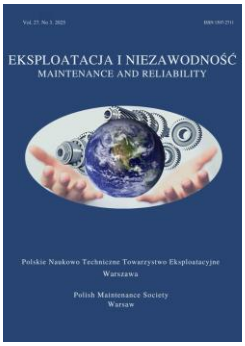

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Equilibrium temperature in diesel particulate filter passive regeneration

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Highlights

- This paper describes a modified DECSE method for determining the equilibrium temperature of a Diesel Particulate Filter (DPF), incorporating seven engine load steps.
- This study presents an investigation into the catalytic properties of a platinum catalyst within a DOC/OC-DPF system, focusing on the oxidation of nitric oxide (NO) to nitrogen dioxide (NO2) during soot regeneration.
- This work addresses the crucial role of equilibrium temperature in the context of passive DPF regeneration and its impact on fuel consumption reduction.
- This research outlines the experimental methodology, including a seven-phase DECSE test utilizing polynomial approximation of pressure variations for precise determination of the equilibrium temperature.

Abstract

The paper presents the results of experimental studies of the DOC/OC-DPF diesel particulate filter system of a compression-ignition engine in the aspect of nitrogen oxide transformations and oxidation of soot with nitrogen dioxide in oxidizing platinum catalytic coatings. The equilibrium temperatures between the formation of soot and its oxidation by NO_2 were determined as an important parameter determining the passive regeneration of DOC/OC-DPF beneficial to the environment and operational problems.

The analysis was carried out for selected operating points of the engine depending on the exhaust gas temperature in terms of occurrence of high conversion of NO to NO_2 at constant engine speed.

Keywords

diesel particulate filter (DPF), equilibrium temperature, passive regeneration, nitrogen dioxide (NO_2), DECSE method

1. Introduction

Every vehicle approved for sale with a compression-ignition engine is equipped with a catalytic system for the treatment of exhaust gas from soot. This system consists of a DOC and an OC-DPF [1, 2]. In order to ensure sufficiently effective regeneration, the DPF should have the right temperature. It should also be supplied with gaseous oxidants such as nitrogen dioxide and/or oxygen. The primary source of heat used for the oxidation of particulate matter is the exhaust gases. However, the temperature of the exhaust gases of compression-ignition engines, especially when operating at partial loads, may not be sufficient for soot oxidation and effective filter regeneration. For this reason, the oxidation temperature of particulate matter should be reduced using passive (catalytic) methods. This minimizes the need for active methods during engine operation. As part of the exhaust gas treatment system, Diesel Oxidation Catalysts (DOCs) are usually positioned upstream of the diesel particulate filter. Their role is to produce the highest possible amount of NO2. This compound is then used as an oxidizer of the soot accumulated in the filter. A high Pt content is necessary for converters to generate a NO2 concentration in NOx of about

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80% [2], even at the lowest exhaust gas temperatures. However, due to the relatively low exhaust gas temperatures in diesel engines, mixed passive-active methods are used for DPF regeneration. These include:

- at high exhaust gas temperatures, passive regeneration occurs through the oxidation of soot with nitrogen dioxide. This compound is catalytically produced in a DOC converter and/or by an OC coating in the DPF. This method is sufficient for regeneration.
- at low exhaust gas temperatures, an active method is necessary. It increases the temperature of the exhaust gases to effectively oxidize the soot. However, this process reduces engine efficiency and leads to operational problems.

2. Literature review

Passive-active DPF systems may experience the following operational issues [2]:

- The DOC/OC-DPF system's filter's increased balance-point temperature causes more frequent transitions from passive regeneration mode to active regeneration, which results in energy losses and higher emissions of harmful substances.
- The excessive soot accumulation is linked to excessive engine particulate matter emissions and insufficient NO_2 production [26] in the DOC during passive filter regeneration or insufficient exhaust gas heating system efficiency during active regeneration.
- The DPF monolith thermally degrades due to the rapid oxidation of unevenly distributed soot in the filter cells, necessitating an expensive system replacement with a new one.

Developing a robust and dependable DOC/CO-DPF system with a small volume, high cell density, and the least amount of precious metal is the primary challenge that needs to be addressed. According to the standards for Euro 6 type approval, this approach necessitates expensive and time-consuming experimental testing in laboratory test cycles [2] as well as in the vehicle's actual (RDE drive cycles) operation [2]. Carbon in the form of soot oxidizes with oxygen at temperatures above 600°C, and nitrogen dioxide at temperatures around 250°C, as shown in Figure 1.

In the experiment, the results of which are shown in Figure 1, the converter was filled with a known amount of soot from a compression ignition engine, and a steady flow of oxidizing gas gradually increased the sample temperature, and a mass spectrometer measured the amount of CO_2 produced.

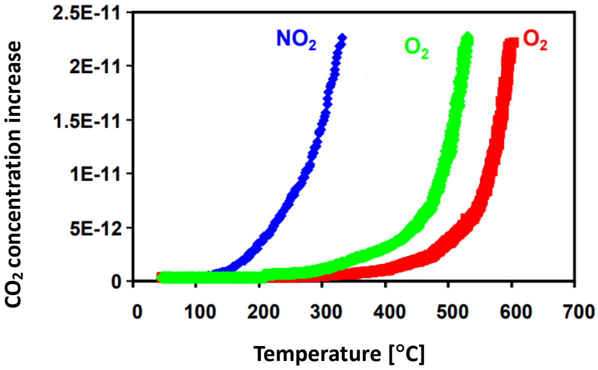

Figure 1. Comparison [3] of the particulate matter oxidation process by measuring the increase in CO2 concentration depending on the process temperature using: O2 – oxygen contained in exhaust gases, O2 – catalytically produced oxygen (close contact of oxygen with soot), NO2– catalytically produced nitrogen dioxide.

