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## A simulation and experimental verification of the operation of the oxidising catalytic converter in diesel engine.

Indexed by:



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### Highlights

- Application of the AVL Boost program to simulate the operation of an oxidising catalytic converter turned out to be an effective way to select the converter dimensions, thereby reducing its costly empirical tests.
- The aim of the article was to examine and compare the properties of the oxidising converter in reducing the concentrations of CO, HC and NO to NO<sub>2</sub> in the exhausts of a diesel engine by using simulation calculations in the AVL Boost program and empirical tests on an engine dynamometer.
- Increasing the volume of the converter and the density of its channels has a positive effect on the conversion of concentrations of CO, HC and NO to NO<sub>2</sub>.

### Abstract

The paper discusses the characteristics of an oxidising catalytic converter for a diesel engine's particulate filter system, analyzed through simulation and empirical studies. Constructed from a metal monolith, the converter has a 1.4 dm<sup>3</sup> volume, 400 cpsi channel density, and a 2.5 g/dm<sup>3</sup> platinum coating. Its chemical composition was examined using a scanning electron microscope, revealing platinum crystallites on a highly porous surface. Simulation tests in the AVL Boost program, utilizing real exhaust gas concentration data, assessed the converter's efficiency in converting CO, HC, and NO<sub>2</sub> in NO<sub>x</sub> at various engine speeds and channel conditions. An experiment on an engine dynamometer paralleled these simulations, verifying their accuracy. The study indicates that the simulation algorithm can predict the converter's performance, potentially reducing the need for extensive empirical testing and aiding in preliminary evaluations.

### Keywords

internal combustion engines, catalytic converters, diesel oxidation catalysts, simulation tests

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### 1. Introduction

Presently, every vehicle with a compression ignition engine must be provided with a diesel oxidation catalyst (DOC) to oxidise harmful exhaust gas components in a non-selective manner [1, 2]. Diesel oxidation catalysts in compression ignition engines are normally placed upstream of the following:

- diesel particulate filter – as a component of the DOC-CDPF exhaust gas treatment system, to generate the maximum amount of NO<sub>2</sub> used as an oxidiser of the soot collected in the filter and oxidise HC and CO. Catalysts in such applications require a high Pt content

to achieve a NO<sub>2</sub> content in NO<sub>x</sub> of almost 80% [2] at the smallest possible exhaust gas temperatures,

- HCat/NH<sub>3</sub>-SCR/ASC catalyst system to oxidise a part of HC and CO, improving NO<sub>x</sub> conversion in the SCR catalyst at low exhaust gas temperature [3] and oxidise a part of NO to NO<sub>2</sub>, which reduces the SCR activation temperature [4]. The NO<sub>2</sub> content relative to NO content should be optimised by selecting the correct platinum content and dimensions of the diesel oxidation catalyst. If the NO<sub>2</sub> levels are too high, the

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efficiency of  $\text{NO}_x$  conversion decreases [4]. The optimum [5]  $\text{NO}_2$  content in  $\text{NO}_x$  is approximately 50% vol., which is the equivalent of an  $\text{NO}_2/\text{NO}$  ratio of approximately 1 for a diesel oxidation catalyst with the optimum Pt content,

The use of modern exhaust gas treatment systems, including, in particular, the DOC-CDPF system, in compression ignition engines causes many undesirable phenomena that present problems for the users. An important phenomenon that attracts plenty of attention during the operation of the catalysts is the gradual decrease of their catalytic activity – the process referred to as “catalyst ageing”. It manifests, in particular [2], in a significant increase in the emissions of harmful substances, often resulting in the disqualification of the exhaust gas treatment system and a costly replacement with a new system. Also, the effects of ageing result in a significant negative impact of the operation of vehicles on the natural environment, particularly in urban agglomerations. There are two reasons to study this process:

- the first reason is the fact that the regulations require the vehicles to emit low amounts of harmful substances over a long service life, i.e., using catalysts with a long life, which age slowly,
- the second reason are costs. The costs of building a catalyst are strictly connected to the content of precious metals, and the lower the content of such metals, the higher the sensitivity of the catalyst to ageing.

During the operation of the catalyst, the following essential adverse changes occur [2]:

- increase in the exhaust gas temperature at which the catalysts becomes active when it heats up,
- reduction of the conversion rate at specific operating temperatures.

