Experimental research on Diesel Particle Filter (DPF) in relation to the fuel type

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Abstract. The experimental research is developed to validate or to dismiss theoretical suppositions considering the efficiency of particulate matter filters for internal combustion engines. This paper is pointing out the ideas of a practical test regarding soot impact upon the diesel particle filter from after treatment system, supplied with different fuels in operation mode. Measurements are recorded with after treatment system scanner and subsequently the experimental data are processed and graphically presented using digital module. Experience and know-how concerning the after-treatment system applied to the exhaust pipe of a Diesel engine is extremely useful in modelling the protocol for sustainable technical design of the automotive powertrains. The present paper outlines an applied process of controlling and analysing at least four parameters defining the clogging level of an actual diesel particle filter in K9K792 euro 5 internal combustion engine in relation to the fuel type. Engine supplied with Diesel standard has a wide range of clogging, but when changing to more blended fuels containing biodiesel from soy methyl ester and ethanol, the after treatment process is influenced significantly. The experimental testing is designed to reiterate for each fuel type in real time and after a distance of one thousand kilometres – in engine speed regime of two thousand revolutions per minute.

1. Introduction

The necessity for approaching the after treatment of the exhaust gases from car engines is based on the researchers and engineers awareness and efforts to diminish the pollution impact upon the environment by creating more sustainable solutions in combustion and in motorized mobility of the future, both on our planet and beyond if space travel would be further developed [1]. The chemical and physical pollution affect through nitrous oxides, particulate matter and aerosols climatic changes, biodiversity, oceanic acidity, ozone layer thickness and the life quality in general for all living beings. In the last decades, the after treatment systems have been considered and developed for different types of exhaust architectures in automotive sector, but in order to keep up engine's performances and to maintain power value when configuring particle filter and catalyst the system has to be further analysed and electronically controlled [2]. Potential of after treatment system is yet to be highlighted and further studied through the spectrum of modern equipment in sooth combustion control and exhaust gas dynamics [3].

The complex transport operations lead to higher particulate matter emissions, thus polluting the environment, with different sizes of particles and residues. Recent developed technologies are available today for reducing traffic and transport particulate products and to lower pollution [4]. Researching and measuring the particulate filters and their efficiency is now possible with digital assisted equipment, both in laboratory and road operation of cars [5]. Main objective of this research is to outline an innovative solution for particulate matter (PM) filter in K9K792 Diesel engine operation. The specific objectives are the tests with four types of fuels and mixtures in order to point out the viable experimental operating regime and also to evaluate the sensors data in working state. The integrated system for differential pressure measurement and soot impact, based on complete handling of Diesel engine, allows the creation of a regeneration map. The important achievement will be the creation a specific model available for testing and applicable on large scale production, if possible. Other specific steps are: development of a working plan for particulate matter monitoring and an electronic control phase for actual components in the after treatment system destined to evaluate the soot impact, temperature, voltage and differential pressure.

PM stands for particulate matter (also tagged or labelled as particle pollution): the expression for a mixture of solid particles and liquid droplets appearing in the atmosphere [6]. Solid or material particles, such as dirt, soot, dust and smoke, are large enough to be observed with the eye. Some other particulate matter appears so small they can only be monitored using electronic equipment or digital micro-scope. The particulate matter exists in many sizes and shapes and may be generated from multiple and various chemicals. Some PMs are generated directly from a specific source, such as a construction site, unpaved road, fields, smoke stacks or fires. Most PMs from the earth's atmosphere were generated by complex reactions of many chemicals such as sulphur dioxide and nitrogen oxides. These groups of substances are pollutants emitted by power plants, industries and automobiles [7]. Pollution with particulate matter includes: PM10: small particulate matter, with medium diameter of 10 micrometres; PM2.5: smaller and fine inhalable particles, with diameters of 2.5 micrometres or lower. Particulate matter consists of microscopic solid compounds and liquid droplets which are small enough to be inhaled and cause cancer or other health conditions [8]. PMs have less than 10 micrometres in size, posing the highest risk, due to the fact that they can travel deep inside the lungs. Through this mechanism some of the particulate matter will get in the blood and other organs. Small particles as PM2.5 are the important causal factor for lowered visibility (haze) in polluted zones, some parks and other areas [9].

