Effect of Diesel Sulfur on the Regeneration of Catalyst based Diesel Particulate Filters

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***Abstract* – Diesel particulate filters are used in diesel engines to clean the particulate matter, which is released into the atmosphere. These particulate filters have a mechanism, which is affected by diesel sulfur level. My study refers to the effect with which the sulfur in diesel affects the regeneration rate of the diesel particulate filters. Two filters with different coatings were taken. Diesel Sulfur with different concentrations was tested. It was observed that there was linear relation between sulfur level and balance point temperature. Also, it was observed that this was the cause for not using full-blend biodiesel, as the emission standards could not be met due to high sulfur levels in the biodiesel.**

Keywords – Diesel particulate filters, particulate matters, balance point temperature, catalytic coating

I. INTRODUCTION

In the age of galloping pollution levels, the need for more efficient engines and lesser emission levels are the need of the hour. Also, in order to keep up with stringent emission policies, research is being done in releasing cleaner smoke from automobiles and factories. Pollution emission levels are usually higher in diesel engines as the diesel is burnt due to compression of the fuel-air mixture. This is where the diesel particulate filter (DPF) comes to place. It cleans the particulate matter released after burning the fuel. The DPF is placed in the exhaust where it collects the particulate matter. The harmful gases are reduced to harmless gases. Diesel particulate(PM) are typically soot particles with adherent hydrocarbons, sulphate and other condensed compounds[1]. The filter is either replaced or the soot is burnt and the filter is regenerated for further use.

II. DIESEL PARTICULATE FILTERS

The replaceable DPFs are used in industries where diesel powered machineries are used. The regenerative DPFs are largely used in automobiles, as replaceable ones are tedious to work with as well as time consuming. These regenerative DPFs use a catalyst material that converts carbon monoxide to carbon dioxide. It also traps the PM releasing a much less polluted air. These DPFs are called catalyst based diesel particulate filters (CB-DPF). These CB-DPFs help in meeting the emission standards in various parts of the world. The EU and the U.S environmental protection agencies have capped a PM emission of 0.01g/bhp-hr and a sulfur emission level of less than 15-ppm sulfur [2].

The exhaust system with which the CB-DPF consists of the following parts (refer fig 1) [3]:

1. Temperature sensor
2. Oxygen sensor
3. Differential pressure sensor
4. High pressure sensor pipe
5. Low pressure sensor pipe
6. Diesel particulate filter
7. Temperature sensor

Temperature Sensors

The DPF system uses two temperature sensors. One, which is located in the turbocharger outlet elbow, measures the heat of the exhaust exiting it. The other measures the heat before it passes through the DPF as it is located in the DPF inlet. The sensors provide the information needed to calculate the balance point temperature (BPT).

Differential pressure sensors

The differential pressure sensor is located in the engine compartment at the turbo level. Two pipe connections on the sensor are connected to the inlet and

outlet ends of the DPF. The pipes measure the inlet and the outlet pressures of the DPF.

Diesel particulate filter [4]

The DPF is located in the exhaust system. The filter has catalytic coating, most of them made from silicon carbide, housed in a steel container. It is designed to maintain the optimum backpressure. The filter surface (porous) has thousands of small parallel channels positioned in the longitudinal direction of the exhaust system. These channels are alternately plugged at the end (refer fig.2). This forces the exhaust gasses to flow out and the particulate matters are collected and stored in the channels.

III. REGENERATION OF DPF

The most important feature of the catalyst based diesel particulate filter is its ability for regenerate. Regeneration is the burning of particulate trapped by the filter to prevent obstruction to the free flow of exhaust gasses [5]. Regeneration is vital as an overfilled filter can cause extensive damage to engine and the filter.

Diesel particulate filter regeneration can be divided into active regeneration and passive regeneration.

Active regeneration

It starts when the particulate loading in the DPF clogs the entry of exhaust gases inside. The temperature inside the filter is increased to the combustion temperature of the particulate matters. This is achieved by post-injection of diesel fuel.

The first post-injection delays the combustion process inside the engine cylinder. This results in an increase in the exhaust gas temperature. The second post injection of fuel is done late during the power stroke. This causes partial combustion of the diesel fuel. Later, the exhaust gas along with the unburnt fuel is sent to filter. The increased temperature inside the filter burns the fuel, further increasing the temperature.

