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2008-01-0768

Pre-Turbocharger-Catalyst – Catalystic performances on an Euro V type Diesel engine and robust design development

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SAE World Congress
Detroit, Michigan
April 14. - 17., 2008

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ABSTRACT

Future emission legislation and new diesel engine technology tighten the requirements for modern diesel vehicle exhaust after-treatment systems. In particular, the oxidation catalyst system requires more efficiency to treat increasing raw emissions of HC and CO at low exhaust gas temperatures resulting from advanced combustion processes. This represents a big challenge for all developers today where the cost of raw materials continues to rise.

Splitting the oxidation catalyst volume into two parts and mounting a very small part in front of a turbocharger on Euro III or Euro IV Diesel engines has been proved very efficient: Light off and maximum pollutant conversion rates were improved. New results gained with Pre-Turbocharger Catalyst (PTC) on a Euro V type diesel engine are confirming previous observations.

The complete after-treatment system of today's vehicles should be designed and developed for the whole life of the vehicle. Due to its position in front of the turbine any failure of the PTC, in either the metal substrate or of the coating, would result in particularly severe consequences due to turbine damage and/or loss of turbine function. A robust design for the metal substrate has been defined with the help of Finite Element simulation of thermal stress and has then been validated on the component test bench.

INTRODUCTION

Turbo-charged Diesel engines with common rail technology are very popular in Europe. Diesel engines are seen today in small city cars, as well as in luxurious or sporting passenger cars, and also in Le Mans Series race cars. Nowadays the Diesel market share accounts for 50.8 % in West Europe in 2006 [1]. It is expected to rise in the North-American market and also in Asian markets. The reasons are:

- a low fuel consumption, which is of major importance for the end user, and which allows today's Diesel engines to be a significant way to reduce CO_2 emissions and limit the greenhouse effect driving global warming,
- a high low end torque synonymous of "fun to drive",
- a very high specific performance with the introduction of two stage turbo-charged systems.

With the diesel emission limits being continuously tightened by legislation from Euro Stage III in 2000, to Euro Stage IV in 2005, to Euro Stage V in 2009 and beyond to Euro Stage VI in 2013- 2014 within Europe for example (Figure 1), Diesel engines are continuously improving to especially reduce NOx and PM engine out emissions in order to limit the requirements for the after-treatment system. If, however, a particulate filter becomes mandatory to fulfill the PM legislation from the Euro V stage, expensive NOx after-treatment solutions like NOx trap or SCR technologies won't be required in all Euro V applications and, particularly, small and medium passenger cars can still delay their usage.

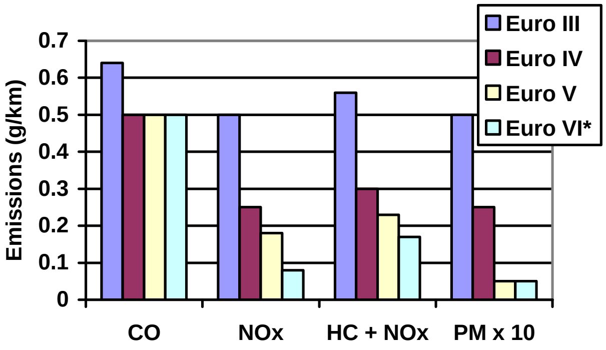


Figure 1: European exhaust emissions standard for diesel passenger cars. (Euro VI is still in discussion)

This NOx limitation is gained by mean of a better combustion process control aiming to reduce combustion temperature [2], hence, the exhaust gas temperatures are lowering. This trend was already seen from Euro III to Euro IV versions of a same diesel engine (Figure 2). During this transition, Hydrocarbon (HC) and Carbon Monoxide (CO) emissions were reduced too.

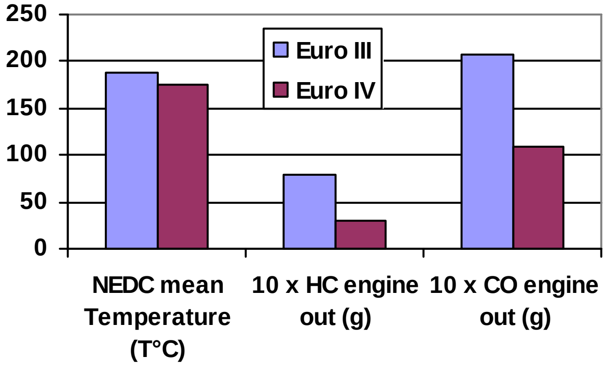


Figure 2: Mean Temperatures and HC and CO engine out emissions over the New European Driving Cycle (NEDC) of the Euro III and Euro IV versions of a 1590kg inertial mass vehicle with a 2 l, 4 cylinder Diesel engine.

With the transition Euro Stage IV toward Euro Stage V and beyond, the exhaust gas temperature is expected to decrease further and be accompanied, on the contrary to the previous transition, by a dramatic increase of CO and HC emissions [2, 3], which would lead to a most severe requirement for the Diesel oxidation catalyst function: How to treat much more pollutants at lower temperatures? This question becomes more significant when one looks at the current Diesel Oxidation Catalyst (DOC) solutions existing for Euro IV applications, all being located downstream of the turbocharger and using already very high Platinum Group Metal (PGM) concentrations.

The idea to split the oxidation function in two parts, one part upstream of the turbocharger to take advantage of higher temperatures in combination with a standard second part downstream of the turbocharger, represents a potential solution for future Euro V (and beyond) Diesel engines. At the same time, integrating a catalyst in front of the turbocharger can have additional consequences due to the potential for damage to the turbocharger and its function: the physical integrity of such a catalyst, either in the metallic substrate or of its coating, must be maintained in order to protect the exhaust turbine.

The paper deals with this concept and focuses on the oxidation function, located upstream of the exhaust turbine, that is provided by the Pre-Turbocharger Catalyst (PTC). The paper reviews briefly the PTC concept and experiences in this field, and presents recently gained emission results on a Euro V type development engine together with development work for a durable solution.