The creation of a robust and dependable DOC-DPF system with the least amount of precious metal, as well as its volume and channel density, and high activity in NO oxidation to NO_2, allowing passive system regeneration at the lowest exhaust gas temperatures, is a significant issue that necessitates the improvement of current solutions. This solution necessitates expensive and time-consuming experimental research in laboratory test cycles [4] and in real-world [5] vehicle operation (RDE driving cycles) in compliance with Euro 6 homologation criteria. In paper [6], simulation and experimental studies, including NO oxidation to NO_2 for passive DPF regeneration, are described.

The article [7] describes exhaust gas temperature simulation downstream of the reactor for particulate matter oxidation in the DPF, among other purposes. Consideration was given to the aggregation of hydrocarbons within the reactor and their quick oxidation upon reaching the ignition temperature. Combining the two procedures allows for precise reactor exhaust gas temperature modelling that considers the significant temperature increases brought on by the quick conversion of stored hydrocarbons. A paper [8] established a mathematical model that describes thermal events in the particle filter (DPF) and the oxidation reactor (DOC) during regeneration to construct a reasonable DPF regeneration control approach.

Investigations were conducted on the effects of the primary exhaust gas parameters, including temperature, oxygen concentration, mass flow rate, and reagent emissions. Analysis was also done on the impact of the primary control strategy parameters, soot loading and DOC outlet temperature. The findings of these investigations make a more logical design of control techniques for DOC-DPF regeneration systems possible. The primary obstacle impeding the advancement of DPF filter use was the regeneration of particulate matter while the filter was operating. The impact of fuel injection technique, converter (DOC) use, and air intake throttling on exhaust gas temperature is investigated in the paper [9]. It was noted that the exhaust gas temperature could be significantly raised by lowering the intake throttle opening during low-speed and low-load operating circumstances. The effect of active DPF regeneration on Euro 6 vehicle efficiency and exhaust emissions is also assessed in the research [10]. The rise in carbon dioxide (CO_2) and pollutant emissions (solid particle number (PN) and nitrogen oxides (NOx)) in cars evaluated both in the lab and in use was examined in this study. The study examined the effects of several emission control systems, such as exhaust gas recirculation (EGR), diesel oxidation catalysts (DOC) converters, lean NOx traps (LNT), and selective catalytic reduction converters (SCR), on NOx emissions in addition to the DPF. The frequency and length of regeneration were also ascertained by comparing emissions with and without regeneration. The findings showed active DPF regeneration significantly reduced CO_2, NOx, and PN emissions. Lastly, it was noted that active DPF regeneration had a comparable effect on fuel usage to driving with lights and air conditioning (A/C) on. This article [11] evaluates a diesel-powered vehicle's emissions and performance under actual driving circumstances. The exhaust gas temperature was used to identify active DPF regeneration events. Analysis was done on the engine's power, fuel consumption, and exhaust emissions while running with and without active DPF regeneration. According to the results, three out of the thirty-two test trips had active DPF regeneration events. Fuel consumption and particulate matter, nitrogen oxide, and carbon dioxide emissions rose as a result of the active DPF regeneration event. An efficient technique for passive and active regeneration of the Diesel Particulate Filter (DPF) is using DOC converters [12]. Thus, the main boundary condition for the regeneration process is the proper exhaust gas temperature at the DOC's inlet. The DOC converter's inlet temperature is more influenced by the quantity of fuel injected than by the injection's length. Research on DPF regeneration under vehicle operating circumstances is lacking despite DPF filters frequently being used in laboratory testing on engine or chassis dynamometers. The impact of active DPF regeneration on a diesel vehicle's fuel consumption, gas emissions, and particulate matter emissions under actual driving circumstances is examined in the paper [13]. Several dozen Real Driving Emissions (RDE) tests were conducted in total. According to the findings, the vehicle's DPF underwent active regeneration every 130 kilometres. Despite its infrequent occurrence, DPF regeneration resulted in an average 13% increase in fuel consumption. Since the fuel combustion required to reach high exhaust gas temperatures for filter renewal took place under lean burn combustion conditions, the CO and THC emission factors tended to rise with active DPF regenerations. Last but not least, DPF regeneration significantly exceeded authorized emission limitations by increasing particulate matter emission factors by 27 times compared to operations without DPF regeneration. A one-dimensional model of the diesel particulate filter was used [9] to test the efficiency of DPF regeneration. Three common DPFs' regeneration performance was examined, and numerical simulations were used to evaluate the effects of different parameters on regeneration efficiency under temperature pulsation settings. It was discovered that a DPF's thermal conductivity significantly impacts soot oxidation, which in turn influences the regeneration process.

In the paper [15], the active regeneration of the wall-flow DPFs at low ambient pressures at high altitude above the sea of the vehicle was investigated. A reduction in the soot oxidation rate at low ambient pressures was found with standard boost pressure control. Access of oxygen and residence time negatively affect soot oxidation under these conditions. Higher temperature at altitude above sea level can maintain the rate of soot oxidation.

