Measurement of EGR delay and its effects on NOx emissions using the NDIR500 and CLD500

Introduction

Exhaust Gas Recirculation (EGR) is employed to reduce NOx production rates by diluting the oxygen content of the intake charge and reducing combustion temperature. However, the rate of EGR needs to be carefully controlled, as too much EGR results in excessive particulate emissions and a reduction in engine efficiency, and too little EGR results in excess NOx (which is not treated by oxidation based after-treatment systems).

Traditionally EGR control is achieved using a mapping of EGR for given steady-state engine conditions. However, the requirements for the control of EGR during transients, as the engine conditions change during a load transient or gear change for example, can be significantly different to those expected from the steady-state calibration alone. Therefore further calibration to assist during transient operation may be required, if emissions are to be kept within the required limits.

This application note describes the use of the Cambustion NDIR500 Fast CO/CO_2 and the CLD500 Fast NOx analyzers to measure the delay of delivery of EGR during transient engine operation, and observe the effects of EGR transients on NOx emissions.

Experiment

In this experiment the NDIR500 was used to measure CO_2 and the CLD500 was used to measure NOx in a modern, turbocharged, Euro Stage 3 compliant diesel passenger car, during the New European Drive Cycle (NEDC). The fast CO_2 and NOx analyzer outputs and the EGR drive pressure were logged on the fast data acquisition system. The vehicle speed was also logged. The CO_2 was sampled in the EGR pipe (immediately after the EGR valve) and the intake port of cylinder #1, and the NOx in the exhaust port of cylinder #1 and immediately post-turbo.

Results

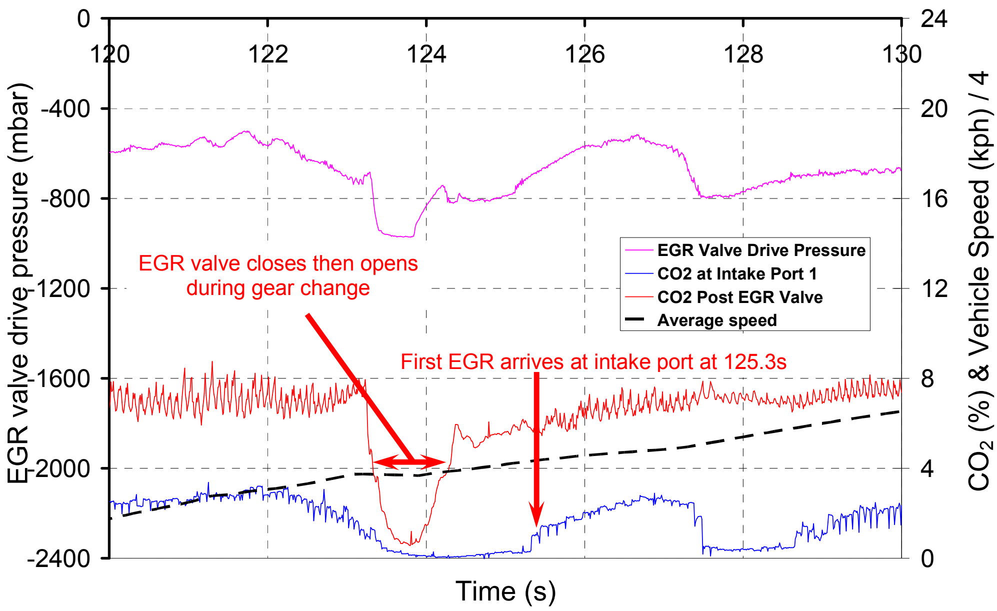

Chart 1 - Delay in EGR delivery during gear change

At 123seconds, the NEDC has a gear change, during which the EGR valve is closed (as shown by the pink trace in **Chart 1**). When the EGR valve closes, the CO_2 measured after it (shown in by the red trace) falls as expected, and begins to rise again as the EGR valve re-opens at 124seconds. However, the EGR at the intake port of the engine does not recover immediately, as there is some time taken for the gas to travel through the EGR pipe from the valve to the intake port.

It would be expected that this delay in delivery of EGR to the cylinder would have an effect on NOx production rates, as during the time between when the EGR valve re-opens and the EGR arrives at the intake, the engine is not receiving any re-circulated exhaust gas.

The data below in **Chart 2** shows the effect of the delay in EGR, and as expected, the NOx emissions from the engine are significantly higher during the period where there is effectively no EGR. It is noticeable how long this transient effect lasts, and also how there is an increase in NOx emissions during the acceleration that begins at around the 127second point (which also corresponds to a period of low EGR – see **Chart 1**).

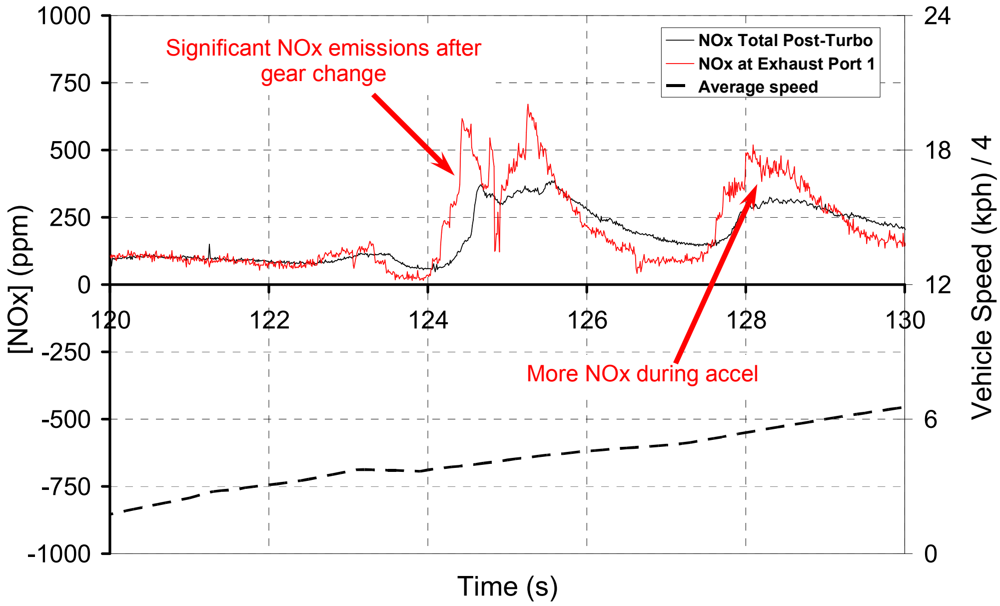

Chart 2 - NOx emissions due to EGR delay

Conclusions

Control of EGR during transient operation is important, as the contribution of the emissions during these events is a significant contributor to the total emissions during the drive cycle. The NDIR500 is capable of observing the EGR delivery to the intake of the engine, and indicating periods where little or no EGR is being delivered. The effects of these transients in EGR delivery can be observed using the CLD500, which has been used to observe the increased NOx emissions when EGR is low during transients due to both gear changes and load changes where the EGR valve has been closed.