PTC CONCEPT

The PTC concept was presented for the first time by [4, 5]. The aim for the location of a catalyst volume upstream of the turbocharger is to benefit from higher exhaust gas temperatures. Indeed, the turbocharger soaks the energy of the exhaust gas to produce compressed air and therefore the temperatures are lowered from between 50°C and 150°C behind the turbocharger [6]. The results obtained with the first PTCs tested on truck or passenger cars were very encouraging. Although the volume placed in front of the turbine was very small, about 20 to 100 ml due to space constraints, very high CO and HC conversion efficiencies (up to 80%) were gained, although this was not predicted by simulation models. One possible reason to explain these very high efficiencies with small catalyst volumes was that the turbulent flow into the PTC channel leads to a better mass transfer of the pollutants from the gas stream to the active coated walls. This turbulence phenomenon was verified later on by calculation of the mass transfer coefficient ß as a function of the gas speed or catalyst diameter [7]. The influence of the PTC on the main DOC is also presented in [7], with the PTC reducing the pollutant concentrations in the exhaust gas and producing a resultant exotherm, the main DOC gets an earlier light-off and a better overall performance than without a PTC.

EXPERIENCE IN THE FIELD

The PTC oxidation functionality has been further proven on Euro III and Euro IV Diesel passenger cars [6, 7]. It has been shown that the addition of a PTC (with volume up to 40 ml) in the exhaust line could permit the elimination of the under-floor catalyst of a serial solution made up of a CCC and a UFC (thus reducing by 70% the total volume of the DOC function in this case), or to replace the main Euro IV DOC of an Euro IV vehicle by its prior Euro III part (thus decreasing the PGM loading by 50g/ft³).

Two other aspects of the PTC have been reported [8]. It has been shown that the incorporation of a PTC leads to a more durable diesel oxidation function: Even if the PTC coating is aged, the PTC has a very quick light-off due to the higher temperatures in front of the exhaust turbine, which offsets any loss in light-off performance. Its presence doesn't interfere with the regeneration strategy of Coated Diesel Particle Filters (CDPF): Temperatures of 650°C were reached at the CDPF inlet on the chosen NEDC operating points. During the fuel post-injection, the temperature in front of the exhaust turbine still remains under the temperature limit fixed by the turbocharger manufacturer. The PTC produces large temperature increases at lower engine load only where the temperatures in front of the turbine are far from the limit.

Influences of PTC on both the engine dynamic and fuel consumption have also been reported [4, 6, 9, 10] with only a small impact being seen.

To evaluate the importance of the PTC concept, the company Ricardo announced a Tier 2 Bin 2 (SULEV) diesel demonstrator vehicle equipped with pre-turbine oxidation catalysts for the end of year 2007 [11].

INFLUENCE OF PTC ON EMISSIONS OF A EURO V TYPE DIESEL ENGINE

After all the experience gained in the field, it is important to test the PTC concept on a new Euro V type engine with NOx engine-out emissions under 180 mg/km. This has been possible thanks to the company Siemens VDO, which made available such a development engine. It is based on an existing Euro IV 2 l, 4 cylinder Diesel engine which was modified according to [3] to deliver 50% less NOx. The paper shows here the first emission measurements from a test program started only in 2007.

In order to show the benefit of a PTC, the exhaust gas conditions of this engine have been first characterized and compared to those of its basis Euro IV engine. Then the efficiency of the Euro IV OEM catalyst solution has been evaluated. In a second step a small catalyst has been mounted upstream of the turbocharger for emission measurements.

COMPARISON EURO IV – EURO V ENGINE OUT BOUNDARY CONDITIONS

The Euro V type development engine has been installed on a dynamic test bench for simulation of a vehicle with an inertial mass of 1590kg. Its exhaust gas conditions were compared to those of the Euro IV base engine on the NEDC. The exhaust gas temperatures measured at the close-coupled catalyst inlet for both engine variants are shown in Figure 3.

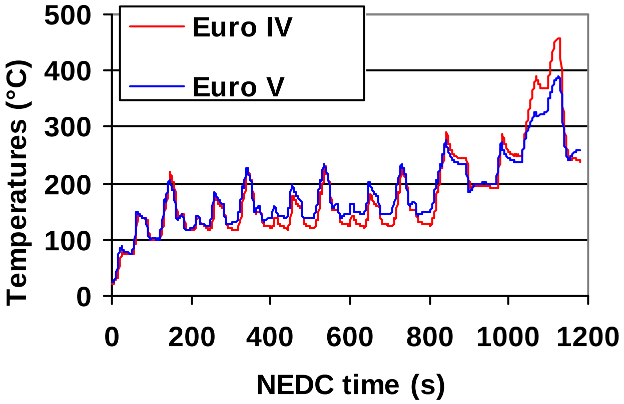


Figure 3: Exhaust gas temperatures at close-coupled catalyst inlet for the Euro IV and Euro V versions of a 2l, 4 cylinder Diesel engine.

One can see that the temperatures with the Euro V engine variant are barely reduced in practice. One reduction occurred during the first acceleration to 50 km/h, and the other during the Extra Urban Driving Cycle (EUDC) part of the NEDC only. The maximal temperature decrease observed during the first acceleration to 50 km/h is equal to -14 °C. This decrease is important because it compromises the catalyst light-off conditions. Otherwise, the temperatures of the Euro V engine variant are at the same level for all other temperature peaks, and higher during the idle phases of the Urban Driving cycle (UDC) part of NEDC.

Modal CO and HC cumulated emissions for both variants are shown in Figure 4a and 4b, respectively. Over the NEDC CO and HC emissions for the Euro V engine variant are 1.5 times and 3 times higher, respectively. The CO and HC emissions increases are more important during the start phase: almost 3 times more CO and 15 times more HC after 90 seconds.