To test regeneration at low temperatures (less than 300°C), medium temperatures (between 300 and 550°C), and high temperatures (greater than 550°C), respectively, concerning the equilibrium point temperature, the paper [16] presents a developed model of continuous regeneration of the diesel particulate filter of compression-ignition engines supported by electrical regeneration. The rate of constant regeneration is increased by raising the NOx content and flow rate at the input. The rate of passive regeneration tends to rise at low and medium temperatures due to the rapid thermal reaction; this trend increases as wall thickness and channel density decrease. The outlet temperature rises in the high-temperature range, and as cell density and wall thickness decrease, the temperature gradients that occur during the early stages of regeneration get steeper. The effects of regeneration temperature, regeneration time, and exhaust gas flow rate on regeneration efficiency and exhaust emissions are covered in the article [17]. In every regeneration test, the rear and centre sections of the DPF reached the highest temperatures, according to the temperature distribution profiles. Large particles were released when the regeneration temperature exceeded 525°C. The maximum temperature, maximum temperature gradient, and regeneration efficiency were all negatively impacted by increasing the exhaust gas flow rate. In the course of thermal regeneration, the work replicated testing of the filter's temperature distribution in its cells [18]. According to the results, the temperature will rise as the mass flow rate of the exhaust gas increases during the thermal regeneration process. There is an ideal flow region for the highest radial temperature gradient value when the exhaust gas mass flow is between 20 and 30 g/s. The maximum axial temperature gradient value will progressively drop. Additionally, damage from thermal stress can be prevented by loading the filter with less than 5 g/l of particles.

Introducing more fuel oxidises the filtered particulate matter at a high temperature during the active DPF regeneration process. This process increases fuel consumption and may eventually cause thermal damage to the filter. The diesel engine was subjected to experimental testing under various load and speed circumstances. The findings show a consistent pressure drop (i.e., the soot oxidation rate equals the soot deposition rate) at 320°C and, more significantly, a filtering effectiveness of over 96% during the soot accumulation stage. A rise in pressure drop is shown when the temperature is raised to 340°C, which can be accomplished with a slight modification to the engine load. This suggests that passive regeneration is taking place. The filtration and continuous regeneration of the diesel particulate filter system, which consists of a catalytic coated diesel particulate filter (OC-DPF) and an oxidation converter (DOC), on the engine dynamometer were examined in the study [20]. For ongoing regeneration, DOC and OC-DPF both offered a significant NO to NO_2 conversion. Nearly 100% of the solid particle number (SPN) emissions were reduced by the filtration efficiency. The accumulation mode was primarily responsible for the formation of the particles that followed OC-DPF. Variations in the soot filter's filling were responsive to additional SPN increases. This occurrence makes it possible to utilize the technique of measuring the trend of SPN concentration to determine the equilibrium point temperature.

3. Methodology of research

3. 1. Aim of the study, object and test stand

The aim of the study is to present a new method of measuring the equilibrium temperature of the diesel particulate filter, the idea of which was presented in the papers [21, 22] through the following modifications:

– use of 7-degree changes in engine load as opposed to 5 changes used in the DECSE test to test a wider range of exhaust gas temperature changes upstream of the filter,
– approximation of pressure changes in the filter, caused by the change of filter filling with soot, the second-order polynomial at the stage in which the pressure change in the DECSE test is approximated by a simple linear function with its slope approaching zero in order to more accurately determine the filter equilibrium temperature.

The object of the study was the LDV vehicle’s passive-active soot filter system consisting of:

– diesel oxidation catalyst (DOC) converter,
– soot filter with oxidizing catalytic coating OC-DPF

The DOC catalytic converter has a volume of 1.4 dm^3 and a cell density of 400 cpsi. The active ingredients were applied to the metal monolith of the converter using the "slurry" method, which involves immersion application of an oxidizing intermediate layer with a content of 2.5 g/dm^3 of platinum.

The OC-DPF soot filter manufactured by Umicore Automotive Catalysts was made of a SiC monolith with a diameter of Φ=130 mm and a length of l = 300 mm and covered with platinum in the amount of 1 g/dm^3.

The test stand consisted of:

– LDV compression-ignition engine with high-pressure common rail fuel injection with a displacement of 1248 cm^3,

- Schenck W 150 eddy current brake with a controller enabling obtaining and measuring a constant rotational speed and measuring the engine load,
- exhaust gas analyzer for measuring NO, NO_2 and NOx concentrations using the CL method,
- a set of reference and auxiliary gases used for calibration of exhaust gas analyzer measurement systems,
- smoke meter (filter paper blackening) for measuring soot concentrations in exhaust gases,
- Apliens gas pressure gauge type APR – 2000ALW,
- multi-channel temperature measurement system consisting of EMT – 100 index and NiCr – NiAl(K) temperature sensors type TP – 371K – W1,
- computer system for recording component concentrations and exhaust gas temperature.

The engine was powered by commercial B7 diesel oil with a cetane number of LC = 55 and a sulphur content of 8 ppm. A photo of the DOC + OC-DPF system is shown in Figure 2.

Figure 2. A photograph of the DOC/OC-DPF system with installed exhaust gas intake probes and temperature sensors.

A diagram of the test system is shown in Figure 3.

