifications
Type	6 cylinder, 4 stroke
Intake air handling	Turbo charged
Fuel injection type	DI
Displacement (cc)	11,051
Compression ratio	17.1:1
Max. Power (kW/rpm)	220.5/2200
Max. Torque (N·m/rpm)	1078/1300

Table 2. Specification of ceramic filter.

Diameter (cm)	14.38
Length (cm)	15.24
Cell density (cm^2)	254
Wall thickness (mm)	0.44
Volume (l)	2.5
Filtration area (cm^2)	11083
Mean pore size (Microns)	12
Maximum soot loading (g)	15



1. Dynamometer control desk
2. Intake air flow meter
3. Throttle actuator
4. Fuel temperature controller
5. Oil temperature controller
6. Air pump analyzer
7. Exhaust analyzer
8. Pen recorder
9. Smoke meter
10. Mini dilution tunnel
11. DPF trap

Figure 1. Schematic diagram of experimental measuring apparatus.

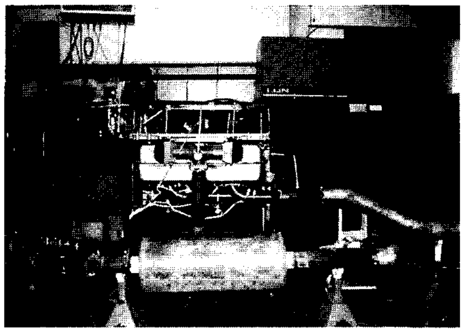


Figure 2. View of engine equipped with DPF.

Table 3. Major specification of ceramic filter.

Quantity (EA)	19
Form	CANDLE
Nature	CERAMIC FIBER
Regulations (cm)	26.6 × 30.5
Collection capacity (g)	66

analyzer and MDT constitute a measuring apparatus.

Figure 1 shows a schematic diagram of experimental measuring apparatus.

3.2. Types of Diesel Particulate Matters (DPF)

3.2.1. Electric heater type

This method constitutes filter, ECU and auxiliary equipment. The specification and the configuration are shown in Table 2 and Figure 2.

3.2.2. Burner type

DPF by burner constitutes filter, burner, ECU, fuel supplier, exhaust gas supplying equipment and etc. The specification and configuration for filter are shown in Table 3 and Figure 3.

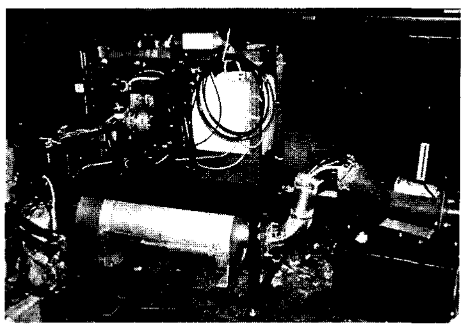


Figure 3. View of engine equipped with DPF.

3.2.3. Fuel additive type

The filter used in fuel additive type is a honey-comb ceramic type manufactured by Corning company in

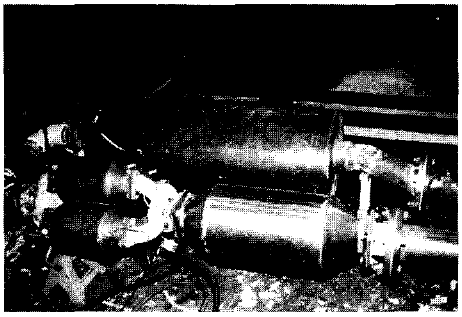


Figure 4. View of engine equipped with DPF

USA. The filter constitutes an additive supplying and an electronic system. Fe was used as an additive and iron oxide formed by Equation (1) reacts with carbon and is converted to iron. And then they went through exhaust gas pipe and were built up. When certain temperature was reached, O_2 formed around iron oxide reacted with PM so that regeneration of PM could be regenerated in the existence of O_2 catalyst. Figure 4 shows the system of fuel additive type.

$$Fe_{(S)}+\frac{1}{2}O_{2(g)}=FeO_{(S)}$$

$$\Delta G^{o} = -259600+62.55T \quad (1)$$

$$3Fe_{(S)}+2O_{2(g)} = Fe_3O_{4(S)}$$

$$\Delta G^{o} = -1091060+312.75T \quad (2)$$

3.3. Experimental Method

3.3.1. Engine performance

Engine performance was conducted under base condition and 100% engine load but various speeds from 1000 rpm to 2200 rpm with 200 rpm interval. In different driving conditions, data of fuel consumption rates, engine power, and exhaust gas temperature, and intake temperature were obtained, and arithmetic average was taken for about 30 second after stabilizing the driving condition for about three minutes. Similarly, after installing DPF, similar procedures were taken repeatedly.