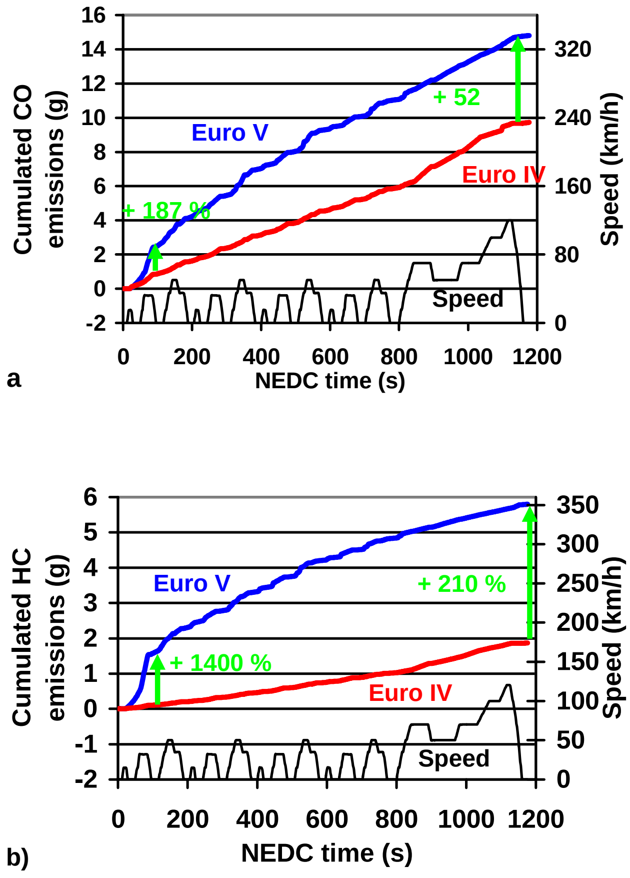


Figure 4: Cumulated CO (a) and HC (b) engine-out emissions for the Euro IV and Euro V versions of a 2l, 4 cylinder Diesel engine.

EVALUATION OF THE OEM EURO IV DOC SOLUTION ON THE EURO V ENGINE VARIANT

Emission measurements have been carried out with a fresh series Euro IV DOC system, consisting of a 1.2 l Close-Coupled Catalyst (CCC) and a 1l Under Floor Catalyst (UFC). Results were compared to those obtained on the Euro IV engine variant with aged catalysts where the UFC is primarily used as burner for DPF regeneration and has only a little influence on the tail-pipe emissions. Figure 5 shows the cumulated CO emissions up- and down-stream of the catalysts. It can be seen that the fresh CCC on the Euro V engine variant lights off at the same time (after 160 seconds) as its aged version on the Euro IV engine variant. The addition of the UFC reduces just a little the CO emissions and does not represent a real solution for additional CO reduction. Figure 6 shows the cumulated HC emissions (engine-out and after DOC in fresh state). It can be seen that the addition of the Euro IV series UFC, which doubles the catalyst volume, is not enough to reduce HC emissions of the Euro V engine variant to below the limit (0.55g per NEDC cycle). Nevertheless, this total catalyst volume could be maintained in the case of an improved start up phase with lower HC emissions.

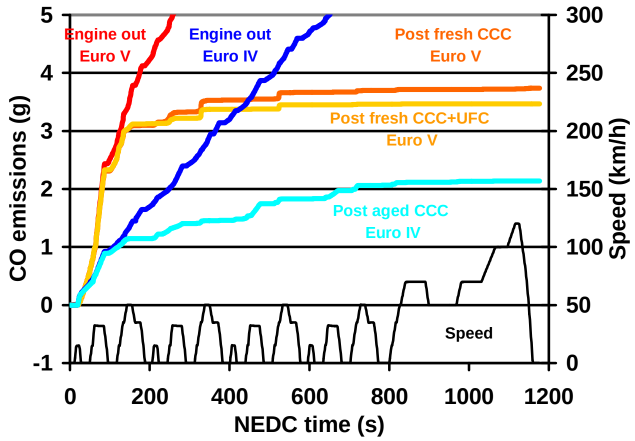


Figure 5: Cumulated CO Emissions (up and down-stream of the catalyst on Euro IV and Euro V engines.

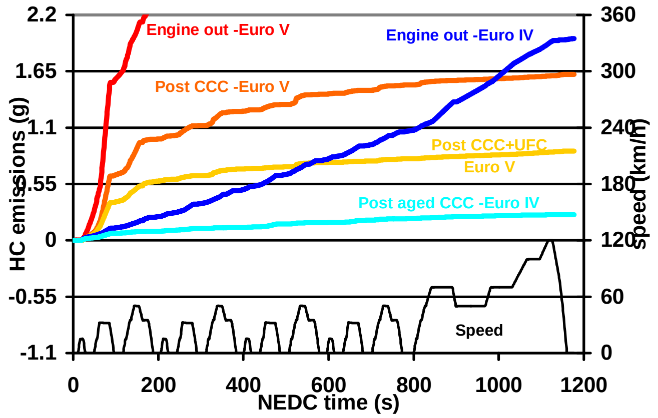
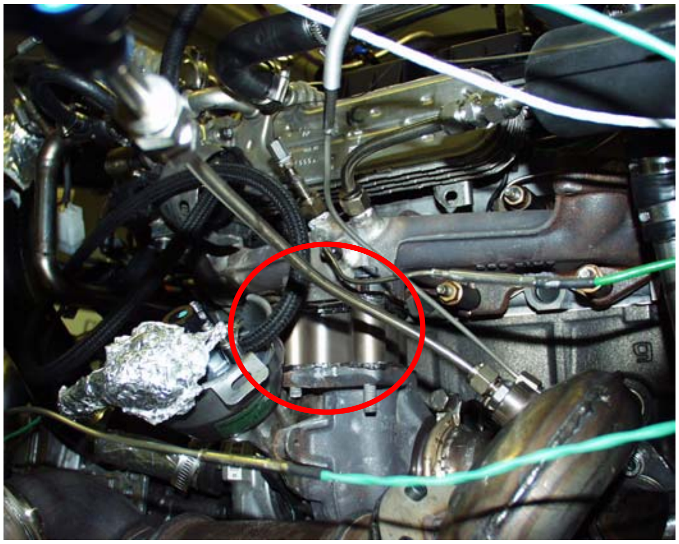


Figure 6: Cumulated HC Emissions (up and down-stream of the catalyst on Euro IV and Euro V engines.