2. Methodology and material

By using the ubiquitous networking and computer processing power of today in applied science and engineering regarding even the PM research, there may be designed a specialized tool or a method for particulate matter control in a complex after treatment system from automotive field. Approaching the subject of particulate matter emission impact correlated with automotive and transportation allows the control and proper management of these pollutant compounds, materials and substances which harm the environment and living beings. The present research paper is based on a method of experimental testing in four distinct scenarios when supplying the engine with four different types of fuels. The research method is developed on a compared analyse of three solutions with the standard recipe when supplying the engine with Euro 5 commercial Diesel (Standard Diesel). A specialized automotive engineering methodology for after treatment monitoring and control is put into practice. Methodological solution applied in this case makes use of computer aided engine scanning and automotive expertize for PMs control in the Diesel Particle filter 14, according to figure 1. In this graphical representation of the tested power train there are shown the main parts of the applied equipment, such as the internal combustion engine 1, clutch 2, gear box 3, transaxle 4, traction wheels 5, engine speed sensor 6, fuel pressure regulator 7, common rail 8, fuel pressure sensor 9, temperature sensor 10, electronic control unit 11, air temperature sensor 12, exhaust gas manifold 13, after treatment equipment 14 and exhaust pollutant analyser / smoke meter.

The research methodology consists in comparative analyse of the three strategies of supplying the engine with mixtures of Diesel Standard (DS) with Bio Diesel (BD) and Ethanol (E) in different ratios with the reference supply mode with DS only. The schematic strategy of the testing protocol is shown in figure 2, which describes the structure of the dual branch evolution in the performed experimental research. First branch consists in specific and individual tests with each fuel type, starting with the reference fuel (Diesel Standard). After recording the actual values with DS as reference fuel, the testing has been developed with alternative fuel recipes such as: Diesel Standard 95% + Bio Diesel 5%

- DS95BD5 (numerical indexing expressing the volumetric participation of each fuel component); Diesel Standard 90%+ Bio Diesel 10% - DS90BD10; Diesel Standard 85% + Bio Diesel 10% + Bio Ethanol 5% - DS85BD10BE5. The second direction or branch of the research consists in a compared analyse of the collected actual values. This study makes a parallel graphic comparison of numerical data received from electronic control unit monitoring the after treatment system with DPF.

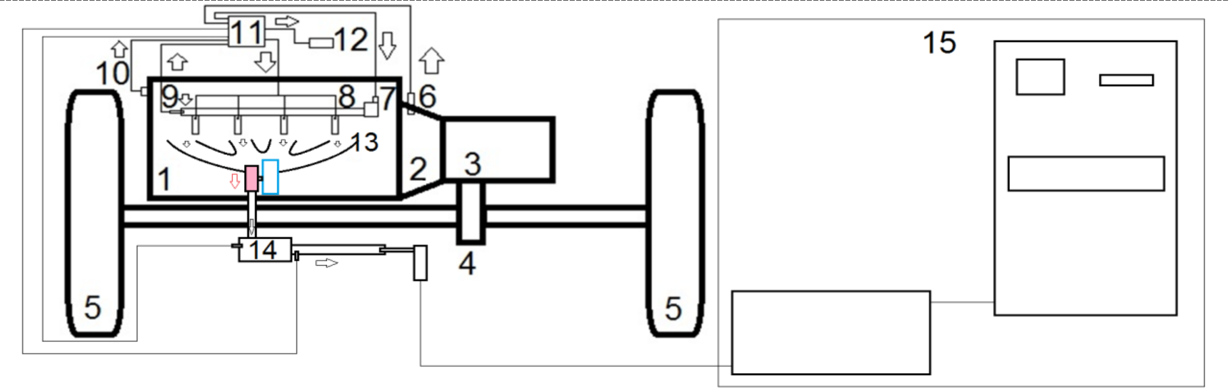


Figure 1. The main components of the tested power train with after treatment system and analyser.