The increase in the temperature of obtaining activity (mainly the T50 temperature) significantly increases the emission of exhaust pollutants in vehicle research tests and during long-term operation. However, a reduction in the conversion rate, in steady-state thermal operating conditions of the converter, results in an increase in emissions when the hot engine is operated

Also, the following faults may appear in passive-active

systems [2]:

- increased balance-point temperature of the filter of the DOC-CDPF system, causing more frequent transition from passive regeneration mode to active regeneration, resulting in energy losses and higher emissions of harmful substances,
- uncontrolled regeneration of the filter is due to the excessive accumulation of soot, which is connected, on the one hand, to excessive PM emissions of the engine and, on the other hand, to the insufficient production of  $\text{NO}_2$  in the DOC during passive filter regeneration or inadequate efficiency of the exhaust gas heating system during active regeneration,
- burn-out of the filter monolith due to the rapid oxidation of unevenly distributed soot in the cells of the filter, requiring a costly replacement of the entire system with a new one.

The main problem that has to be solved is the development of a durable and reliable catalyst with the smallest possible amount of precious metal and the smallest possible volume and cell density, separately for each of the DOC applications described above. This solution requires costly and prolonged experimental tests in laboratory test cycles [6] and according to the Euro 6 type approval requirements in the actual (RDE drive cycles) operation of the vehicle [7]. A partial reduction of the duration and costs of experimental tests can be achieved by using software to aid the research activities and simulate the operation of the DOC. At the moment, there are several programs of the afore-mentioned type available in the market, dedicated primarily to the modelling and simulations of catalytic exhaust gas treatment systems. By using a simulation program capable of combining multiple phenomena occurring in the catalysts, designers and engineers can verify the design assumptions at an early stage of the development of catalyst systems.

## 2. Literature review

Simulation tests and their experimental verification in laboratory conditions and in the operating conditions of the vehicles have been the subject of extensive research in recent years. A digital model of a diesel oxidation catalyst using spatial, physical and chemical processes occurring in the catalytic

monolith has been shown in paper [8]. The model also considered water condensation and evaporation to predict the behaviour of the catalyst during a cold engine start. The kinetic parameters of the reaction were assessed based on a series of laboratory experiments. A correlation was developed between the kinetic parameters and precious metal content.

The simulation of the operation of a diesel oxidation catalyst [9] also considered the formulas for heat and mass transfer in transitional engine operation conditions. The chemical reactions were described using the Langmuir-Hinshelwood reaction mechanism. The simulation considers the models of HC storage in the catalyst.

In the paper [10], the authors developed a 3D DOC model in the SOLIDWORKS program. The gas flow analysis in the designed model was subsequently imported into ANSYS FLUENT 16.2 as an IGS file. The design of the model was verified using the results of simulations, which found that the pressure drop in the catalyst was within the acceptable range.

A comprehensive numerical study designed to provide a better understanding of mass transfer in channel flows with catalytically active walls at moderate temperatures and with moderate surface reaction rates was shown in paper [11]. The geometry of the catalyst was modelled using the 1D flow equations, while the boundary layer was modelled using 2D equations and Navier-Stokes equations. Diffusion limitations in the porous layer were considered using the simplified zero-dimensional model of the effectiveness factor and multidimensional reaction-diffusion models. The conversion of pollutants on a platinum catalyst was described by a reaction mechanism consisting of 74 reactions among 11 gas-phase species and 22 adsorbed surface species. The results of the digital simulations were compared with experimental data.

The modelling of exhaust gas temperature downstream of the catalyst due to heat release was described in paper [12]. Heat release is calculated based on the enthalpy of a one-step reaction. The agglomeration of hydrocarbons in the catalyst and their rapid burn-off after reaching the light-off temperature was considered. Thanks to the combination of the two processes, it is possible to accurately model the exhaust gas temperature in the catalyst, which considers rapid temperature increases due to the rapid conversion of the stored hydrocarbons.

Paper [13] uses a 1D mathematical model of a diesel

oxidation catalyst to simulate the hot start of an engine in the New European Driving Cycle (NEDC). The model was developed to investigate CO conversion by the catalyst. The comparison of model simulations and experiments showed a satisfactory consistency both in terms of the substrate temperature and CO emissions at the catalyst outlet, proving the effectiveness of the applied methodology.

Usually, automotive converters [14] are simulated using the ANSYS (Fluent) program. It was found that converter performance depends on its length, cell density, output pressure and inlet velocity.

Paper [15] discusses the development of a series of dynamic models using the Simulink® program. The results of the simulation were confirmed by experimental data gathered by the Clean Diesel Engine Laboratory (CDL) at the University of Windsor. Its potential of active flow control, improving the energy-efficiency of exhaust gas treatment, in DOCs was demonstrated. The developed thermal models were verified using data from the US and Japanese test cycles for compression ignition engines.

