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Achieving Higher Cleaning Efficiency and Lower Pressure Drop Across a Chocked Diesel Particulate Filter (DPF) by Dosing Amino-ethanol

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Abstract: With the implementation of the Bharat Stage VI emission norms, the accumulation of ash in the diesel particulate filter (DPF) will pose a serious problem for automotive industries during the operating period. In the future, vehicles equipped with DPF will use a DPF regeneration method to burn the trapped soot. This regeneration process leaves the ashes in the DPF, which causes an increase in the pressure drop in the DPF. Due to this pressure drop the engine power loss, efficiency decrease and fuel consumption increases. It also affects the soot loading capacity and the activity of the catalyst in the catalyzed DPF. The main source of ash is lubricating oil, which is involved in combustion. Lubricant additives are responsible for the formation of metallic ash in the DPF. The secondary source of ash is fuel and engine wear. To study the effect of ash accumulation, the DPF sample is canned by designing proper shell through stuffing and selecting right mat, to maintain proper Gap Bulk Density (GBD). Accelerated ash loading of DPF is carried out with burning a diesel with a 5-10 % (by volume) of lubricating oil. Pressure drop and weight is estimated through actual measurement of fresh as well as ash loaded sample. The modeling of DPF is done in Catia, CFD analysis done in Ansys-Fluent and simulation of the Diesel particulate filter and DPF dosing unit is developed in GT- Power software. The simulation results shows pressure drop reduced by 80 mbar to 30-40 mbar on different- different RPM. Experiment are conducted by cleaning the ash loaded DPF with Amino-Ethanol dosing unit cleaning system. In this dosing unit system we no need to remove DPF from the vehicle. These cleaning system are compared in terms of high cleaning efficiency and low pressure drop.

Keywords: DPF Dosing Unit, DPF Pressure Drop, DPF Cleaning, DPF, DPF Cleaning Method

1. Introduction

Bharat Stage VI emission norm requires the implication of critical After Treatment System (ATS) in order to lower the engine emissions. In BS VI, the emphasis has been given to the Particulate Matter mass and Particulate Number reduction. For this emission control, the add-on after treatment device like Diesel Particulate Filter (DPF) plays a very important role. The ash is formed inside the DPF which comes from the burning of lubricant oil inside the combustion chamber, beside from the engine wear & tear and sulphur contain in the fuel. The thesis explain about the accelerated ash loading of DPF and cleaning the filter with the Amino-ethanol dosing system and reduce the pressure drop 40-80 mbar and increase cleaning efficiency.

2. Literature Review

The diesel engine is one of the main sources of solid carbon particles called soot, which are released into the air. The emission of diesel particles consists of unburned carbon particles, which come from fuel and lubricating oil as well as soluble organic substances. PM can consist of elemental carbon (soot) with adsorbed compounds such as organic compounds, sulfate, nitrate, metals and other trace elements [1]. The carbon black particles accumulated in a diesel engine depend on individual diesel combustion processes, such as. B. Air intake, injection, flame spread. The quality of the combustion depends on how the fuel is mixed with the air. The mixture in some areas of the combustion chamber may be too rich because there is not enough oxygen. The combustion is then incomplete and carbon black particles form. Carbon comes from the smoke / soot diesel engine [2]. The heterogeneous combustion mode of diesel engines produces fine soot particles, and these fine particles develop and agglomerate when combustion takes place. Hydrocarbon from fuel and petroleum, as well as the sulfates generated by the combustion of sulfur from fuel, are absorbed by soot particles during expansion and in the exhaust system [1-3].

DPFs are emission control devices that physically trap diesel particles to prevent their release into the atmosphere and to allow other gases to pass through. The ceramic honeycomb wall flows through the monolith, which has a filtration efficiency of solid particles of 95% to 99.9% [3, 6, 16]. Diesel particulate filters are the most effective technology for controlling diesel particulate emissions, including the mass and number of highly efficient particulates. [4, 11, 13], in DOC (diesel oxidation catalytic converter), DPF and SCR (selective catalytic converter reduction) are connected in series. The performance of the exhaust systems is monitored by various sensors in accordance with OBD (On Board Diagnostic) requirements.

