GDI vehicle NOx breakthrough due to scavenging (blow-through)

Introduction

Downsized turbocharged GDI vehicles are often calibrated to minimise trapped residual gas at low speed & high load conditions by employing large amounts of valve overlap. This can lead to a "blow-through" condition where intake air can short-circuit the cylinder and emerge in to the exhaust when both the intake and exhaust valves are open.

Although this is effective at removing burned gas (reducing the probability of knock) and also with some turbocharger inertial benefits, it does introduce oxygen in to the exhaust system and can bias the exhaust chemistry "lean".

Real world driving conditions (and some drive cycles) often require the engine to operate at conditions where blow-through can occur and short periods of lean exhaust operation can cause transient breakthrough of NOx emissions as described in this application note.

Vehicle and Engine

A 2014 model year BMW Mini (Euro 6) with 2 litre turbocharged GDI engine and advanced variable valve timing features ("double VANOS") was used for this testing on a robot-driven chassis dynamometer (*Figure 1*). The vehicle had 20,000km on the odometer (suggesting a fairly "fresh" three-way catalyst).

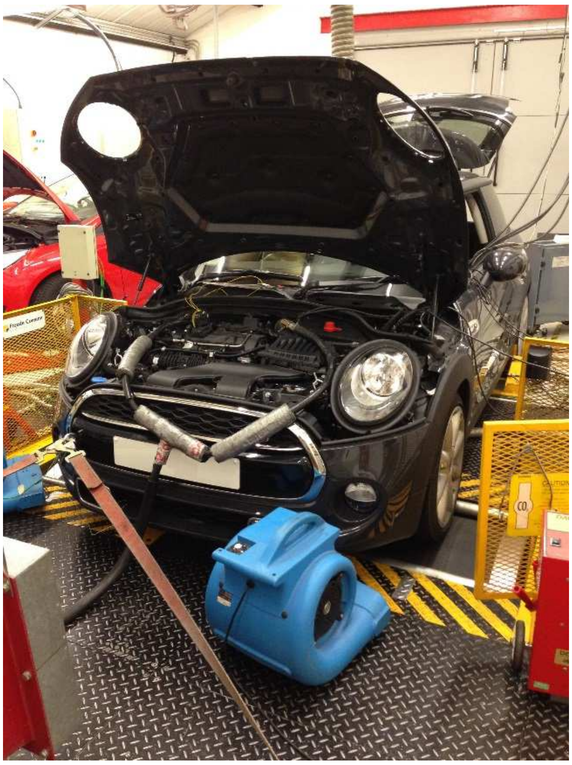

Figure 1: Vehicle on chassis dynamometer

The vehicle was driven on the WLTC drive cycle (*Figure 2*) which includes some hard accelerations at low speed and the fast [NO] engine-out and tailpipe data were recorded from a CLD500 fast NOx analyzer. The cumulative mass emissions were calculated from a conventional emissions analyser and the dilution tunnel.