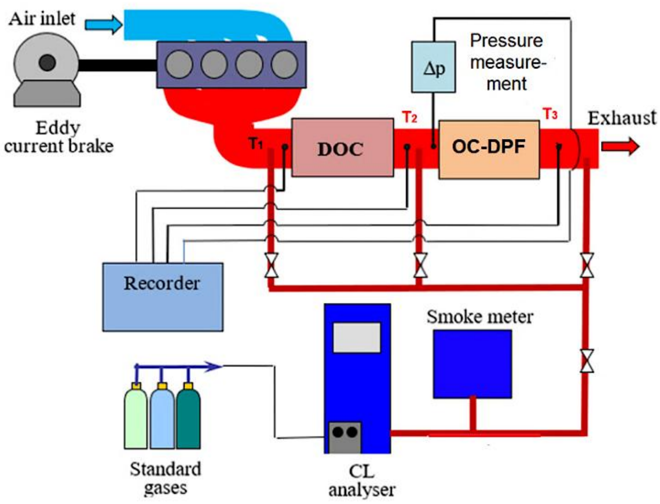

Figure 3. A diagram of the test system with a diesel engine.

3.2. Studies on the impact of exhaust gas temperature on the formation of NO_2 on platinum catalytic coating

The key parameter in the soot oxidation process is the temperature of the exhaust gases. In order to identify the processes of catalytic oxidation of NO to NO_2 and the conversion of soot in the tested DOC/OC-DPF system depending on the exhaust gas temperature, dynamometer tests were carried out on the load characteristics at n = 2000 rpm.

Nitrogen dioxide is a very active soot oxidizer, but its concentrations in the exhaust gases of the diesel engine are relatively low and do not exceed 10% of the sum of concentrations NO + NO_2 = NO_X. Therefore, DOC converters use a catalytic coating in the form of platinum, which is very active in the oxidation of NO to NO_2. This reaction can be written by equation [23]:

$$2NO + O_2 \leftrightharpoons 2NO_2 \quad (1)$$

However, the rate of oxidation of nitric oxide can be written by equation [19]:

$$-d[NO]/dt = 2k[NO]_2[O_2] \quad (2)$$

Where: k - reaction rate constant, t - time,

[NO] and [O_2] – nitric oxide and oxygen concentrations, respectively

The highest rate of oxidation of NO to NO_2 occurs in the temperature range of 250–350°C, where the use of platinum catalytic coating [2, 24] can achieve the NO_2 content in NO_X up to 80%.

Empirical studies of nitrogen oxide transformations in the

DOC-OC-DPF system presented in Figure 2 were carried out on the test stand shown in Figure 3. Figures 4, 5 and 6 show NO, NO_2 and NO_X concentrations as a function of the exhaust gas temperature T_1, respectively, measured upstream of the DOC converter, upstream of the OC-DPF and downstream of the OC-DPF at a constant engine speed n = 2000 rpm selected due to stable and high soot emissions depending on the torque developed by the engine.

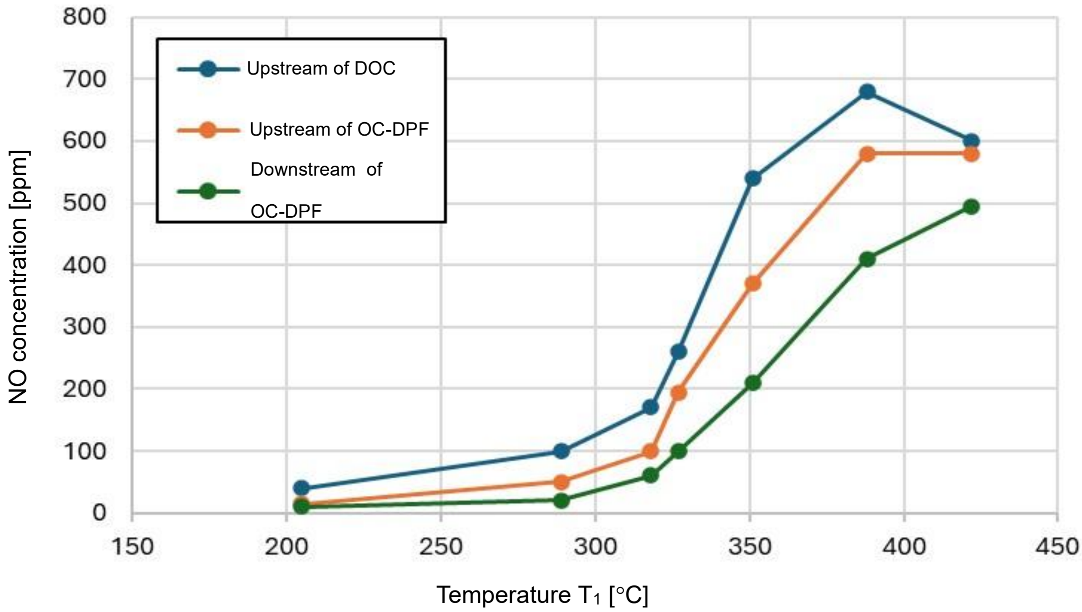

Figure 4. NO concentrations upstream of the DOC catalytic converter, upstream of the OC-DPF and downstream of the entire OC-DPF filter.

A clear decrease in NO concentrations (Figure 4) downstream of the DOC converter and downstream of the OC-DPF is observed, resulting from its oxidation to NO_2 on the platinum coating of the converter and the filter with the increase in exhaust gas temperature.