The in-depth examination clarifies the harmful effects of ash on the DPF material and the increased effects of back pressure on the engine. Different available cleaning methods are discussed. Ash removal is therefore necessary to restore the performance of the DPF by cleaning the ash. [7, 8, 10] Specific additive elements affect the performance of the catalyst and also contribute to clogging of the filter. The accumulation of ash in the DPF (plug formation versus uniform distribution along the canals) is influenced by the regeneration strategy. [5, 4, 9, 12].

Table 1. *Engine Specification.*

Features	Description
Engine displacement (liters)	0.9
Compression ratio	16
Power (kW)	35 @ 3250 rpm
Max Torque (Nm)	120 @ 1500 rpm
Valves/cylinder	4
DPF	Soot 50% Loaded

3. 1-D Simulation in GT-Power

GT-Power is a 1-D simulation program from Gamma Technology, which simulates pressure, temperature and mass flow in different parts. This program is a part the main program GT- Suite. GT-Power is designed for steady state and transient simulations suitable for engine/power train control analysis and can be used to simulate all kinds of I. C engines. The software uses one dimensional gas dynamics to represent the flow and heat transfer in the components of the engine model. The user constructs the model by dragging and dropping objects in the graphical user interface GT-SUITE, where the component data base offers abroad range of engine components. After linking the components with connection objects the user may define properties for each component, setting up simulation options such as convergence criteria and specify desired output plots before running the simulation. [14, 15]

3.1. DPF Dosing Unit Simulation

In the GT- Power DPF Amino-ethanol dosing unit simulate on diesel engine in Figure.

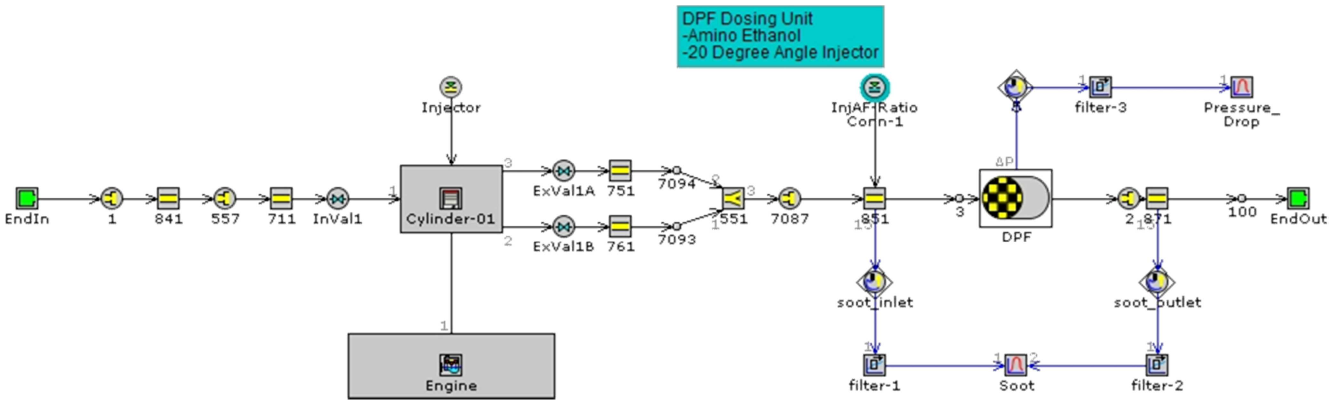

Figure 1. *Diesel Particulate filter Simulation with Amino-ethanol Dosing Unit.*

The engine model consists of snorkel, air filter, intake manifold; exhaust manifold, DPF and exhaust after-treatment system (EATS). The 3D CAD geometry is converted into 1D geometry using GT-Space claim and GEM3D.

GT-SPACECLAIM is a tool that can be used to import CAD geometry of various formats, extract volumes and export them for discretization in GEM3D. GT-SPACECLAIM is used to convert the existing CAD formats to a format and geometry that can be read by the other GT- SUITE preprocessing tools. GEM3D is a tool that can be used to discredit the 3D models of flow and made into model files for use with GT-SUITE. It includes sophisticated discretization logic that is able to transform the 3D model into a model file that is compatible with the GT-SUITE software.