The flow of exhaust gas through the catalysts was described using a mathematical model defined with partial differential equations in paper [16]. A calculation program was developed to solve these equations using a mathematical model of the DOC. The equations were solved using the finite element (volume) method in time steps. The solution of the developed equations was used to calculate CO and HC oxidation at the outlet of the converter. Thus, the model can be used to design DOC converters and predict the reduction of CO and HCs in DOCs.

Paper [17] discusses the development of a wide range of different testing methods based on the operation of the engine at pseudo-steady-state operating conditions and transient experiments (e.g., a pulse of CO was injected into the exhaust gas just upstream of the DOC). It was shown how experiments on an engine could be used to explore: the hysteresis between light-off and extinction curves, catalyst temperature rise during warm-up of a DOC and the promotion effect that hydrogen has on the conversion of CO.

To design a reasonable strategy for the control of DPF regeneration, the paper [18] designed a mathematical model describing thermal phenomena both in a diesel oxidation

catalyst (DOC) and a diesel particulate filter (DPF) during regeneration. The tests concerned the impact of the main parameters of exhaust gas, such as mass flow rate, temperature, oxygen concentration and reagent emissions. The authors also analyzed the impact of the two main parameters of the control strategy: DOC output temperature and soot content. To quantitatively determine the impact of relevant parameters, the authors assessed the correlation coefficient of all the factors with the key indexes of DPF regeneration, such as maximum temperature, maximum temperature increase rate and regeneration duration. The results of this work enable more reasonable design of the strategy for the control of DOC-DPF regeneration systems.

### 3. Methodology of research

The objective of the paper was to run a simulation determining the impact of the volume and number of cells of a diesel oxidation catalyst of the particulate filter system on the achieved levels of CO and HC conversion and NO<sub>2</sub>/NO<sub>x</sub> ratio, including the experimental verification of the calculations at the following stages:

#### 3.1. Simulation calculations

The AVL Boost program enables the user [19] to carry out calculations and compare the results of the experiments with the results of the simulation. The program is very flexible in terms of the type and composition of fuel, including the possibility of using both conventional and alternative fuels. The Aftertreatment module of the AVL Boost program has further modules enabling the simulation of the catalytic phenomena occurring in exhaust gas treatment systems [20], including the kinetics of catalytic reactions used in DOC, TWC, HSO-SCR, Lean NO<sub>x</sub> and NO<sub>x</sub> trap catalysts and the processes of PM filter regeneration with oxidisers such as oxygen and nitrogen dioxide.

The model of the diesel oxidation catalyst used in the program for the internal combustion engine is presented as a single catalyst (CAT1) with the option of defining boundary conditions at the inlet (ATB1) and outlet (ATB2) [21].

A view of such a system used in the computational program for a single catalyst is shown in figure 1.

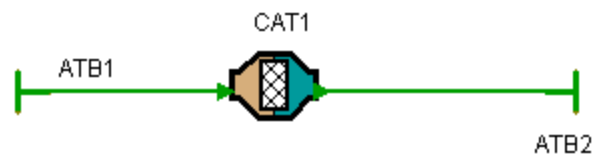


Fig. 1. Simulated [1] diesel oxidation catalyst (CAT1) with the boundary conditions (ATB1, ATB2).

#### 3.2. Design and description of a diesel oxidation catalyst and empirical tests on an engine test stand

The catalyst was made on a metal monolith with a volume of 1.4 dm<sup>3</sup> and a cell density of 400 cpsi. The active components were applied using the “slurry” method, involving the simultaneous, mechanical application of the intermediate layer together with platinum compounds on the catalyst block. The metal monolith was coated with a mixture of aluminum oxide, rare-earth metal and platinum compounds, prepared at a suitable ratio, to provide the catalyst with a platinum charge of 2.5 g/dm<sup>3</sup>. The final stage of catalyst production was calcination at 550°C. Water was removed from the monolith, and platinum compounds were reduced, producing their pure, elemental form with a large degree of dispersion. After the calcination of the monolith, the catalyst is placed in a hybrid mat with a suitable housing.

The active surface of the catalyst was also measured in terms of the specific surface area using the BET method with low-temperature nitrogen adsorption (77 K), assuming the nitrogen particle deposition area  $\omega = 0.162 \text{ nm}^2$ . The results of the measurement of the specific surface area and average pore diameter in the surface measured using the BJH method for the developed catalyst are as follows:

- specific surface area (BET) 23.4 m<sup>2</sup>/g
- average pore diameter (BJH) 69.1 Å

Important information about the chemical composition of the catalyst, particularly the superficial distribution of the elements, was obtained using a scanning electron microscope (SEM). The tests were performed using the LEO 1530 microscope with an EDX Link ISIS micro-analysis system. Microscopic tests were performed on specimens with a size of 5x10 mm whose area was covered with a carbon layer with a thickness of approx. 25 nm in a vacuum sputter coater under the pressure of 10<sup>-5</sup>TPa.