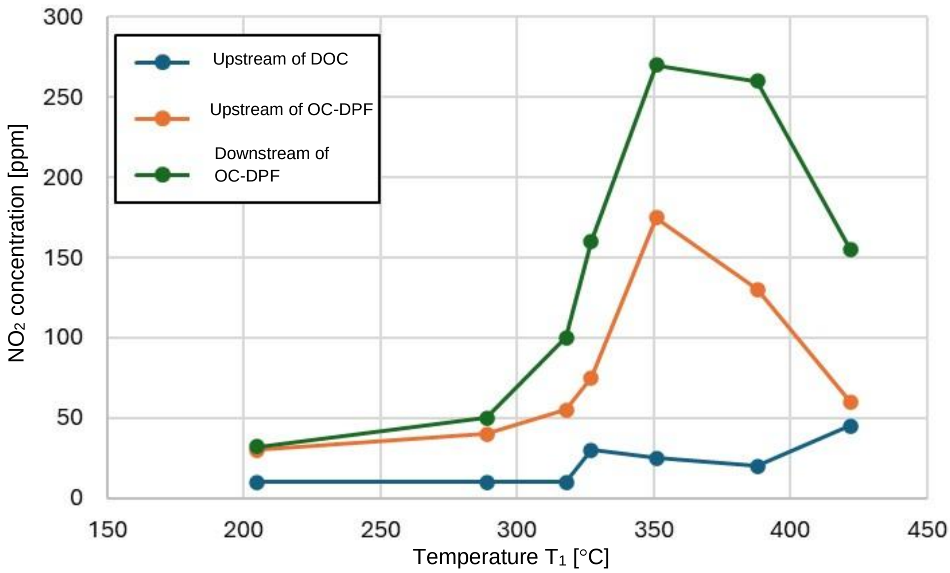

Figure 5. NO_2 concentrations upstream of the DOC catalytic converter, upstream of the OC-DPF and downstream of the OC-DPF filter

A similar situation occurs in the case of NO_2 concentrations (Figure 5), with the difference that their concentrations increase both in the DOC converter and in the OC-DPF filter as a result of oxidation of NO to NO_2 on the platinum coating with an increase in exhaust gas temperature.

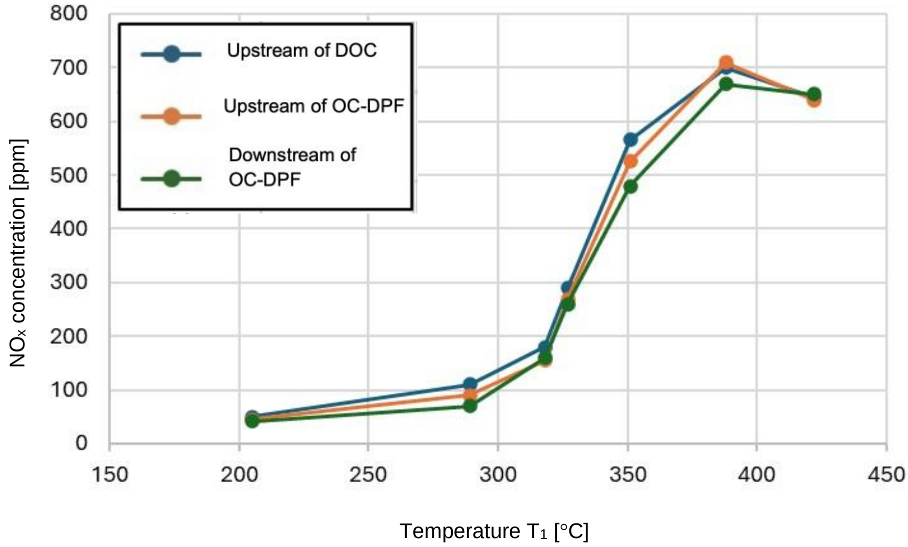

Figure 6. NOx concentrations upstream of the DOC catalytic converter, upstream of the OC-DPF and downstream of the OC-DPF filter

On the other hand, the concentration of $NO_X = NO + NO_2$ is practically the same regardless of the place of sampling of exhaust gas for analysis, which is due to the fact that the oxidation of soot by NO_2 reduces NO_2 to NO.

3.3. Studies on the impact of exhaust gas temperature on the oxidation of soot on platinum catalytic coating

The oxidation of soot with nitrogen dioxide contained in the exhaust gases proceeds according to the following reaction:

$$C + NO2 = CO + NO \qquad (3)$$

The kinetics of soot oxidation with nitrogen dioxide [20] can be written as:

$$R_{C-NO_2} = k_{NO_2} exp\left[\frac{-E_{a,NO_2}}{RT_W}\right][NO_2]C_{load} \quad (4)$$

Where: R_{C-NO_2} - speed of soot oxidation reaction with nitrogen dioxide

k_{NO_2} - factor

E_{a,NO_2} - activation energy of soot oxidation reaction with nitrogen dioxide

$[NO_2]$ – concentration of nitrogen dioxide

T_W - exhaust gas temperature on the filter wall

C_{load} - soot mass in the filter

The reaction constant of soot oxidation with nitrogen dioxide given in [21] is about E_{a,NO_2} = 94 kJ/mol