To simulate DPF filtration, a `DPF Filtration` object must be defined in the DPF. The `DPF Filtration` to calculate pressure drop through the DPF as particulates become trapped in the filter. It is divided into three tabs - main wall and soot properties, soot calibration attributes, and ash modeling. The Primary and Aggregate Particulate Matter Diameters, as well as the Thermal Conductivity of Soot Layer should generally remain as "def". The Maximum Soot Cake-Substrate Contact Layer Thickness is an optional layer to model different regeneration kinetics when the DPF substrate is catalyzed.

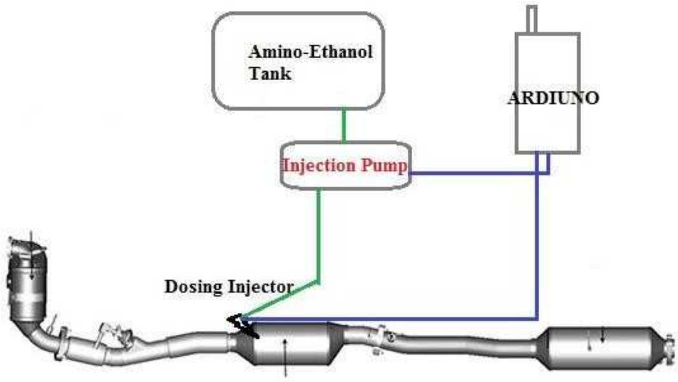

Figure 2. *Diesel Particulate filter Dosing Unit.*

3.2. Diesel Particulate Filter Specification of Dosing Unit

Table 2. *Amino-Ethanol Dosing Specification Unit.*

Voltage	12 V
Speed	1200 RPM
Speed Control	PWM Control
Operating Discharge Pressure	5.5 bar
Max. Operating Suction Pressure	0.3 bar
Min. Flow rate	3970 ml/hr
Max. Flow rate	8070 ml/hr

4. Simulation Result and Discussion

To restore the DPFs condition without removing DPF from vehicle. The results from the backpressure measurement test rig are evaluated in this chapter. The DPFs backpressure is measured at various points in this project against variable mass flow rate. The backpressure of fresh DPF is taken primarily. Then the backpressure is measured for ash loaded DPF to evaluate the increase in backpressure. The DPF is subjected to two different cleaning methods and again backpressure for both the method is measured. The temperature of mass flow is chosen as 650°C as most of the time the DPFs temperature remain in between 250 to 500°C depending on catalyst coating of DPF. The coated DPF is used for this project and 650°C mass flow temperature is selected for reference.

Pressure Drop in DPF

There is as such no defined method to measure the cleaning efficiency but can be evaluated based on the pressure drop. The cleaning efficiency is defined as the ratio of backpressure of clean particulate filter to restored backpressure of particulate filter. The backpressure is considered at different RPM depending on the engine capacity. The cleaning efficiency is calculated for all the mass flow rates. The average cleaning efficiency of Amino-Ethanol by dosing unit without removes DPF from vehicle.