These results underline the improvement that needs to be brought to the diesel oxidation function for Euro V application: earlier light-off in the presence of higher amount of pollutants, as well as a higher system durability to maintain its efficiency during the vehicle life, or a certified 150,000 km, increased from the 100,000 km mandated for Euro Stage IV.

PTC TEST SET UP

An 80 ml metallic catalyst Ø38x70mm, 200cpsi 80µm has been installed as a PTC between the exhaust gas manifold and the turbine inlet of the turbocharger. For that, the exhaust manifold and the turbocharger periphery were modified in order to allow the installation of an intermediate flange, which keeps the PTC in position, as shown by the red circle in centre of Picture 1.



Picture 1: View of the intermediate flange containing the PTC between the exhaust gas manifold (upper) and the turbocharger (lower)

PTC EMISSION RESULTS

Emission measurements with PTC have been carried out with the CCC catalyst in a fresh state only, and have been compared to the measurements without PTC.

Cumulated CO and HC modal emissions are presented in Figures 7 and 8. In Figure 7, it can be seen that the PTC and the CCC together light-off after 60 seconds, with a halving of the CO emission in comparison to the CCC alone. The addition of a PTC in the exhaust line also reduces HC emissions by one third.

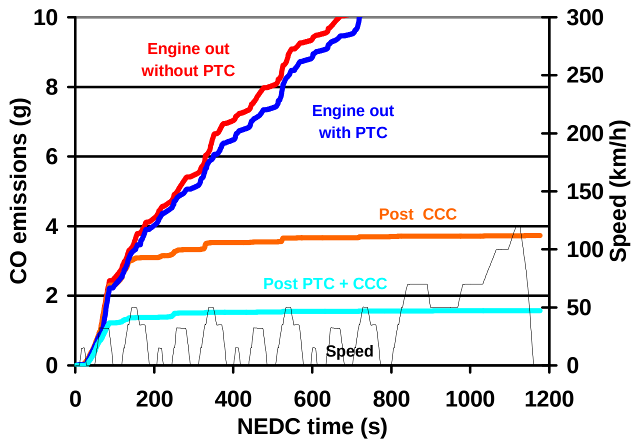


Figure 7: Cumulated CO Emissions (up and down-stream of the catalysts on a Euro V engine, with and without PTC.

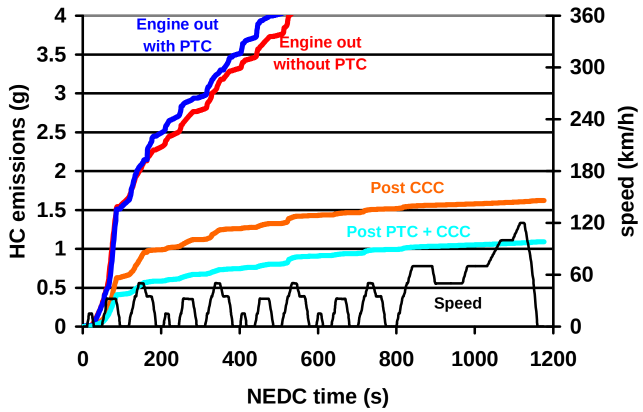


Figure 8: Cumulated HC emissions (up- and down-stream of the catalysts on a Euro V engine, with and without PTC)

By looking at CO and HC concentrations (engine out, CCC inlet and outlet) with, and without, the presence of PTC in Figures 9 and 10 respectively, as well as the temperatures (at exhaust manifold outlet and CCC inlet) in Figure 11 the role of PTC can be fully examined. The PTC is lighting off after 60 seconds at the beginning of the second steady state where it is already seeing temperatures above 200°C. Here on the plateau the PTC can remove about 50% of the CO and about 40% of the HC from engine-out emissions. A consequence of the PTC contribution is an increase of the exhaust gas temperature after it. In figure 11, the CCC inlet temperature is increased by up to 25 °C and is, more or less, constant at temperatures of around 160 °C. This increase of temperature and the reduction of pollutant concentrations together also allow the CCC to light off, particularly for CO, as can be seen in Figure 9.

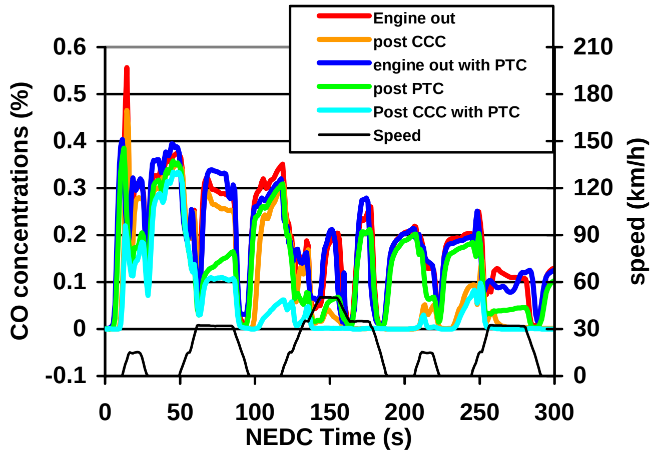


Figure 9: CO emissions (up- and down-stream of the catalysts on a Euro V engine, with and without PTC)