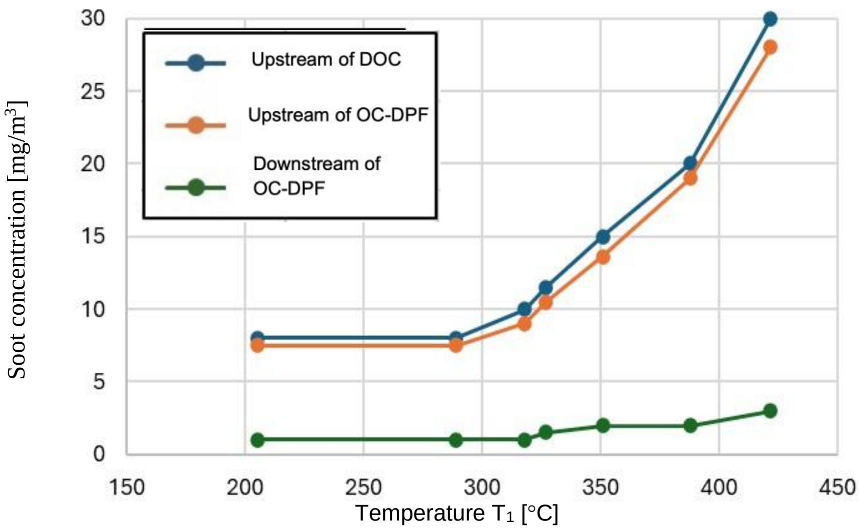

Figure 7. Soot concentration (C) upstream of the DOC catalytic converter, upstream of the OC-DPF filter and downstream of the DOC/OC-DPF

Empirical studies of soot oxidation in the DOC/OC-DPF system shown in Figure 2 were carried out on the test stand shown in Figure 3. Thus, Figure 7 shows the values of soot concentrations (C), while Figure 8 shows the values of its conversion measured in DOC, OC-DPF and in DOC/OC-CDPF at constant engine speed n = 2000 rpm, depending on the temperature of exhaust gases upstream of the DOC converter.

A slight decrease in the concentration of soot (Figure 7) downstream of the DOC converter in relation to the concentrations upstream of the converter is observed, resulting from its slight oxidation in the DOC converter.

In the case of soot concentrations downstream of the DOC/OC-DPF system (Figure 7), its low values are observed, resulting both from its collection in the DPF and oxidation by NO_2

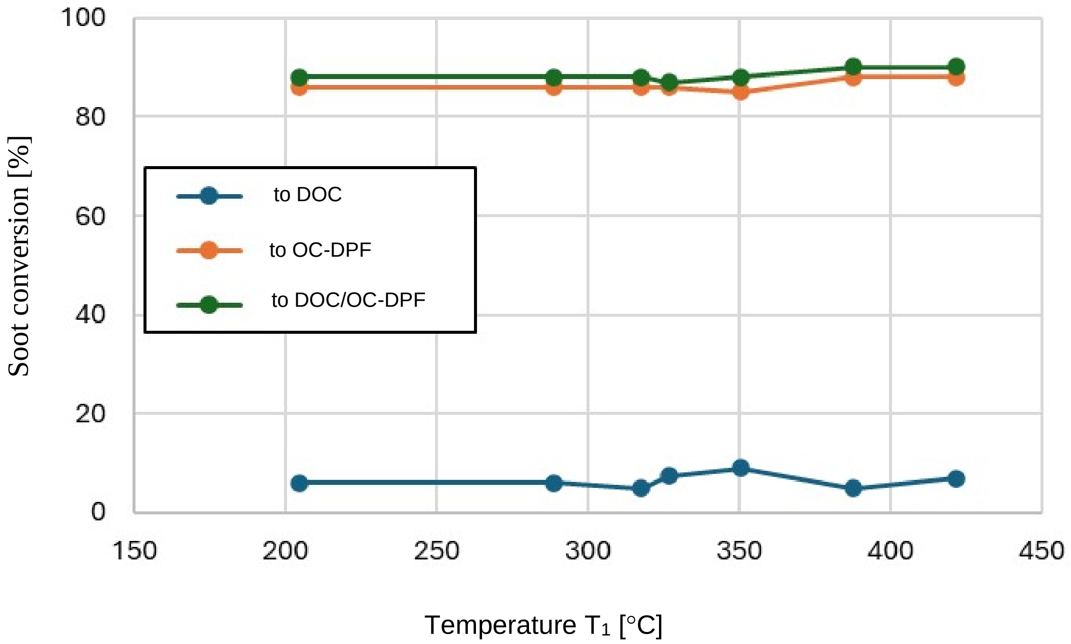

Figure 8. Soot conversion (C) in the DOC catalytic converter, in the OC-DPF filter and in the entire DOC/OC-DPF system

Figure 8 shows that the conversion of soot in DOC is minimal, while in the DOC/OC-DPF system it reaches values in the entire range of tested temperatures of about 90%, which results from both its collection and oxidation at higher flue gas temperatures.

3.4. Equilibrium temperature testing of the diesel particulate filter system using the modified DECSE test

An important parameter of the operation of a passive-active soot filter is its equilibrium temperature. The equilibrium temperature is the temperature at which the amount of soot particles inflowing is equal to the amount of oxidized soot. This parameter determines the temperature values above which the soot particle filter will regenerate. The lower the equilibrium temperature, the less often the active regeneration system will start during the operation of the engine, thus increasing fuel consumption and harmful emissions, and potentially leading to thermal degradation of the filter.