3.3.2. Emission test

Emission test was conducted in both with and without fitting DPF under D-13 mode regulating Korean heavy-duty diesel vehicle and CO, THC and NOx were measured. Smoke was measured by using D-3 mode.

4. RESULTS AND DISCUSSION

4.1. Engine Performance

Figure 5 illustrates engine powers at 2200 rpm with

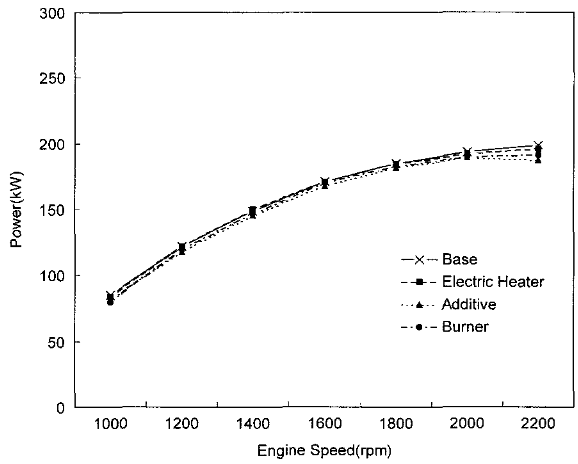


Figure 5. Engine performance test results with and without DPF (Power).

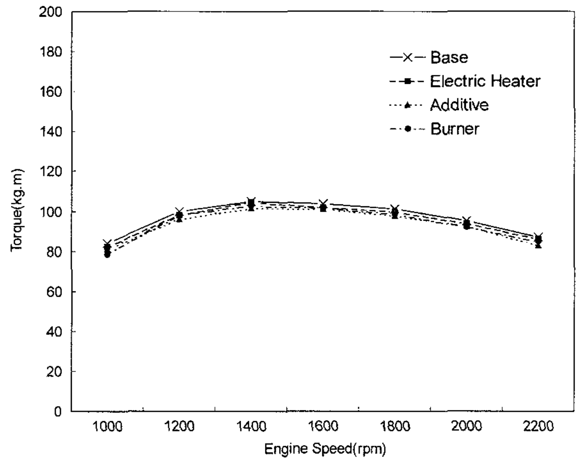


Figure 6. Engine performance test results with/without DPF (Torque).

filters are decreased a little in all rpm ranges but the differences are negligible in terms of overall engine performance. In Figure 6, engine torque was decreased to about 2.3% on burner type, about 1.2% on electric heater and about 5.0% on fuel additive type about at engine speed 1400 rpm by applying DPF. This may be due to increased back-pressure but the effect is very little compared to overall engine performance. Figure 7 illustrates BSFC curve which break specific fuel consumption is constant or increased a little or less. This is due to decreased engine power somehow.

4.1.1. Emission test

PM and Smog

Figure 8 shows the compared result for PM in D-13 mode

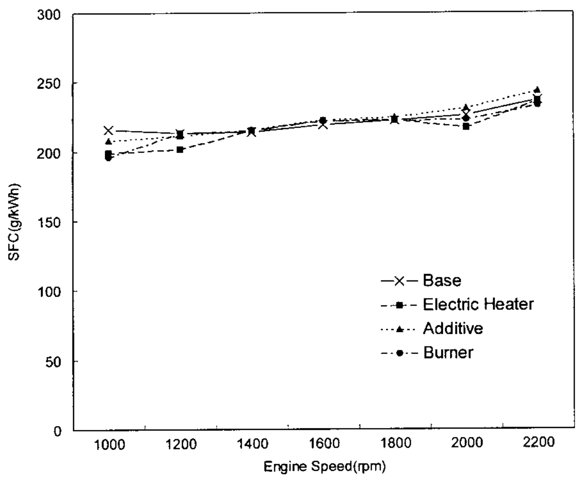


Figure 7. Engine performance test results with and without DPF (Fuel consumption rate).