Figure 2 shows the point micro-analysis of the area of the

catalyst, showing the peaks of platinum presence on the catalyst surface, and figure 3 shows a fragment of the active surface with high porosity with a view of randomly distributed Pt crystallites in the form of bright spots.

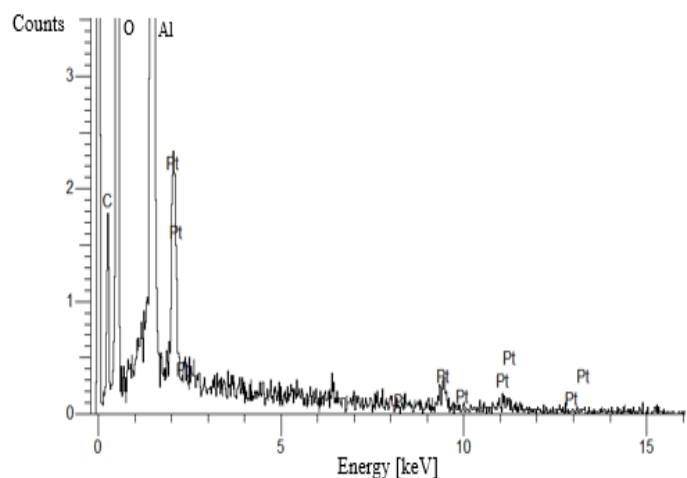


Fig. 2. X-ray point micro-analysis for a catalyst with 2.5 g/dm<sup>3</sup> Pt content on Al<sub>2</sub>O<sub>3</sub> – spectrogram of the specimen.



Fig. 3. SEM image of the topography of catalyst surface with 2.5 g/dm<sup>3</sup> Pt content and 20 000x magnification.

### 3.3. Experimental determination of the boundary conditions of the simulation

The boundary conditions at the inlet and outlet of the catalyst were determined based on data obtained during experimental tests. The tests were conducted on a four-cylinder, turbocharged engine with a capacity of 1248 cm<sup>3</sup>, with Common Rail direct fuel injection. During the tests, engine operated at a variable load ensuring variable concentrations of harmful substances in a wide range at a constant rotational speed of 2000 rpm, i.e. in

conditions similar to the operating conditions of the warmed-up engine. The measurements of the concentrations of exhaust gas components upstream of and downstream of the catalyst were carried out using the following methods:

- CO using the NDIR method
- HC using the FID method
- NO and NO<sub>2</sub> and NO<sub>x</sub> = NO + NO<sub>2</sub> using the CL method

Exhaust gas temperature was measured using the NiCr – NiAl(K) sensors

The boundary condition at the outlet of the catalyst used by the program was only the exhaust gas pressure downstream of the DOC and upstream of the DPF – the values of which are shown in table 1.

Table 1. Boundary condition at the outlet of the DOC.

		Engine torque [Nm]						
		40	60	80	100	120	140	160
Pressure downstream of the DOC	[bar]	1.02	1.02	1.03	1.04	1.05	1.05	1.06

Figure 4, in turn, shows the concentrations of the analysed toxic compounds and DOC temperature vs the torque generated by the engine.

The remaining conditions of the simulation, such as the physical and chemical properties of the DOC, were introduced based on data provided by the DOC manufacturer or available research [21]. The AVL Boost program also enables entering default data based on suggestions.

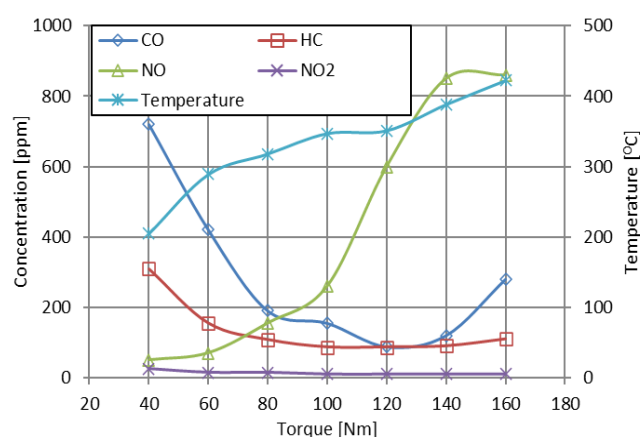
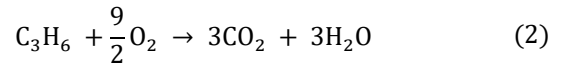


Fig. 4. Concentrations of toxic compounds and exhaust gas temperature upstream of the DOC depending on engine load at n = 2000 rpm used as input boundary conditions for the simulation.