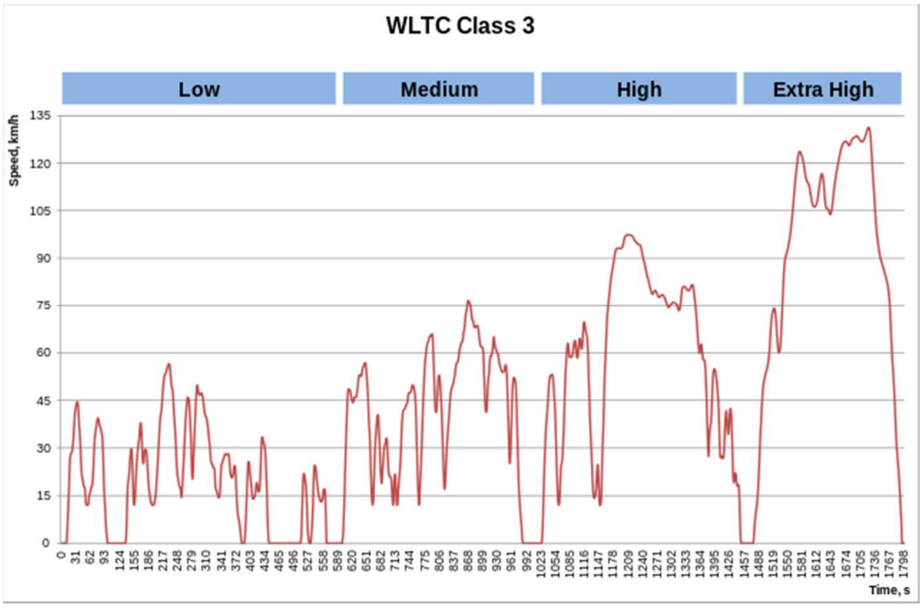

Figure 2: WLTC speed profile

Results

The cumulative tailpipe mass emissions (*Figure 3*) show the typical light-off characteristics of the 3-way catalyst from the cold start, but a feature of concern was the sudden rise in tailpipe NO_x at 1080s of the WLTC.

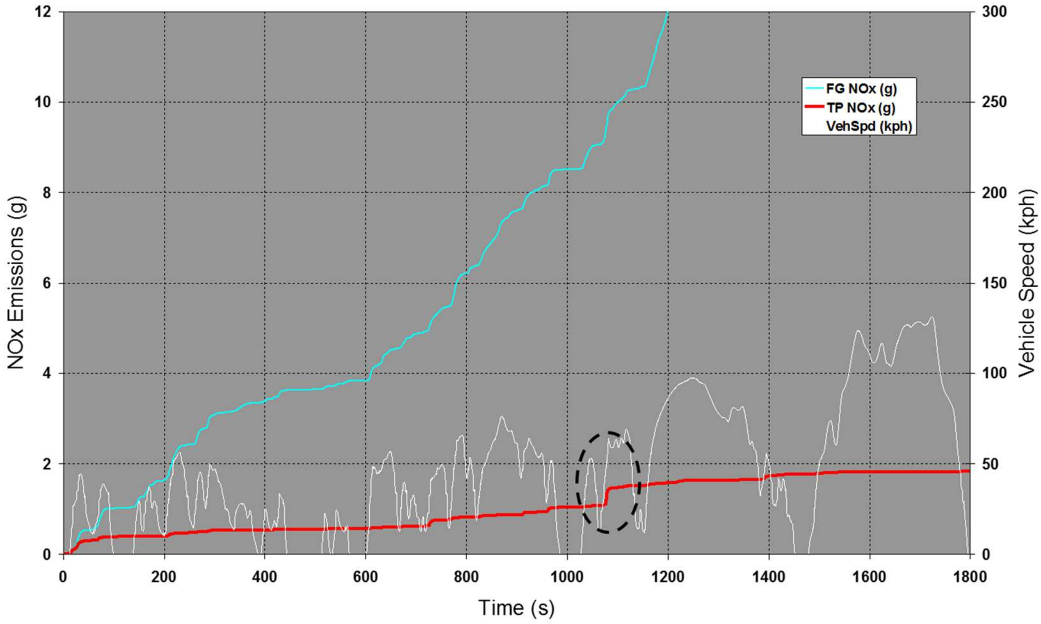

Figure 3: Tailpipe NO shows a significant increase at approximately 1080s

The data from the CLD500 fast NOx analyzer (*Figure 4*) was plotted covering this event and shows several very short duration periods of NO breakthrough to the tailpipe associated with the accelerations and gear changes from that part of the WLTC.