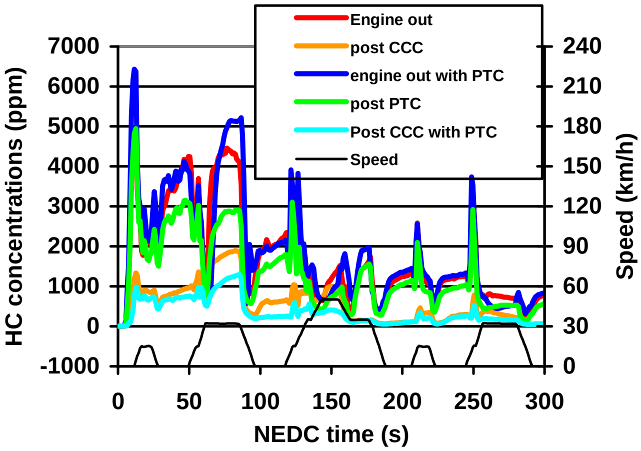


Figure 10: HC Emissions (up and down-stream of the catalysts on a Euro V engine, with and without PTC)

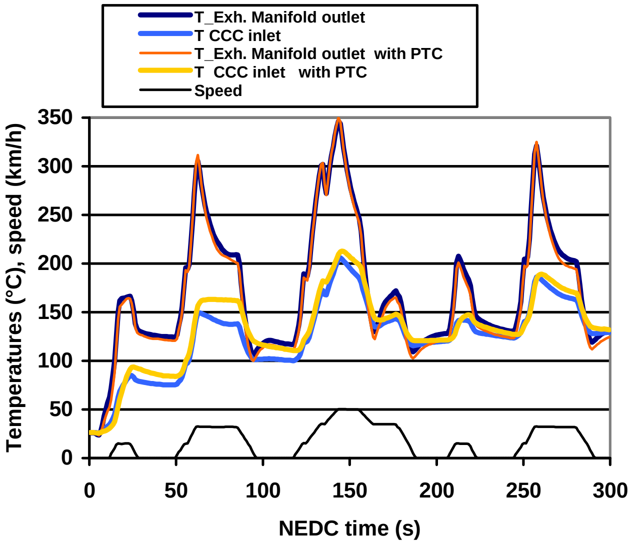


Figure 11: Euro V engine temperatures at exhaust manifold outlet, and in front of the CCC catalyst, with and without PTC

These results show that a small Diesel oxidation catalyst placed in front of the turbocharger can help to meet the future Euro V CO and HC emission targets. CO emissions with fresh PTC are well below the Euro V limit and give confidence that this limit can be still achieved with aged catalysts. Here with this first attempt, the Euro V HC emission limit was not reached with PTC and the CCC alone. However, by increasing PTC and CCC volumes, it should be possible to bring HC emissions well below the limit. In fact, a bigger PTC would get a higher HC conversion rate in front of the turbine, and a bigger CCC would adsorb more hydrocarbons at temperatures below its light-off, the hydrocarbon adsorption being a key function of today Diesel oxidation catalysts.

DURABLE PTC SUBSTRATE DESIGN

Catalyst durability is an important item for all applications, but it is more critical in the case of the Pre-Turbocharger Catalyst (PTC) because of its location upstream of the turbocharger. A PTC failure which results in particle loss (metallic material or washcoat) must be absolutely prevented in order to maintain the life and function of the turbocharger.

PTC: MOUNTING

A metallic pre-turbocharger catalyst consists of a tube or mantle, a metallic honeycomb structure or matrix, and its retaining brazing system.

Depending on engine design, the PTC could be integrated into the exhaust manifold by welding of the PTC mantle to the manifold tubes, or it could be placed between the exhaust manifold and the turbine flanges. In this second case the PTC is installed into the volume defined by the turbine inlet and the exhaust manifold outlet bodies, and requires an additional fixing or holding element such as a flange, a mantle integrated bead, or a widened end. This second type of installation also requires an additional sealing system.

PTC: MECHANICAL FUNCTION AND FAILURES

The basic mechanical function of a metallic PTC is to retain the catalytic coated metal foil matrix (substrate), and to direct unrestricted flow of the exhaust gas from the exhaust manifold through the catalytic coated substrate matrix to the vehicle exhaust system (beginning here with the turbocharger) for the useful life of the vehicle.

Because of its environment, the metallic PTC could be subjected to thermal and mechanical stresses: Severe temperatures and temperature change rates could lead to a loss of the mantle/matrix attachment capability to maintain dimensional and physical properties. The combination of high g-loads applied at high magnitude, and at high frequency, can force the PTC matrix out of the assembly when exceeding the design capability of the matrix and matrix/mantle attachment to hold the substrate in place. A high flow concentration in one location of the catalyst can lead to possible foil damage under the actions of impinging forces. When located at the interface mantle–matrix, the mantle-matrix retention could fail.

Excess stress levels lead to two potential mechanical failures:

- ***Loss of matrix integrity*** which is a mechanical change in matrix foil structure causing higher flow restriction or foil separation which in turn leads to untreated exhaust gas flow (by-pass), or losses of foil materials.

- ***Loss of matrix/mantle retention*** which is a mechanical loss of matrix-mantle interface joint, causing partial or complete matrix detachment.

Moreover, alongside the PTC itself, when it is inserted in between the exhaust manifold outlet and the turbine inlet, the fixing or holding system should resist all stresses within the environment and maintain function.

PTC ENVIRONMENT: THERMO-MECHANICAL CONSTRAINTS

The thermal and mechanical load conditions upstream of a turbocharger were particularly examined on modern turbocharged Diesel engines. Measurements have been carried out on market representative I4 cylinder and V6 cylinder engines.