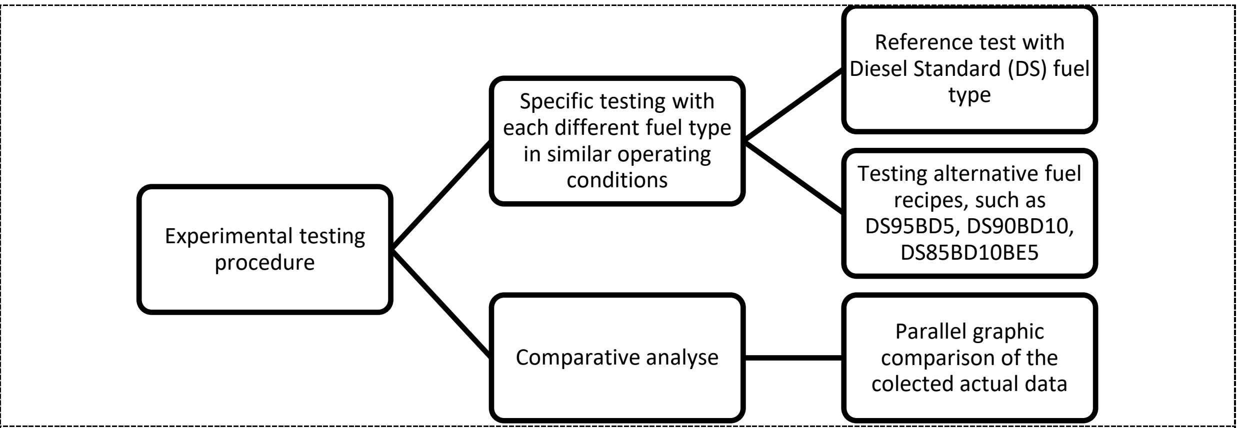
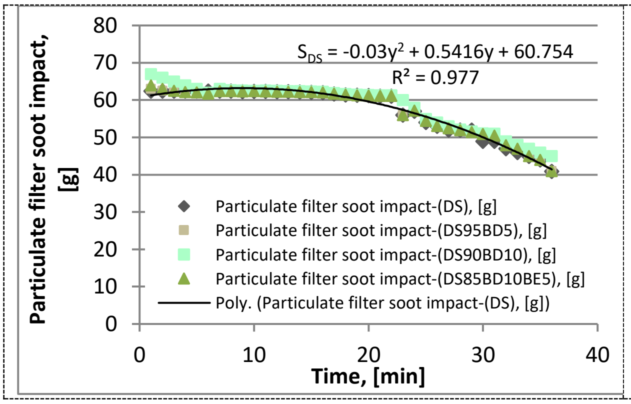


Figure 2. The simplified schematic of the experimental testing strategy put in the research practice..

3. Experimental results and discussions

The first analysed data come from the particular tests with each fuel type. The second part of analyse is concentrated upon the overall comparison of the actual values, as it is shown in figure 3 for the soot impact, in figure 4 the differential pressure, exhaust temperature in figure 5 and voltage in figure 6.



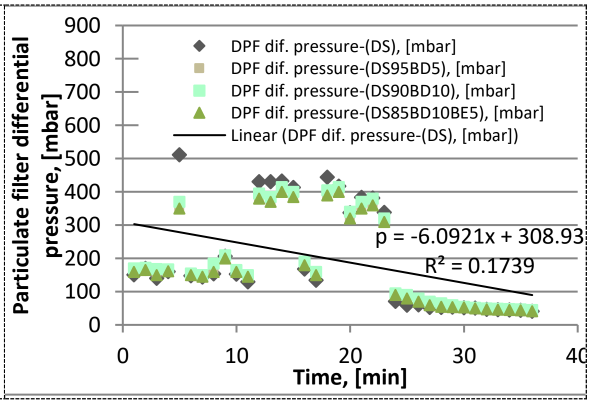
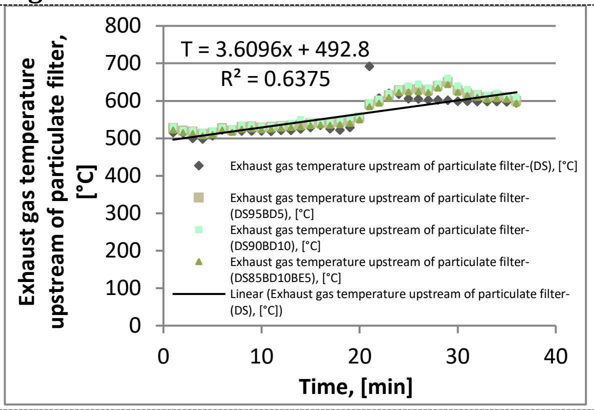