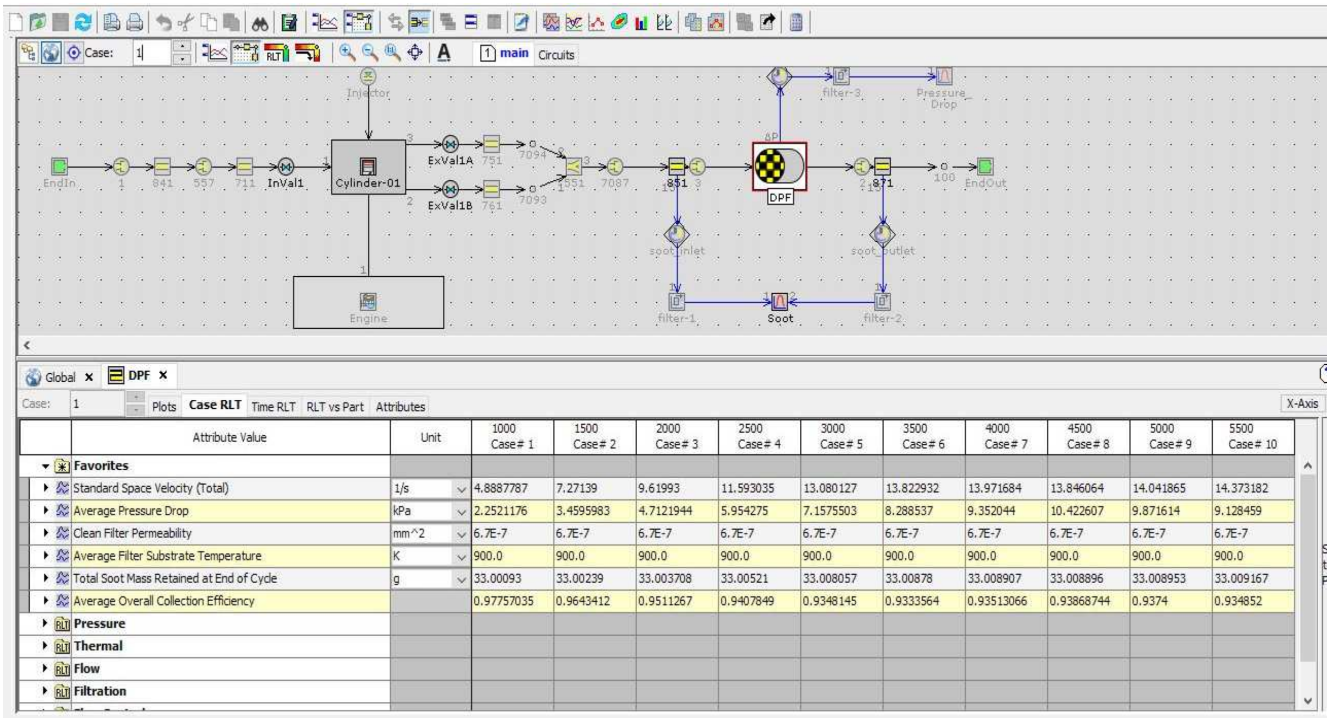

Figure 3. *DPF Simulation Result without DPF Dosing Unit.*

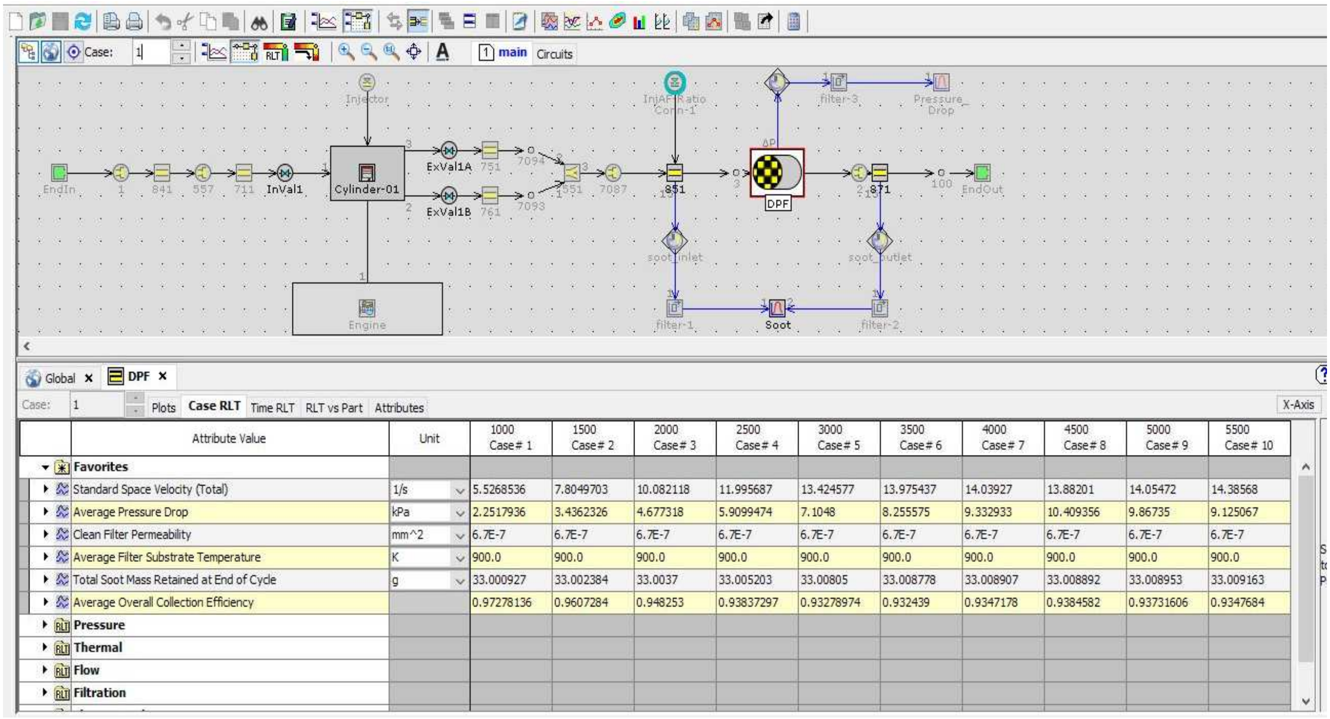

Figure 4. *DPF Simulation Result with DPF Dosing Unit.*

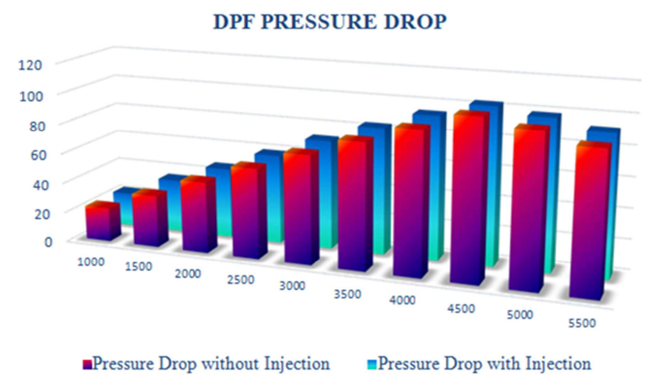

Figure 5. *DPF Pressure Drop without Injection VS with Injection of Amino-Ethanol.*

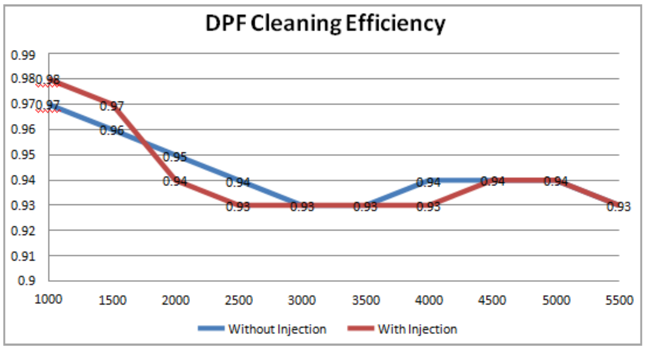

Figure 6. *DPF Cleaning Efficiency without Injection (Active Regeneration) vs With Injection of Amino-Ethanol.*

5. Cleaning Efficiency

There is as such no defined method to measure the cleaning efficiency but can be evaluated based on the pressure drop. The cleaning efficiency is defined as the ratio of backpressure of clean particulate filter to restored backpressure of particulate filter. The backpressure is considered at different RPM depending on the engine capacity.

In the Figure 6. We can see the pressure drop in DPF with 50% loaded soot in Simulation on Different RPM. The Pressure drop decreases to 20 – 55 mbar after injection of Amino-ethanol in DPF.

6. Conclusion