Extreme gas temperature change rates, or transients, of around plus or minus 12000K/min at the turbine inlet, have been measured. These values were obtained during full load acceleration and deceleration driving. The potential maximum exhaust gas temperature at turbine inlet is fixed by the maximum temperature allowed for the turbine. For turbochargers fitted on current Diesel engines the temperature limit is around 850°C. This gas temperature could be achieved during some DPF regeneration phases.

Beside this thermal load, a maximum mechanical load from 5g RMS to 8g RMS, depending on the engine design, were measured.

The exhaust gas flow distribution is less critical in the case of a PTC. Because of its small diameter, a homogeneous gas flow distribution is favored. Moreover, by taking care of the PTC location, an uneven flow distribution can be prevented.

FINITE ELEMENT SIMULATION OF THERMAL SHOCKS

Simulation with Finite Element Analysis (FEA) is today a very powerful tool for the development of any product. It saves development time, diminishes the number of physical tests and finally saves money.

At Emitec Metal substrate Finite Element Simulation is under development, based on Abaqus software. This allows, among other things, a simulation of the mechanical reaction of the substrate due to any thermal loading cycle. The simulation proceeds via temperature mapping within the substrate, an elastic-plastic stress analysis, and then a calculation of the plastic strains. It enables parametric studies of the influences of cell density, foil thickness, matrix winding shapes and types, mantle – matrix brazing design, matrix brazing design, and substrate section shapes. It allows qualitative and quasi quantitative comparisons by giving the following information:

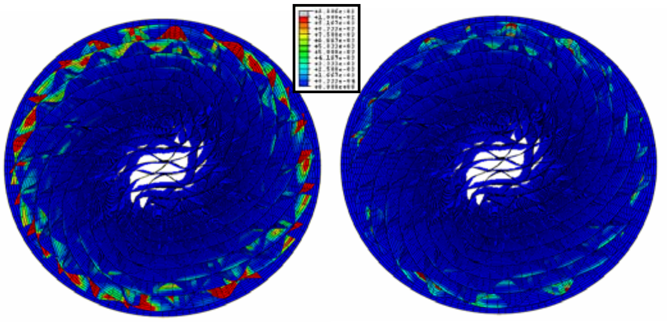
- How the mantle-matrix assembly reacts under thermal stress.
- Where the matrix zones supporting the maximal stress or strains are located.
- Quantification of the strain levels: elastic, plastic.

To make clear what this information means, the zones of the matrix, supporting the maximal strains during thermal shock, are generally characterized in a real test, to a certain extent, by cell deformations and possible cracked foils. When the thermal shock is combined with a vibration load, as it is in real life on an engine, the matrix with the highest level of stress will most probably loose its integrity first.

Therefore FE simulation was used in this study to determine which substrate design, in particular mantle – matrix brazing and matrix brazing design, will show the lowest plastic strain level during thermal shock. Furthermore, additional parameters such as cell density and foil thickness were studied for information only.

Influence of substrate brazing design.

A 40 ml PTC (Ø 36 x 40 mm, 200cpsi, 80µm) has been simulated under a temperature cycle similar to the one measured on the engine. Different designs were compared to a base Design A. Design A is a simple substrate brazing design, easy to manufacture, and used for all first PTC substrate samples dedicated to emissions measurements only. (It consists mainly in a brazing of the foils and the mantle together over the total substrate length.) Figure 12 shows a qualitative comparison of designs A and B. With design A this shows a wide and dense crown near the circumference (i.e. the mantle), with high plastic strains on the substrate inlet face. In comparison, plastic strains generated with design B could be neglected. Therefore the design B, less sensitive to thermal shock, should be chosen for the PTC substrate design.



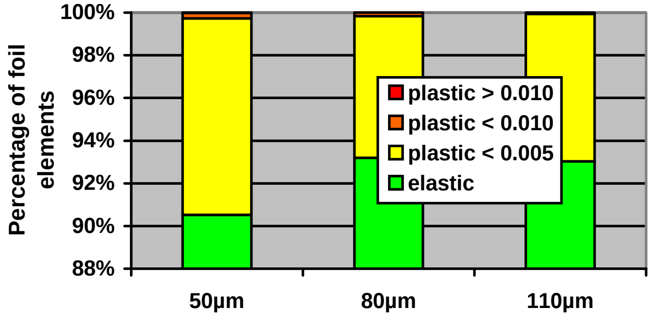
Design A **Design B**

Figure 12: Equivalent plastic strain after three thermal cycles. Perspective view of gas inlet side

Influence of foil thickness.

PTC substrates (Ø 36 x 40 mm, 200 cpsi, design B) with foil thickness of 50µm and 110 µm, have also been simulated, and compared to the 80µm foil thickness substrate. A quantitative comparison, by classification of equivalent plastic strains, is shown in Figure 13. It shows the percentage of foil elements sustaining different plastic strain classes. One can see that the higher the thickness is, the lower the plastic strains are. Therefore it shows that it is possible to improve the thermal shock resistance of PTC substrates by using a 110µm foil thickness. Of course this will be at expense of a higher back pressure.

a) Flat foils



b) Corrugated foils

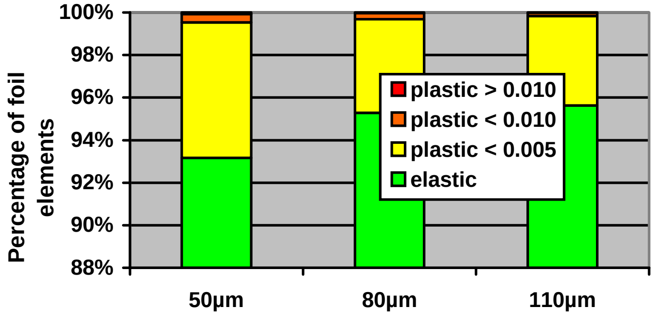
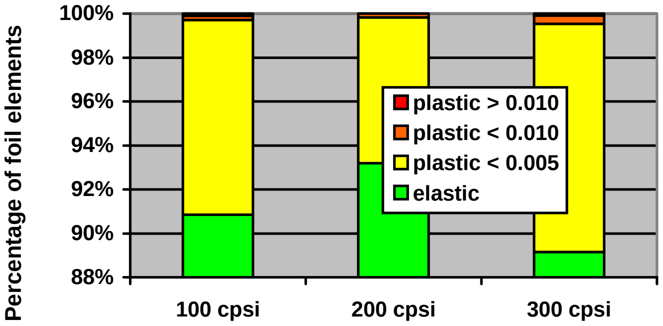


Figure 13: Classification of equivalent plastic strain, due to third thermal cycle, for three foil thicknesses.