### 3.4. Converter model and simulation parameters

The model of chemical reactions used in the AVL Boost program [21] to perform the simulation calculations of the diesel oxidation catalyst of a diesel engine includes the following reactions of the oxidation of carbon monoxide, hydrocarbon and nitrogen oxide:



The simulation program for the calculations uses the reaction rates and kinetic parameters given below [22] [23].

The rate of the first reaction  $r_1$  is expressed as follows

$$r_1 = \frac{[K_{r1} \cdot e^{\frac{-E_{r1}}{T_s}} \cdot y_{\text{CO}} \cdot y_{\text{O}_2}] \cdot [1 + K_1 \cdot e^{\frac{-E_1}{T_s}} \cdot y_{\text{CO}} + K_2 \cdot e^{\frac{-E_2}{T_s}} \cdot y_{\text{C}_3\text{H}_6}]^{-2}}{T_s \cdot [1 + K_3 \cdot e^{\frac{-E_3}{T_s}} \cdot y_{\text{CO}}^2 \cdot y_{\text{C}_3\text{H}_6}^2] \cdot [1 + K_4 \cdot e^{\frac{-E_4}{T_s}} \cdot y_{\text{NO}}^{0.7}]} \quad (4)$$

The rate of the second reaction  $r_2$  is expressed as follows:

$$r_2 = \frac{[K_{r2} \cdot e^{\frac{-E_{r2}}{T_s}} \cdot y_{\text{C}_3\text{H}_6} \cdot y_{\text{O}_2}] \cdot [1 + K_1 \cdot e^{\frac{-E_1}{T_s}} \cdot y_{\text{CO}} + K_2 \cdot e^{\frac{-E_2}{T_s}} \cdot y_{\text{C}_3\text{H}_6}]^{-2}}{T_s \cdot [1 + K_3 \cdot e^{\frac{-E_3}{T_s}} \cdot y_{\text{CO}}^2 \cdot y_{\text{C}_3\text{H}_6}^2] \cdot [1 + K_4 \cdot e^{\frac{-E_4}{T_s}} \cdot y_{\text{NO}}^{0.7}]} \quad (5)$$

The rate of the third reaction  $r_3$  is expressed as follows:

$$r_3 = K_{r3} \cdot T_s^A \cdot e^{\frac{-E_{r3}}{T_s}} \cdot \left( c_{\text{NO}}^2 \cdot c_{\text{O}_2} - \frac{c_{\text{NO}_2}^2}{K_{\text{eq},1}} \right) \quad (6)$$

The following symbols are used in the equations above:

$K_{r1}, K_{r2}, K_{r3}, K_1, K_2, K_3, K_4$ – frequency factors,

$E_{r1}, E_{r2}, E_{r3}, E_1, E_2, E_3, E_4$ – activation temperatures,

$y_{\text{CO}}, y_{\text{O}_2}, y_{\text{C}_3\text{H}_6}, y_{\text{NO}}$ – molar fractions of the substance in the reactive gas-phase surface,

$c_{\text{NO}}, c_{\text{O}_2}, c_{\text{NO}_2}$ – concentrations of the substance on the active

surface,

$T_s$ – monolith temperature,

$A$ – value determining the temperature dependence,

The equilibrium constant  $K_{\text{eq},1}$  in the formula for the rate of the third reaction, defined as a function of the temperature of the catalyst carrier is defined as follows:

$$K_{\text{eq},1} = \left( \frac{p_{\text{atm}}}{RT_s} \right)^{-1} \cdot e^{\left( -18.518 + \frac{13607}{T_s} + 0.5582 \cdot \frac{T_s}{1000} - 0.04489 \cdot \left( \frac{T_s}{1000} \right)^2 - 0.8278 \cdot \log\left( \frac{T_s}{1000} \right) \right)} \quad (7)$$

Where  $p_{\text{atm}}$  is the atmospheric pressure, and  $R$  is the universal gas constant.

The values of all factors in the AVL Boost program are assumed as default values, and they were not modified for the purposes of this simulation.

### 4. Simulation results

The conducted simulation calculations were designed to determine the impact of both the volume of the DOC and the density of cell packing on the achieved levels of conversion of the toxic compounds. To this end, calculations were carried out for 9 configurations of the parameters of the structure of the simulated catalyst. The values of catalyst volume and cell

density set in the program are given in table 2.