The optimum temperature for the combustion of particulate matter is 600 degree Celsius. This achieved after the second post-injection of fuel. The above heating process takes about 20 minutes and the temperature is maintained for another 20 minutes for complete combustion of the PM.

Passive regeneration

It only requires normal engine operation. The passive regeneration involves the conversion of the particulate matter into carbon dioxide. It is performed at 250°C. However, there is only partial conversion of the particulate matter into carbon dioxide. This is due to the chemical reaction process which has an operating temperature range of 250°C to 500°C [6]. The efficiency of carbon dioxide conversion will be higher if higher temperatures are obtained but that is possible only with active regeneration processes.

IV. FACTORS AFFECTING THE REGENERATION OF DPF

Diesel engines are used in mass transportation of goods and services such as long haul trucks, air planes etc. They are also used in urban transportations. These applications are used in different altitudes and temperatures. Hence, to ensure quality functioning and efficient use of vehicles, it is important that there is a smooth functioning of regeneration in diesel particulate filters.

The efficiency of the regeneration of the filter is affected by various factors. One of the parameters used in measuring the regeneration function is balance point temperature (BPT). This is the exhaust gas temperature at which the rate of particulate deposition is equal to the rate of removal through oxidation [7]. This BPT is mainly affected by the sulfur content in the diesel fuel and outside climactic conditions.

V. EFFECT OF SULFUR IN DIESEL PARTICULATE FILTERS

One of the most important factors is the sulfur content in the diesel fuel supplied to the engine. The effects of sulfur level on the balance point temperature of diesel particulate filters were tested as a part of a program in the U.S. [8]

Two diesel particulate filters were taken one fitted with technology A and other with technology B. The difference basically was with different catalytic coatings. Both the DPFs were tested with 3-ppm and 30-ppm sulfur contained diesel. The results are shown in fig 3.

It can be observed that in both the DPFs, there is an increase in the BPT in the 30- ppm sulfur as compared to the 3 ppm sulfur. The increase is about 40°C. This means regeneration will only take place at higher balance point temperature. It also meant that there were higher PM emissions.

As illustrated in the fig. 4, the European and the U.S PM emission could not be met with diesel containing 30-ppm sulfur diesel. Full blend biodiesel has an excess of sulfur levels, which is not suitable for

the emission standards. Hence, biodiesel-diesel blends are used to bring down the emission levels.