The procedure for measuring the equilibrium temperature was developed in the DECSE program [21] and described in the paper [22]. The test involves recording of changes in filter pressure during exposure to several (5) gradual changes in exhaust gas temperature at the filter inlet. Changes in the resistance of the exhaust gas flow through the filter are recorded in the form of pressure measurements and approximated by a linear function. Then the degree of the test is determined, during which no pressure changes are observed, from which it can be concluded that the equilibrium temperature of the filter is present in this range.

Since the temperature equilibrium of the filter depends largely on the soot emission value of the engine, it is therefore not a universal property of the diesel particulate filter. Since filter regeneration depends on the accumulated amount of soot, the equilibrium temperature can vary depending on the filter’s testing history. To minimize these variations, the equilibrium temperature determination procedure must take into account the preconditions for filter testing, which will ensure that the filter is filled with the exact amount of soot required to begin the test. The equilibrium temperature test requires installing a filter in the engine exhaust system and increasing the engine load to increase the exhaust gas temperature. The load on the engine increases gradually, in correspondingly small increments. The exhaust gas temperature before the filter inlet and the differential pressure are recorded over time. The time must be chosen experimentally for the given engine and filter dimensions.

To achieve reproducibility of test results, the initial state of the filter must always be the same [25]. It is preferable to start the test procedure with the filter slightly full, after its regeneration by sufficiently long exposure of the filter to high temperatures. In this study, a new 7-stage test was used to evaluate the soot filter, starting in the first stage with a slight filling of the filter with soot, corresponding to a pressure drop of Δp = 1.25 kPa and a temperature of exhaust gases upstream of the filter of 213°C with a NO_2 concentration downstream of the DOC of about 30 ppm, which corresponds to a concentration of 10 ppm upstream of the DOC (Figure 5). The test consists of continuous measurements of about 30 minutes of pressure increase upstream of the filter in each stage and continuous measurements of exhaust gas temperatures T_1 and T_3, respectively, upstream and downstream of DOC/OC-DPF, when the engine is running at a constant speed of n = 2000 rpm. After each stage, the engine load was gradually increased until the exhaust gas pressure in the filter was clearly reduced in the subsequent stages. For each stage of the test, a linear trend of temperature changes T_1 was determined during each stage of the test. Obtaining the slope modulus of the line with a value close to zero indicates that there is no increase or decrease in the pressure upstream of the filter and thus that the filter equilibrium temperature has been reached.

Figure 9 shows the temperature and pressure relationships measured during the 7-stage test cycle, the values of which, together with trend lines, are summarized in Table 1.

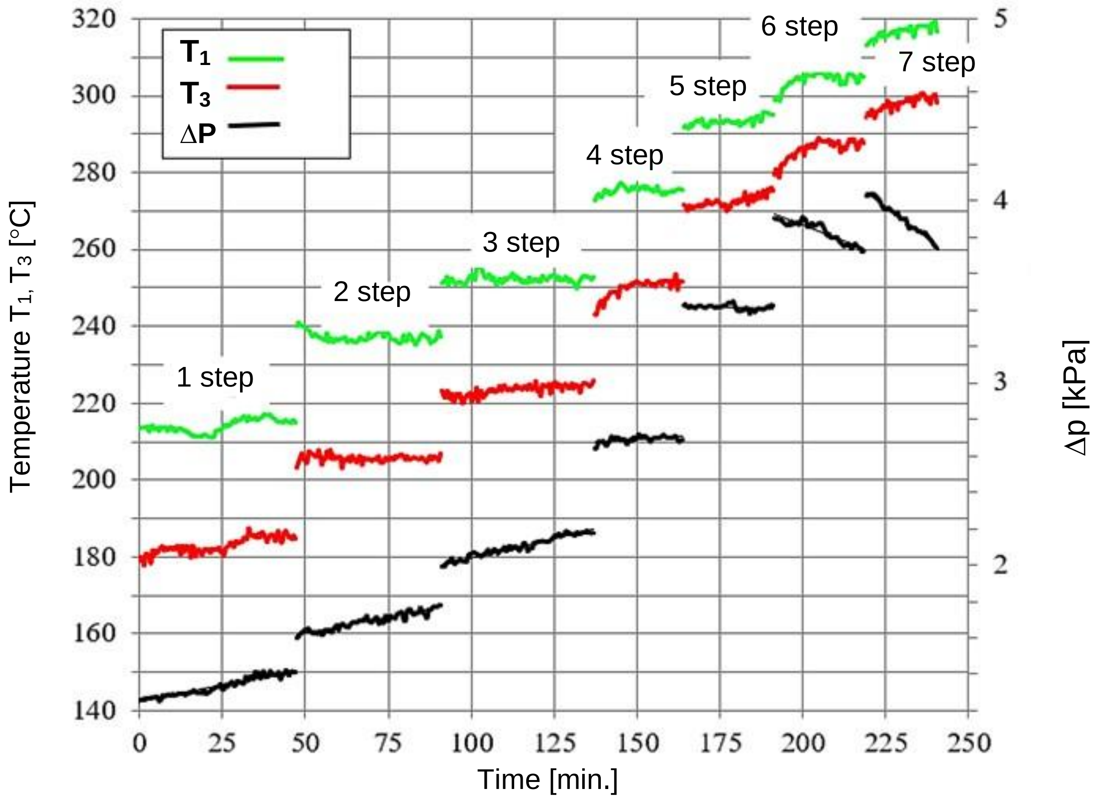

Figure 9. The next 7 stages of the test

Table 1. The results of measurements of the average temperature value T_1 and pressure increase Δp in each step, and linear dependencies y = f(x), where y is Δp and x is the time in each test step. The parameters of step 4, in which the smallest slope was identified, are marked in red.