Table 2. Values of considered configurations of DOC structure parameters.

No.	1	2	3	4	5	6	7	8	9
Cell density [cpsl]	400				200	300	400	500	60
Volume [dm <sup>3</sup> ]	1.0	1.4	1.8	2.2	1.4				

Figures 5–7 show the results of simulation calculations conducted with a constant cell density of the DOC monolith and variable volume (cases 1–4 from table 2).



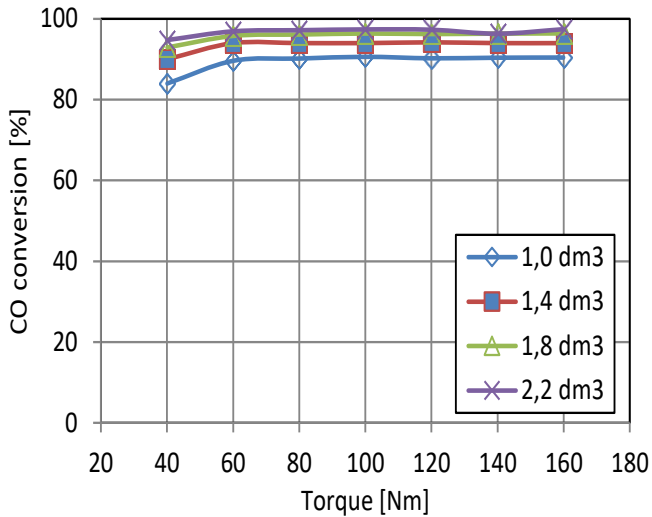


Fig. 5. Simulation calculations of the impact of a change in catalyst monolith volume with a constant cell density of 400 cpsi on CO conversion depending on engine load at  $n = 2000$  rpm.

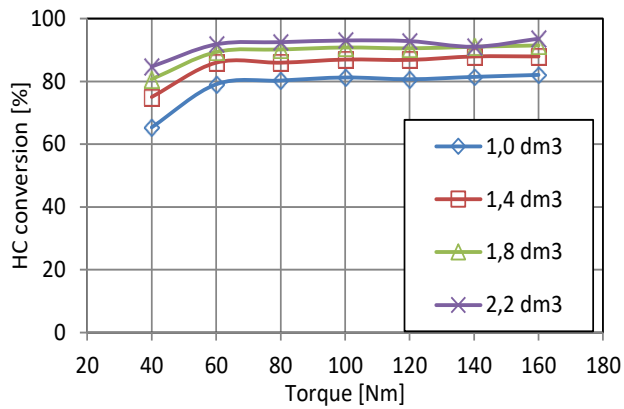


Fig. 6. Simulation calculations of the impact of a change in catalyst monolith volume with a constant cell density of 400 cpsi on HC conversion depending on engine load at  $n = 2000$  rpm.

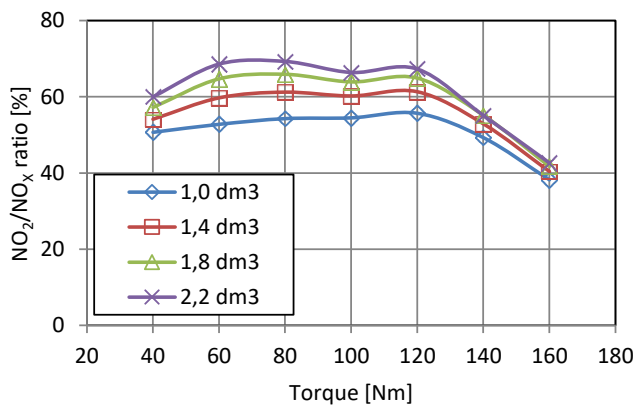


Fig. 7. Simulation calculations of the impact of a change in catalyst monolith volume with a constant cell density of 400 cpsi on the  $NO_2/NO_x$  ratio depending on engine load at  $n = 2000$  rpm

Figures 8–10 show the results of simulation calculations

conducted with a constant catalyst volume and variable cell density (cases 5–9 from table 2).