VI. FIGURES AND TABLES

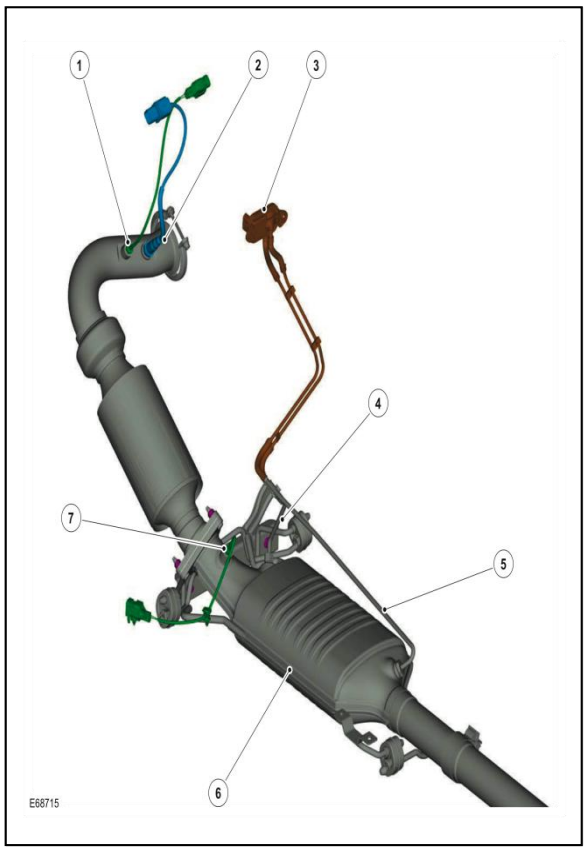

Fig 1. Parts of a diesel particulate filter

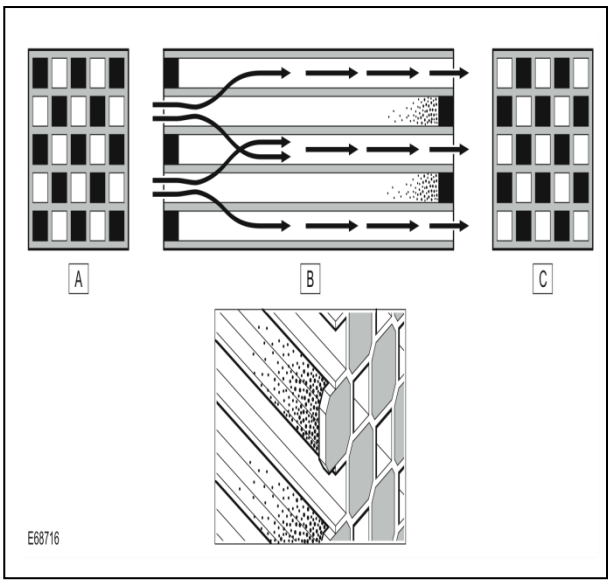

Fig. 2 : Representaion of Catalytic filter in a DPF

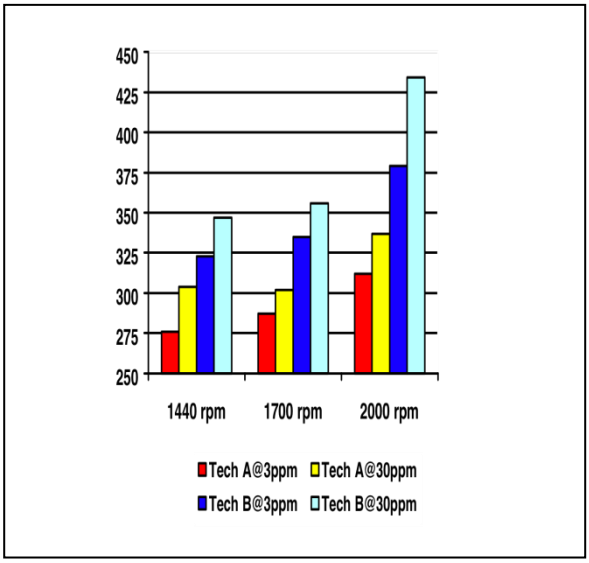

Fig. 3 : BPT as a function of fuel sulfur

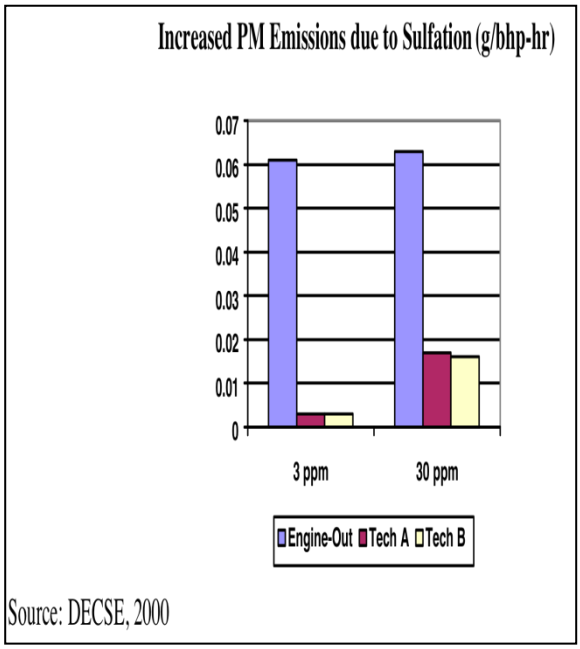

Fig. 4 : Increased PM emissions due to sulfation

A. *Abbreviations and Acronyms*

DPF – Diesel particulate filter

PM – Particulate matters

BPT – Balance point temperature

B. *Units*

g- gram

bhp – boiler horsepower

hr – hour

°C – Celsius

ppm – parts per million

C. References

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VII. POTENTIAL RESEARCH AREAS IN THE DPF

Using a two-point post-fuel injection system, it might be possible to have single post-fuel injection at the late power stroke phase. Though, the fuel wastage is only 2%, this conservation might help in future processes. As observed, using low diesel sulfur will help in smooth functioning the catalytic filter. Also, it is observed that tech B DPF has a higher BPT than tech A. Hence, an ideal catalytic filter with low BPT is advisable this will result in lower fuel consumption. Silicon carbide is the most popularly used catalytic filter. On the greener side,

It would be helpful if a suitable vegetable oil is found which has a low sulfur content. This will be helpful as the biodiesel synthesized can be used in greater proportions with the diesel.

VIII. REFERENCES

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