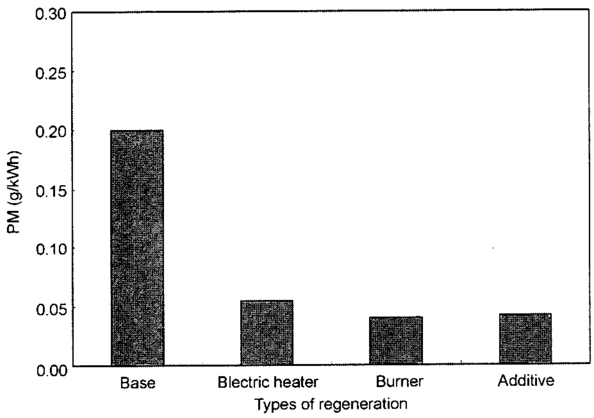


Figure 8. PM test result for D-13 mode.

and PM are decreased to about 75~85% with regardless of types of generation.

Figure 7 illustrates the smog concentration rates are decreased to about 93% at the driving condition of 40% engine speed (a) under D-3 mode. Similar tendencies were found in Figure 9(b) at 60% engine speed and in Figure 9(c) at 100% engine speed.

Gas Materials(CO, HC, NOx)

Figure 10 illustrates CO were decreased to about 3% after applying a burner type, to about 86% after applying an electric heater type and to about 0.9% after applying an fuel additive type to engine. All types satisfy to a regulation value, 4.9 kg/kW-h both the cases with and without the DPF.

Figure 11 illustrates THC concentration are decreased to about 59.6% and 14.9% for electric heater and fuel

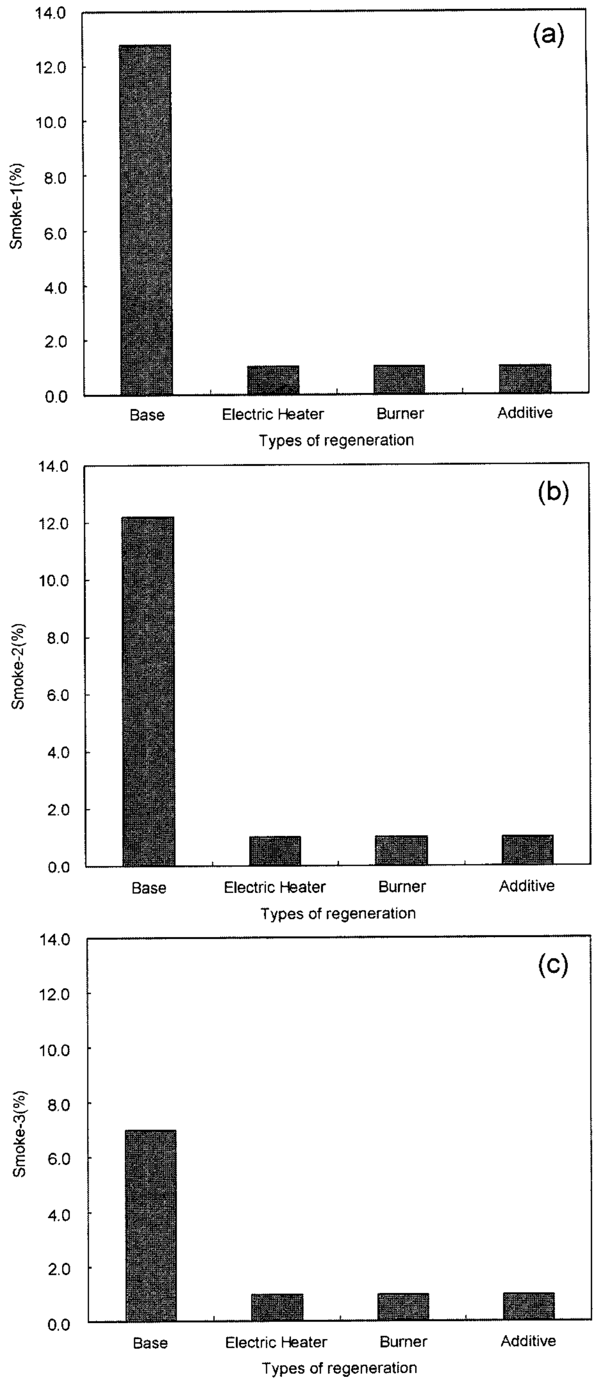


Figure 9. Smoke test result for D-3 mode.

additive types respectively. But tendency in burner type is similar to one in base condition.

