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An on-engine method for dynamic characterisation of NO_x concentration sensors

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ABSTRACT

An on-engine method for dynamic characterisation of automotive NO_x concentration sensors is presented. Steps in start of injection on a diesel engine are employed to achieve step-like NO_x concentration variations on exhaust flow. On the basis of the sensor response, delay and dynamic response can be easily identified; the paper shows a simple least squares procedure although other models and identification techniques could be used. Application data is presented for three NO_x sensors: a research-grade chemiluminescence exhaust gas analyser, and two different commercial ZrO_2-based sensors.

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1. Introduction

World attention about environmental protection resulted in new strict laws which establish the requirements for pollutants emissions, and therefore define priorities in the technology development. Particularly in mobile sources, diesel engines must reduce NO_x emissions by 20% with Euro 5 and 50% with Euro 6, with respect to previous Euro 4 standards [1].

Engine development has to guarantee low emissions while keeping or achieving higher efficiency, performance and reliability. This purpose requires not only efforts on engine design and on operating conditions, but also in the development of reliable measurement systems to get information about the process, which is needed for the implementation of control strategies, specially for transient conditions [2].

Recent improvements in NO_x sensor technologies and, among them, those which are based on ZrO_2 [3] employed to measure gas at wet condition (i.e. without removing exhaust gas water steam content), allow an on-board measurement of the NO_x concentration. Closed loop control and on-board diagnosis for nitrogen oxide engine emissions reduction can be based on models [4,5], but more commonly are confided to fixed calibrations. Several studies have evaluated the accuracy and time response of real time NO_x sensor measurements for these applications [6,7].

NO_x sensors based on planar ZrO_2 technology have suffered a big evolution over the last 15 years [3] and now are manufactured using the planar zirconia multilayer technology [8], which combines thick film screen printing and ceramic tape casting [9]. Last versions of these sensors offer reduced warmup time, smaller size, lower weight and cost-effective production, which encourage their implementation on commercial engines. This kind of sensors simultaneously provides a measurement of the relative air-to-fuel ratio (λ) and NO_x concentration:

In a first cavity, an electrochemical pump adjusts the oxygen concentration to a predefined value, thus providing a linear measurement of λ. At the same time, a fast binary output is provided, differentiating between rich and lean conditions in the exhaust gases.

In a second cavity, the oxygen produced through the dissociation of NO_x is pumped out in a similar way by means of a second electrochemical pump. The output of this pump is proportional to the NO_x concentration in the exhaust gases.

Such "amperometric NO_x and oxygen sensing device" could be the key for the selective catalyst reduction (SCR) systems [10] (although improvements in precision as it is mentioned in [11] are needed to fulfil current laws) or for improving exhaust gas recirculation (EGR) control when important cylinder-to-cylinder distribution dispersion appears [12].

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