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Notes and comments

The influence of three-way catalysts on harmful emission production

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ABSTRACT

This article deals with the influence of three-way catalysts on the production of basic emissions, such as carbon monoxide, unburned hydrocarbons and nitrogen oxides from spark-ignition engines. A virtual simulation of the new European driving cycle is used. Characteristics of components in emissions in the front and back of the catalyst are measured on the test bed to form the basis of the simulation. The results relate to emissions for 1 km travelled.

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1. Introduction

Poor air quality has been shown to have seriously averse effects on public health. The World Health Organization estimated that 650,000 people died prematurely from urban air pollution in developing countries in 2000. (Gwilliam et al., 2004) and the European Environmental Agency (2007) has claimed that about 9% of the EU-27 population live within 200 m of a road carrying more than 3 million vehicles per year, and 25% within 500 m resulting in 4 million life-years are lost each year due to pollution.

Pollutants are still emitted into the air during hydrocarbon fuel burning in an engine despite legal controls and regulations. (Takáts, 1997). Between 1990 and 2005, emissions of acidifying substances decreased by 36%, ozone precursors by 45% and particulates by 33% (European Environmental Agency, 2008) largely due to advances in exhaust gas after-treatment devices, including advanced three-way catalytic converters and particulate filters and improved fuel quality (European Automotive Research Partnership Association, 2007). The remaining pollution partly depends on the correct functioning of emissions control systems.

Here we look at the impacts of the three-way catalyst. The current system of vehicle emission used in much of the European Union, testing is also under review. The idle and fast idle tests are done according to EU Directive 92/55/EEC and involve measuring the concentration of CO at idle and fast idle of an engine (European Union, 1992). During this the load on the engine load is low and a relatively small area of catalyst is enough to transform the gases thus allowing even a catalyst in bad condition to meet the test criterion.

2. Material and methods

The influence of a catalyst on harmful emissions is evaluated using a virtual simulation of the European homologation driving cycle for the vehicles up to 3.5 tones. (European Union, 2007). The emission characteristics are measured on a test bed in front and at the back of the catalyst. The individual points of the emission characteristics are transformed into continuous characteristics for CO, HC and NO_x according to the rpm and torque of the motor using an algorithm developed

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Table 1
Motor parameters.

Maximum power	50 kW
Maximum torque	106 Nm
Fuel	Petrol
Cylinder number	4
Cylinder diameter	75.5 mm
Piston stroke	75.5 mm
Compression ratio	10:1
Nominal rpm	5000 min^{-1}

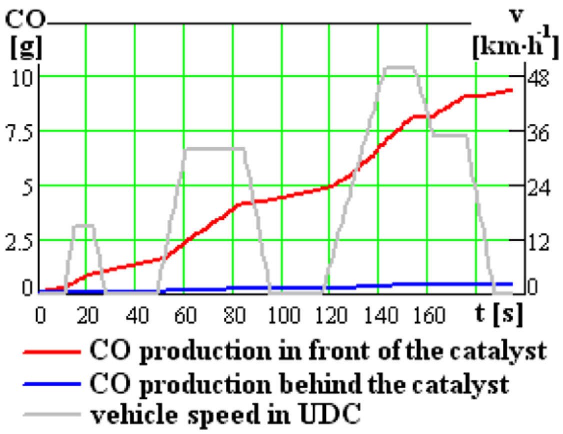

Fig. 1. Emission production CO in front of and behind the catalyst in urban cycle UDC.

within the MathCAD program. The European driving cycle algorithm defines vehicle speed processes depending on the cycle time and is transformed into the rpm process and motor torque over the cycle.[1] The driving cycle is examined using a Skoda Felicie with a motor 1.3 MPi motor – Table 1.

3. Interpretation

First, measurements are obtained with zero values in the lossy torque by sequential interpolation in torque and in rpm transformed into a square matrix P to form the basis for creating continuous engine characteristics. For this, the rpm range and motor torque is defined by the matrix M to give final continuous characteristic seen in Eq. (1).

$$\mathrm{fit}(x,y) := \mathrm{interp}\left[\mathrm{cspline}(M,P), M, P, \begin{pmatrix} x \\ y \end{pmatrix}\right] \tag{1}$$

where fit(x, y) is the continuous characteristic of an individual emission component; M is the matrix that defines the rpm range and motor torque; and P is the interpolated value matrix of an individual emission component.

Second the driving cycle speed is transformed into rpm and motor torque by considering, road resistances, individual gear step models, drive slip, etc.

Finally the continuous characteristics of individual emission components production are interconnected with the rpm course and motor torque in the driving cycle. There is possibility of setting the immediate rpm and then the cumulated values of the production of individual emission components through this connection. Cumulated values of emission productions for the whole cycle through known driven distance can be converted into the specific value per kilometer driven. Specific emission production is defined by Eqs. (2)–(4). Figs. 1–6 show courses of individual emission production components in the front and back of the catalyst in the urban (UDC) and extra urban (EUDC) parts of the new European driving cycle (NEDC). The production of individual emissions per kilometer in the front and back of the catalyst, and individual components of the NEDC are shown in Table 2. The combined value of specific emissions is in terms of the weighted average of urban and extra urban part of the cycle; urban component being 36.8% and the extra urban 63.2%.

$$CO_s(i) := \mathrm{fit}(n_m(i), M_m(i)) \cdot 3.6^{-1} \tag{2}$$

where $CO_s(i)$ [g s^{-1}] is a course of immediate emission production CO in front of the catalyst; fit is a function that defines a continuous surface and $n_m(i)$ [min^{-1}] is a course of rpm during the cycle; $M_m(i)$ [Nm] is a course of torque during the cycle

[1] For details of how the two approaches relate to each other see, Hromádko (2007a,b)