Influence of cell density.

PTC substrates (Ø 36 x 40 mm, 80µm, design B) with cell density of 100cpsi and 300cpsi have been simulated and compared to the 200cpsi substrate. A quantitative comparison, by classification of equivalent plastic strains, is shown in Figure 14. One can see that 200 cpsi shows the lowest percentages of foil elements with high plastic strains, and is indicated as an optimal cell density for a higher resistance to thermal shock.

a) Flat foils



b) Corrugated foils

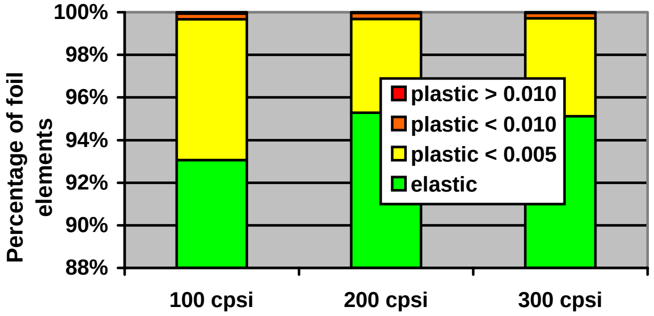
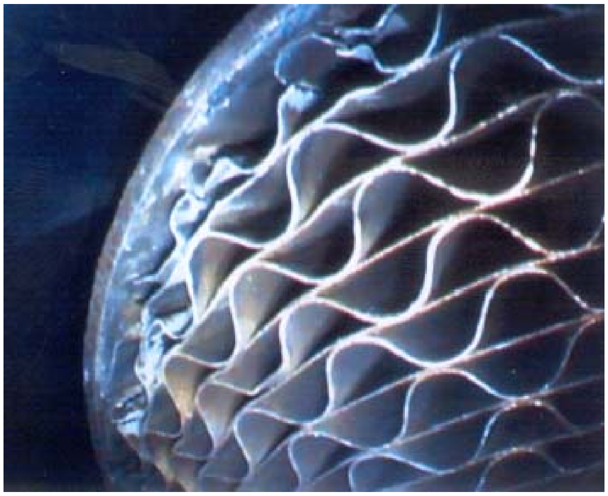


Figure 14: Classification of equivalent plastic strain, due to third thermal cycle, for three cell densities.

EXPERIMENTAL VALIDATION: PTC DURABILITY DEMONSTRATION

The experimental validation has been carried out on a component test bench, as already shown in [12], combining an electro-dynamic shaker, that delivers the required mechanical load, and a power modulated burner, which exposes the catalyst to the required temperature transients and the maximum temperatures. In such a system we try to mimic the conditions that will be seen by a PTC during a manifold crack test on an engine test bench, for example.

Previous internal results in a similar component test had confirmed the prediction of the FEM simulation for Design A. As shown in Picture 2, a PTC with Design A shows deformed cells, and foil cracks near the mantle (Picture 2), which could lead later on to possible loss of material.



Picture 2: View of outlet PTC substrate face (200 cpsi 80 µm) with design A after 24 hours of durability test on component test bench.

Therefore it was decided for this project to test a 64ml coated PTC (Ø 44 x 44 mm, 200cpsi, 80µm) with only design B.

The mechanical load was fixed first to 12g RMS in order to get a comfortable margin of 4g RMS with respect to the values measured on the cars. The power spectrum applied to the shaker is like the one shown in Figure 15. In addition, a second test with 25 g RMS was performed to get an overview of the influence of the vibration level on PTC durability.

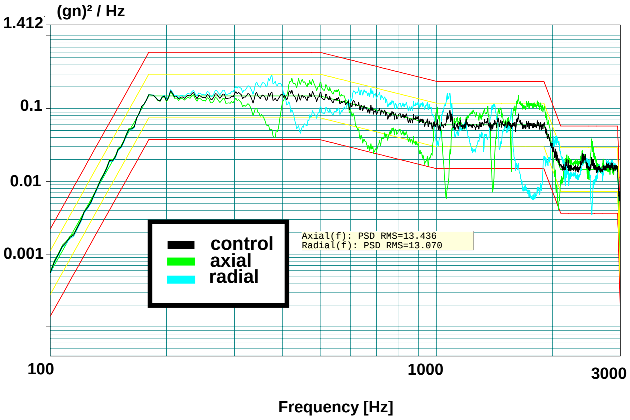


Figure 15: Power spectrum example applied to the shaker

The temperature transients of +/- 11890 K/min were achieved, as a consequence of the burner control. A maximum gas temperature of 922°C was applied, instead of 850°C, as shown in the temperature diagram from Figure 16. Due to the combustion in the PTC of unburned propane coming from the burner, the PTC matrix temperature reaches 969 °C. Under these conditions, the PTC matrix sees temperature transients of + 8580K/min and –9480K/min. The duration of the temperature cycle is 8 minutes.