Figure 12 illustrates NO concentration is approximate 8.5 g/kW-h with regardless of DPF types. To meet regulation value 6 g/kW-h, it is necessary to develop emission techniques.

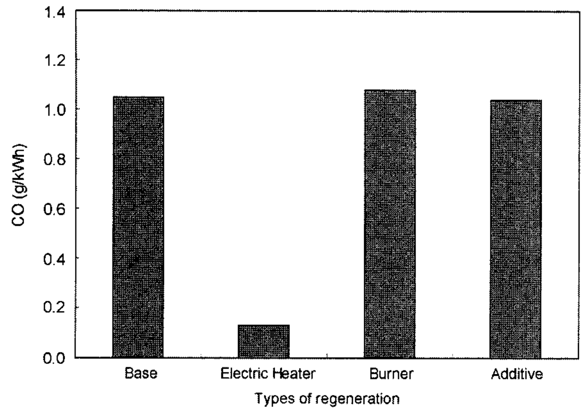


Figure 10. CO test result for D-13 mode.

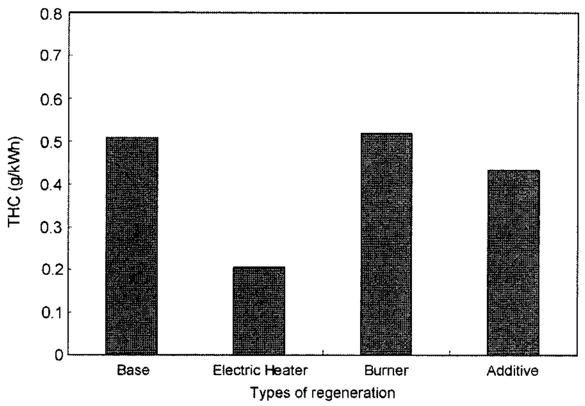


Figure 11. THC test result for D-13 mode.

5. CONCLUSION

With the application of burner, electric heater and fuel additive types of DPF to turbocharged 11,000cc heavy-duty diesel engine, some results are summarized in case of before/after DPF in engine performance and emission characteristics.

(1) Torque and engine power are decreased somewhat and Brake Specific Fuel Consumption is increased a little but the affect in overall engine performance is very little.

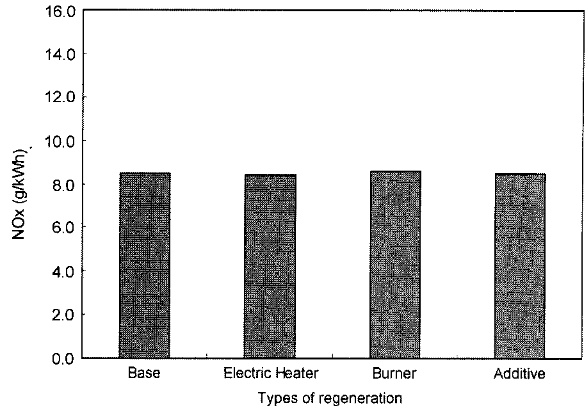


Figure 12. NOx test result for D-13 mode.

Therefore, the possibility of practicability is highly promising.

(2) With the application of burner type of DPF, PM is decreased to about 75%~90%, and smog is decreased to about 90%.

(3) Among three different types, electric filter type is apparently superior in reduction of CO and HC, but none of these types are effective in reducing NO.

(4) With application with three different types of DPF, PM is about 0.04 g/kW-h and smog is about 1%. When compared a 2002 year's regulation value 0.1 g/kW-h for PM and 25% for smog, data satisfies to the regulation.

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