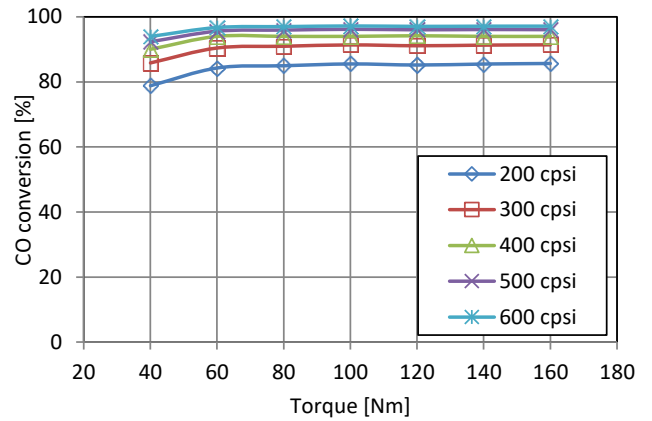


Fig. 8. Simulation calculations of the impact of a change in monolith cell density with a constant volume of  $1.4 \text{ dm}^3$  on CO conversion depending on engine load at  $n = 2000$  rpm

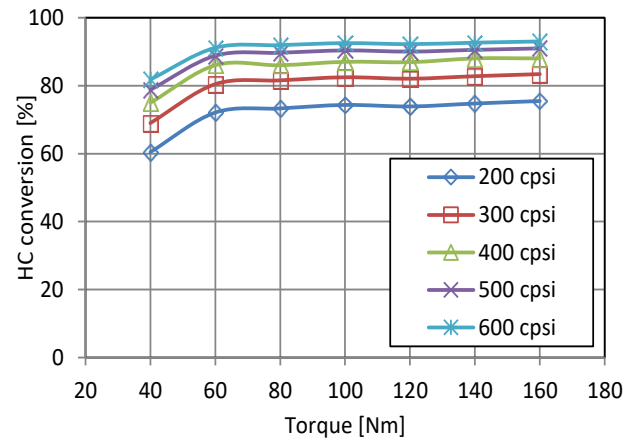


Fig. 9. Simulation calculations of the impact of a change in monolith cell density with a constant volume of  $1.4 \text{ dm}^3$  on HC conversion depending on engine load at  $n = 2000$  rpm.

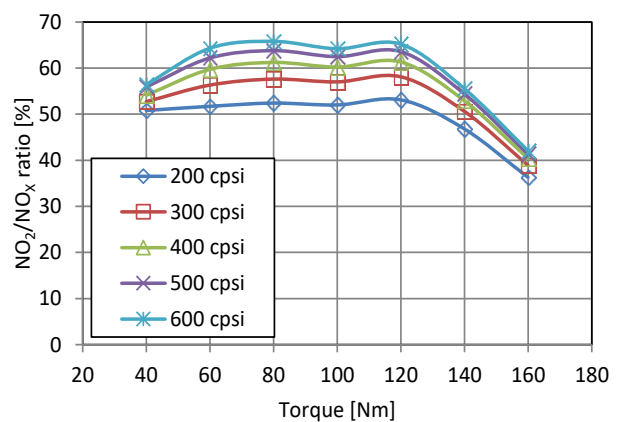


Fig. 10. Simulation calculations of the impact of a change in monolith cell density with a constant volume of  $1.4 \text{ dm}^3$  on the  $NO_2/NO_x$  ratio depending on engine load at  $n = 2000$  rpm.

## 5. Experimental verification of simulation results

The simulation tests were verified by measuring the conversion of CO and HC and the  $\text{NO}_2/\text{NO}_x$  ratio, as a parameter relevant [24] to the regeneration of the particulate filter.

Figures 11–12 show the results of simulation calculations and experimental measurements of CO and HC conversion. The calculation results are fairly consistent with the results of the experiment.

Figure 13 shows the results of the measurement of  $\text{NO}_x$  conversion and the  $\text{NO}_2/\text{NO}_x$  ratio upstream of the catalyst and the results of the calculations of the  $\text{NO}_2/\text{NO}_x$  ratio downstream of the catalyst. The results of the calculations of the  $\text{NO}_2/\text{NO}_x$  ratio are consistent with the results of the experiment. Approx. 60% of NO is oxidised to  $\text{NO}_2$  in the DOC, with a loss of several percent of  $\text{NO}_x$ , most likely [6] due to its selective reduction by the hydrocarbons on the platinum.

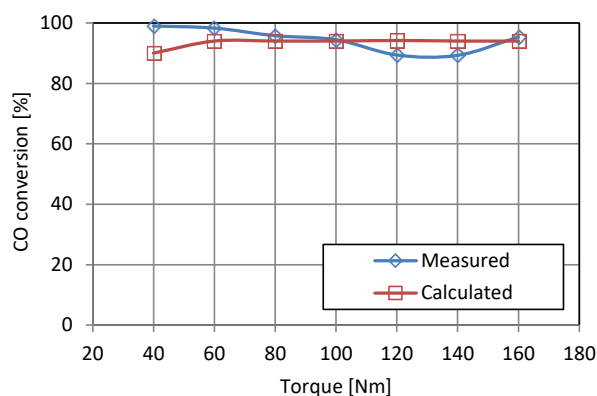


Fig. 11. Simulation calculations and experimental measurements of CO conversion in a diesel oxidation catalyst depending on engine load at  $n = 2000$  rpm.