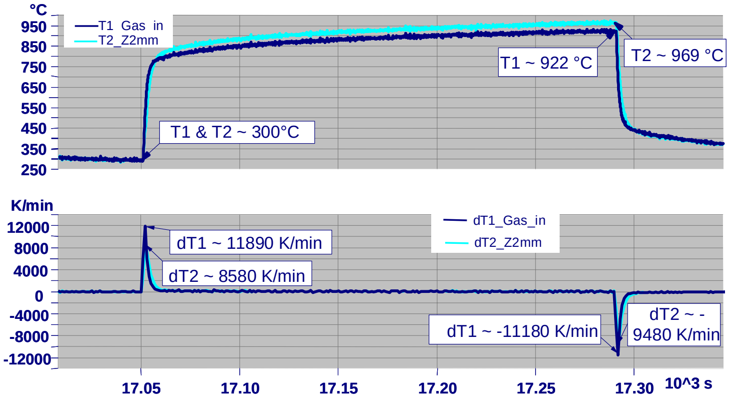


Figure 16: Temperature cycle for the durability test on component test bench.

The testing was conducted until PTC failure. The PTC failed after 540 cycles and 285 cycles, by a detachment of the matrix from the mantle, with 12 g RMS and 25 g RMS respectively, as shown in Figure 17.

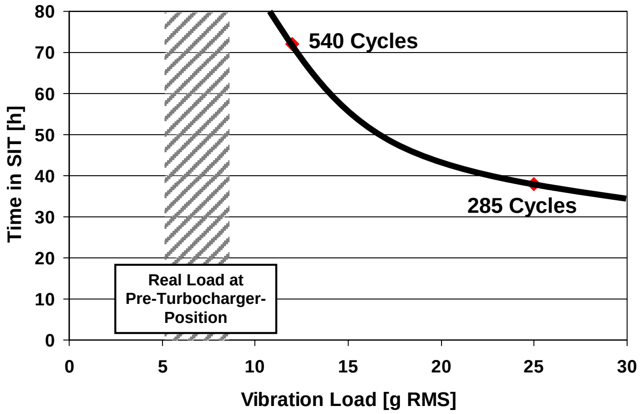
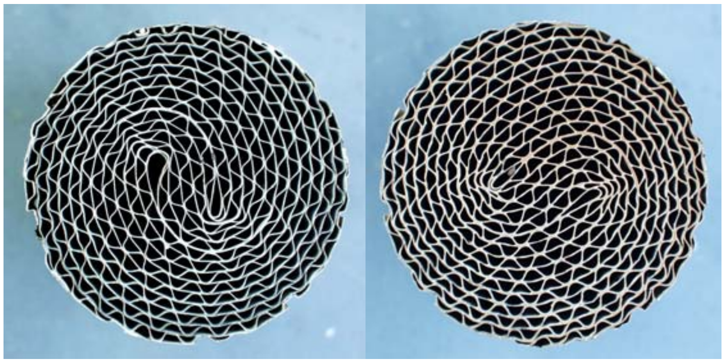


Figure 17: PTC Durabilities on component test bench, in function of the vibration level.

Moreover, the PTC was over-tested if one considers that the maximum matrix temperature of 969°C exceeded by about 100°C the originally required temperature of 850°C. Figure 17 let imagine what would be the durability of the PTC in real vibration load.

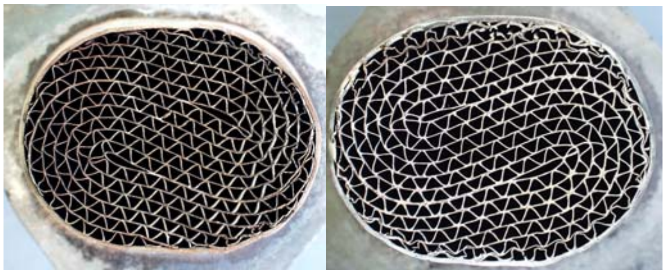
The component test is particularly helpful to establish general fitness for use, and to establish key design criteria. However, further testing is necessary to establish if we can effectively correlate results on a component test bench to the results of typical system sign-off tests, as used by individual OEMs and their specific engine and vehicle applications.

The important finding here is the state of the matrix itself. As can be seen (picture 3), there are no deformed cells and no foil fractures. The matrix has kept its integrity. The metallic substrate with design B used here completely fulfils the PTC requirements for applications on Diesel engines.



Picture 3: View of inlet (left) and outlet (right) matrix faces of PTC substrate after detachment from the mantle at the end of the durability test.

In parallel to the component test bench, a PTC with Design A was tested on a V6, 2.7l engine during a high speed durability cycle presented itself. This test had been identified within the FMEA as having the right mix of thermal stress on both PTC, and connection with the turbocharger, together with high mass flows which would show possible failure modes such as foil cracking, coating loss etc. The test was stopped after completion of 220 hours due to an engine failure. The PTC matrix is still firmly attached to the mantle. Anyway, similar to what has been seen in component test work, cell deformations and foil cracks occurred on both inlet and outlet faces of the PTC catalyst at the end of the durability test, as shown in picture 4.



Picture 4: View of inlet face (left) and outlet face (right) of PTC substrate (44x34x49 mm, 200cpsi 80µm) with design A, after 220 hours of a high speed durability test on engine test bench.

Further testing on engine bench with design B was not performed in this project but it is expected to show similar benefits as shown with the component test work.

CONCLUSION

After a review of experience in the field of pre-turbocharger catalysts, the concept has been evaluated on a development Euro V Diesel engine. Results show that a PTC, with an earlier light-off and a high specific efficiency is highly suitable to cope with the upcoming tasks related to Euro 5 Diesel engines like further decreasing exhaust gas temperatures and increasing HC and CO raw emissions, and therefore offers a simple and efficient solution for future DOC-systems.

The mechanical durability has been ensured by help of extensive simulation exercise. Tests on component test bench as well as engine test bench proved the capability of the PTC design to withstand the loads occurring in the pre-turbo position at modern Diesel engines.

ACKNOWLEDGMENTS

The authors would like to thank the company Johnson Matthey who supplied coatings for the PTC, an all Emitec colleagues who carried out the tests.

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