Figure 3. Soot mass in DPF for tested scenarios.

Figure 4. Differential pressure before DPF.



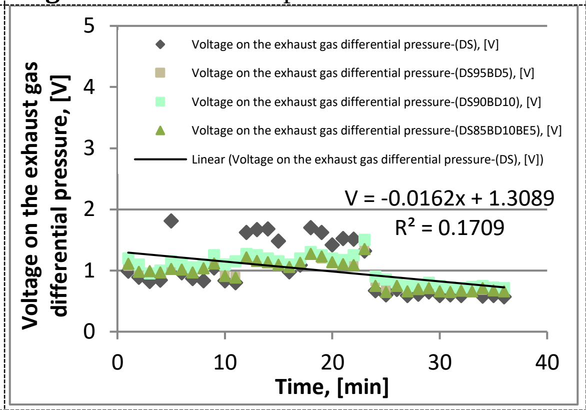


Figure 5. Exhaust Temperature upstream DPF.

Figure 6. Voltage on diff. pressure sensor.

The measurements were taken during the regeneration procedure in an overall interval of 40 minutes. The first and the last two extreme measurements were excluded. In statistical analyse, an outlier value is a measured point that is deviated in relation to other collected values. Such an outlier in the present case is due to variability in the (initiating and ending) after treatment monitoring procedure and it will indicate experimental error; thus to avoid the latter mentioned errors the problematic extremes were excluded from the actual data sheet, resulting in only 36 points presented in the graphics.

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The engine has been wormed up and made ready for testing when starting the practical determination during experimental research. The trend line was traced for reference measurement.

The summary technical data sheet is given in table 1, showing the targeted operation during experimental tests, exhaust gas flow in manifold and some other significant values.

Table 1. Technical data of the Diesel Particulate Filter after treatment architecture.

Parameter	K9K792 Diesel Particle Filter
Target process	Particle capture (PM 10 & 2,5)
Exhaust gas flow, [m^3/h]	100
Temperature, [°C]	600
Targeted Pollutant	Particulate matter (PM), Hydrocarbons (HC)
Efficiency, [%]	98

The most important and basic parameter, that is considered for mathematical modeling and is highlighted for a more comprehensive analyze, consists in soot impact correlated to regeneration time, as a total mass of soot in DPF monolith when K9K792 tested engine is kept in full load and driven with third gear ratio, given by the relations:

$$S_{DS} = -0.57x + 67.8 \tag{1}$$

where x is the time variable considered in minutes of operation in regeneration mode, for a linear progression of the soot combustion model.

$$S_{DS} = -0.03y^2 + 0.54y + 60.8 \quad (2)$$

where y is the time variable considered for a polynomial progression of the soot mass model.

4. Conclusions

In this research paper, were studied the parameters of after treatment process with multiple fuel recipes, taking as a reference fuel type the Diesel Standard Commercial euro 5, with the detailed specification given at https://www.petrom.ro/services/downloads/00/petrom.ro/1522164440041/sf-43-motorin-standard.

The highest soot impact factor was recorded in the test made with DS90BD10 fuel type in the beginning of the procedure. Most elevated differential pressure was for point 5 with DS at 512 mbar. Peak temperature was at 692 °C for measurement point 21 with DS.

Acknowledgments

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