Stage number	Engine torque [Nm]	Linear interpolation	Average temperature value T_1 [°C]	Average pressure value Δp [kPa]
1	34.6	y = 0.0036x +1.2478	214	1.3
2	40.8	y = 0.0035x +1.4522	238	1.7
3	45.4	y = 0.0041x +1.6305	252	2.1
4	56.1	y = 0.0005x +2.508	274	2.68
5	68.1	y = - 0.0006x +3.5246	294	3.45
6	76.2	y = - 0.0071x +5.2852	302	3.8
7	82	y = - 0.0133x +6.9488	315	3.9

To determine the equilibrium temperature of the diesel particulate filter, the test step was chosen in which the slope of the simple differential pressure equation is closest to zero.

The 4th stage (Figure 7) was selected for further analysis from the diagram of the relationship of the temperature upstream and downstream the filter, the overpressure and the time. The differential pressure diagram shown in this figure has been this time approximated with a second-order polynomial. An increase in pressure means that particulate matter is still being collected in the particulate filter. The point at which the line reaches the peak of its value is the point at which the mass of the particles entering the filter is equal to the mass of the particles oxidized in the filter. The temperature at which the diesel particulate filter does not change the flow resistance of the exhaust gases is called the equilibrium temperature of the tested filter. This temperature is calculated as the temperature upstream of the diesel particulate filter. Figure 10 shows the temperature-pressure relationships measured during the stage 4 of the test cycle in order to accurately determine the filter equilibrium temperature based on the interpolation of the second stage of pressure changes.

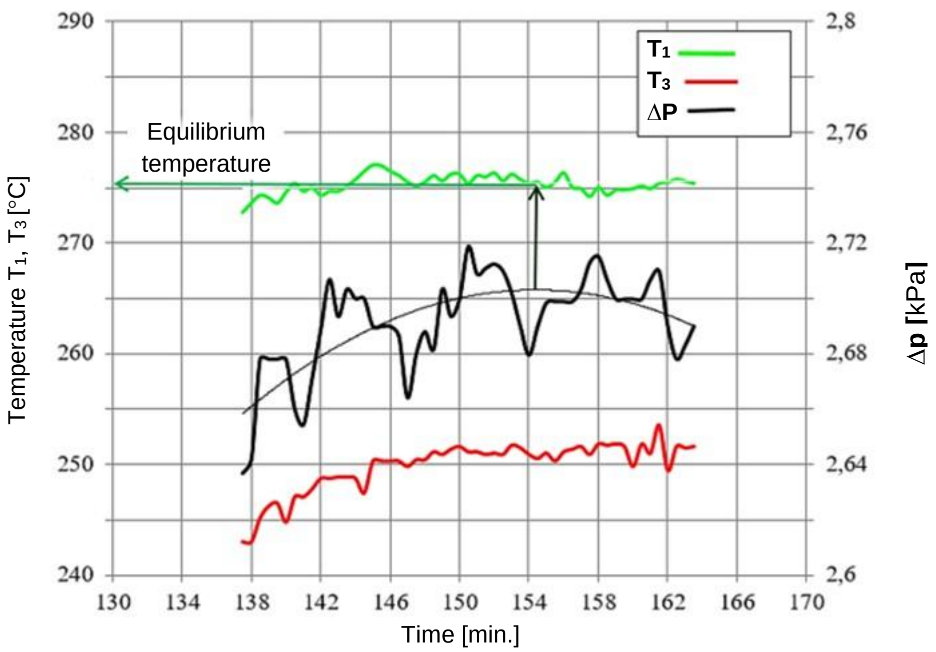

Figure 10. Interpolation of pressure changes and determination of the filter equilibrium temperature.

The change in pressure Δp was approximated by a second-order polynomial with the equation ($y = 0.0002x^2 + 0.0483x - 1.256$), whose maximum Δp is 2.705 kPa, which corresponds to the equilibrium temperature T_1 = 276°C.

The equilibrium temperature of the DOC/OC-DPF system determined by the second-order polynomial pressure interpolation method is 276°C; At this temperature, NO_2 concentrations are about 40 ppm (Figure 5) and soot concentrations are 7 mg/dm^3 (Figure 7).

4. Summary

A test carried out on an engine dynamometer is a good method of testing the diesel particulate filter. It allows to easily determine one of the most important parameters of the filter, which is its equilibrium temperature. In order to be able to compare different types of filters with this measuring procedure, the prerequisites must be provided so that the filter is filled to exactly the level required to start the test. The exact same initial state also allows for repeatable results. Therefore, in this method, it is recommended to start the tests with the filter, after its regeneration caused by high temperature, but in the surface filtration phase, in which filling of the filter causes an almost linear pressure drop.

The modified method allows for a relatively simple determination of the equilibrium temperature of the DOC/OC-DPF filter unit in order to assess it due to:

– dimensions of the tested filter,
– the content of catalytically active materials, including precious metals or base metal oxides in the filter,
– the location of the filter in the engine exhaust system,
– impact of fuel impurities, e.g. sulphur content.

The modified method makes it possible to partially eliminate costly particulate mass emissions tests in the WLTP and RDE test cycles in the initial measurements, while at the same time enabling a preliminary assessment of the increase in energy consumption during active filter regeneration during its operation.

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