As the development of high-performance diesel engines continues, the demand for high efficiency, maintenance of durability and emission control remains. The DPF, which helps bring the zero-emission performance closer to the other ATS, is blocked by the ashes. This project solves the problem and offers the solution for cleaning the blocked DPF. The dosage of amino-ethanol in DPF remains very effective depending on the blocked state of DPF. This dosing system is implemented in the vehicle itself to clean the DPF without having to remove the DPF from the vehicle.

Table 3. *Backpressure & Cleaning Efficiency.*

	Target	Amino-ethanol Dosing System
Pressure Drop in DPF after cleaning at different RPM	40 – 200 mbar	20-55 mbar
Cleaning Efficiency of DPF without removing from vehicle	>75 %	93 %

Definitions/Abbreviations

BS VI	Bharat Stage VI
ATS	After Treatment System
PM	Particulate Matter
PN	Particulate Number
DPF	Diesel Particulate Filter
OBD	On-Board Diagnostic
DOC	Diesel Oxidation Catalyst
SCR	Selective Catalyst Reduction
SiC	Silicon Carbide
Cd	Cordierite
AT	Aluminum Titanate
ACM	Acicular Mullite
CTE	Coefficient of Thermal Expansion
CDPF	Catalysed Diesel Particulate Filter
CO	Carbon Monoxide

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