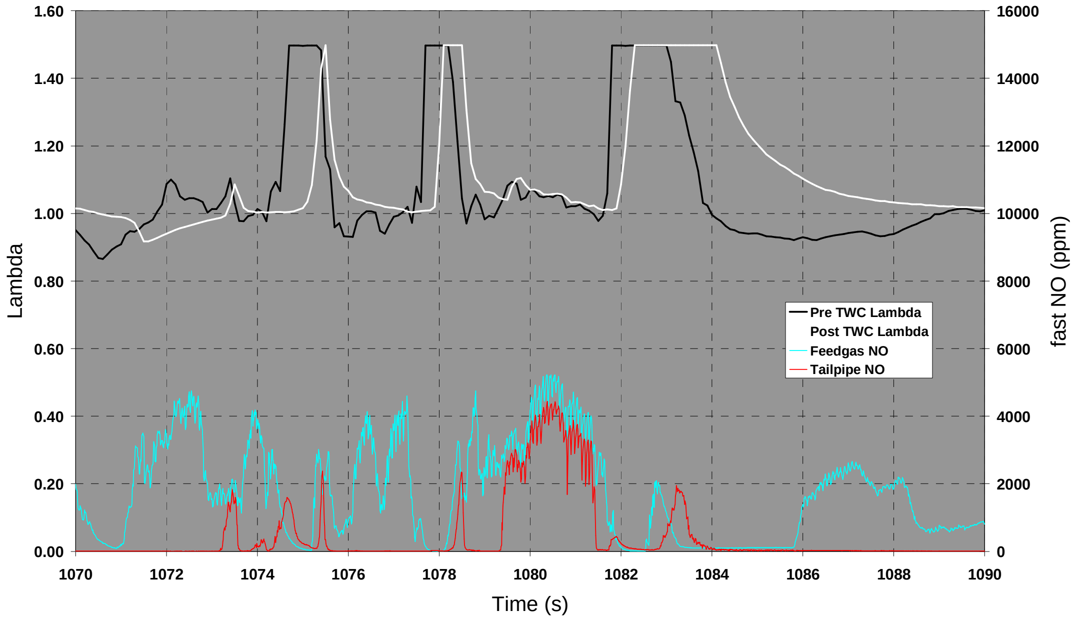

Figure 4: Fast measurement of engine-out and tailpipe [NO] during transients

Displaying the exhaust lambda (as indicated from a wide band oxygen sensor) shows that the exhaust is lean at this time and the low engine speed and high load measured at that time (*Figure 5*) also suggests that blow-through is the cause of this NOx breakthrough.

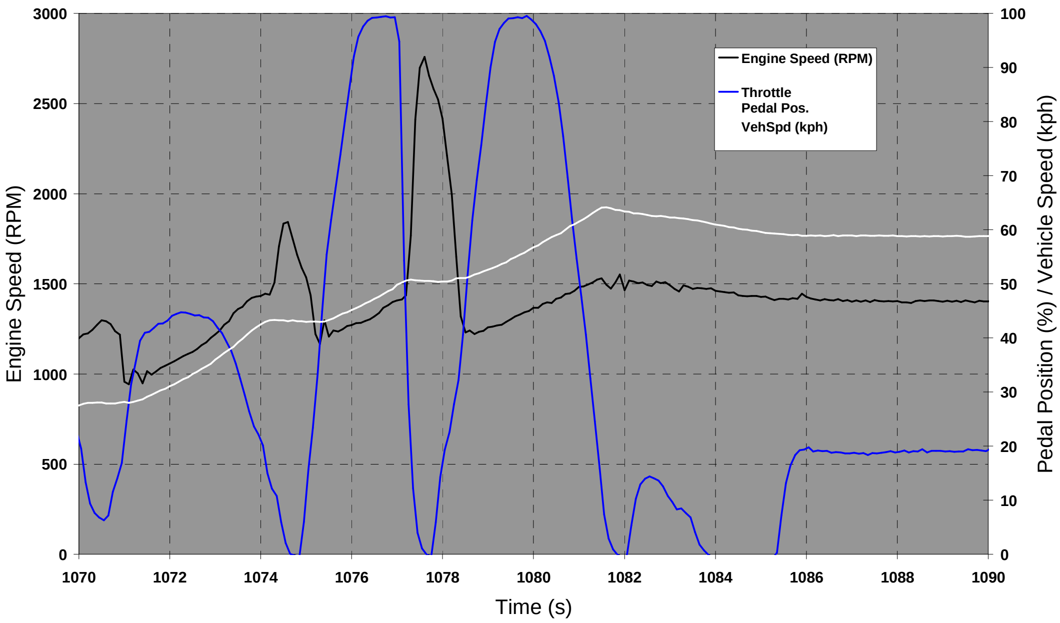

Figure 5: Indication of engine speed and load during transients

Conclusion

The highly transient nature of WLTC and RDE driving conditions increases the probability of very short duration "spikes" of tailpipe NOx emissions. These can only adequately be understood and quantified using fast response emissions measurement equipment and can allow accurate correlation with other engine parameters.