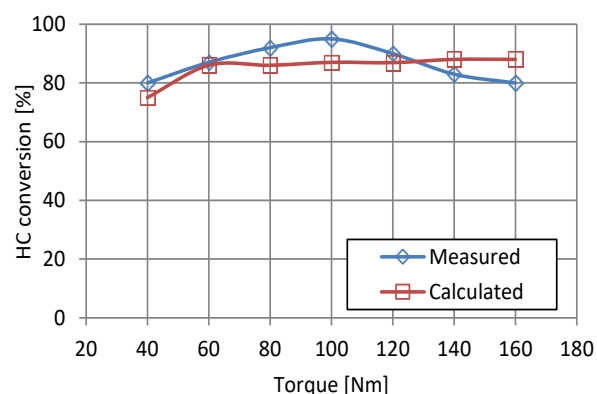


Fig. 12. Simulation calculations and experimental measurements of HC conversion in a diesel oxidation catalyst depending on engine load at  $n = 2000$  rpm.

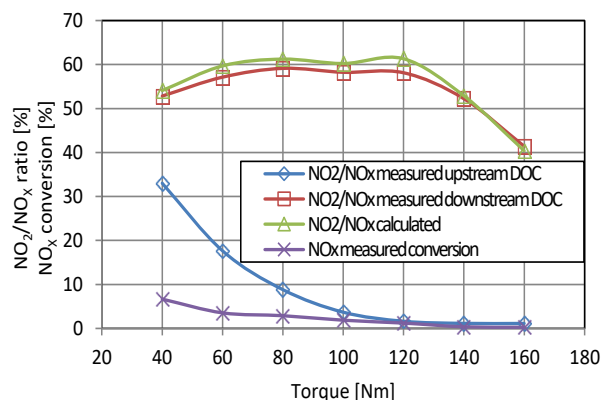


Fig. 13. Simulation calculations and experimental measurements of the conversion of nitrogen oxides in a diesel oxidation catalyst depending on engine load at  $n = 2000$  rpm.

## 6. Conclusions

Based on the results of simulation calculations obtained in the AVL Boost program and experimental tests, the following conclusions could be made:

- the Aftertreatment module of the AVL Boost program used allows to easily simulate the processes taking place in exhaust gas treatment systems, without the need to design the entire combustion engine,
- the highest levels of CO and HC conversion and the shares of  $\text{NO}_2$  in  $\text{NO}_x$  were obtained for the converter with the largest simulated volume of  $2,2 \text{ dm}^3$  at a channel packing density of 400 cpsi. CO and HC conversion levels that are approximately 10% higher occur across the entire engine load range, while higher shares of  $\text{NO}_2/\text{NO}_x$  of approximately 20% occur at lower engine loads,
- with a constant simulated volume value of  $1,4 \text{ dm}^3$ , an increase in the density of the channels results in an increase in the conversion of CO and HC and an increase in the share of  $\text{NO}_2$  in  $\text{NO}_x$ . An increase in the density of the channels from 200 to 600 cpsi results in an increase in CO conversion by approximately 10% and HC by approximately 20%, and the share of  $\text{NO}_2$  in  $\text{NO}_x$  up to approximately 25% at low engine load, decreasing to approximately 10% with increasing engine load,
- the computational changes in the conversion of CO, HC obtained and the shares of  $\text{NO}_2$  in  $\text{NO}_x$  are approximately analogous to the values obtained in the



actual tested oxidation converter.

Experimental tests have confirmed that the platinum oxidising catalytic converter will convert approximately 60% of NO to NO<sub>2</sub> practically without changing the total amount of NO<sub>x</sub>, which is confirmed by the data presented in work [25]. Only a few percent conversion of NO<sub>x</sub> in the range of low engine loads, is observed, probably resulting from the phenomenon of passive selective reduction of nitrogen oxides

by hydrocarbons contained in exhaust gases (HC-SCR reactors). The research results obtained may be an indication for the design and construction of oxidation catalytic converters ensuring, despite their operational aging, a supply of adequate conversion of CO, HC and NO to NO<sub>2</sub>. The proposed methodology for evaluating the operation of a DOC converter can be used in preliminary work on improving oxidation converters used in compression-ignition combustion engines.

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