GDI blow-through during scavenging at high load

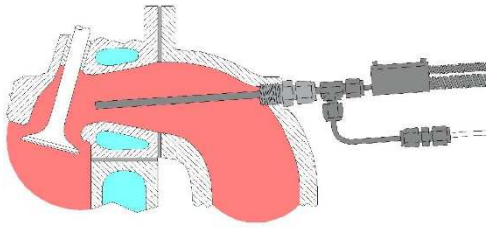
Modern downsized turbocharged GDI engines benefit from efficient scavenging of residual burned gas to prevent knock problems at high load. This can be performed by (either or both) delaying exhaust valve closure (EVC) and advancing intake valve opening (IVO) to increase the valve overlap period and create more effective scavenging of the cylinder contents.

A consequence of this action can be that "over-scavenging" or "blow-through" can occur where incoming fresh air charge exits the cylinder before EVC.

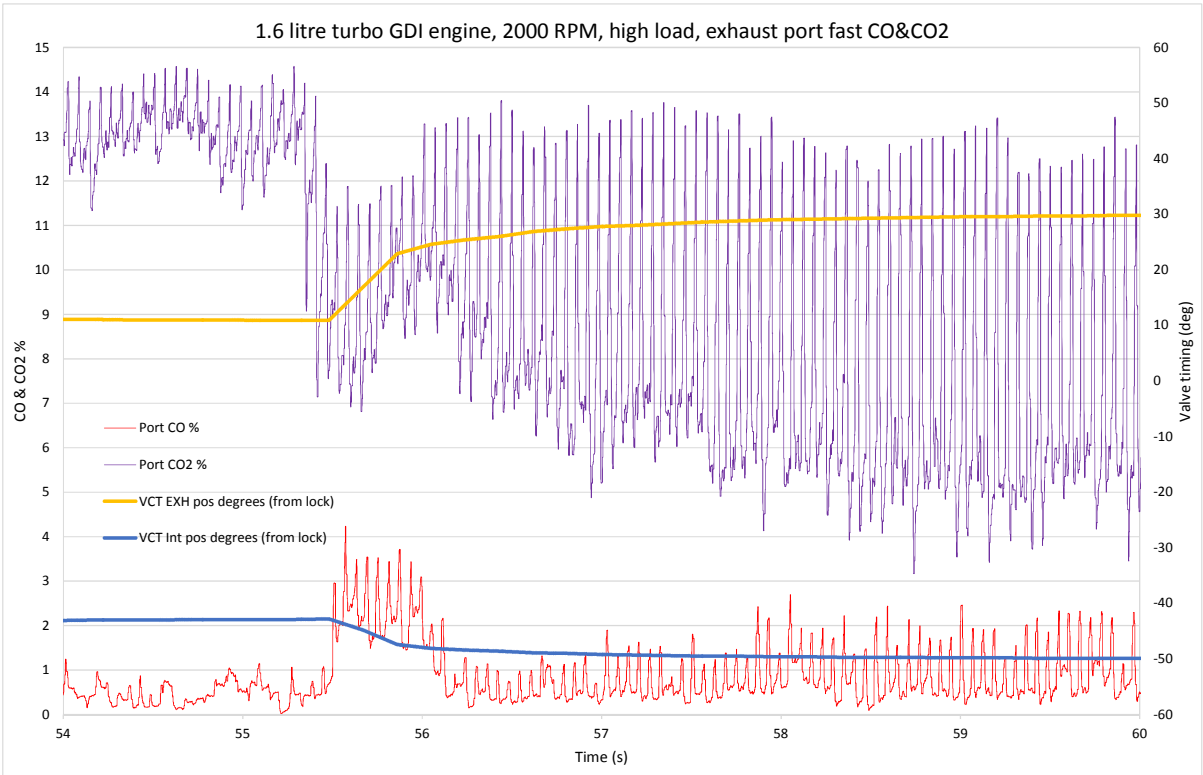
The presence of air in the exhaust affects the closed-loop AFR control with the oxygen sensor reading a "lean" condition. The subsequent enrichment of the combustion can introduce products of rich combustion (mostly CO in GDI engines) which, along with the available O_2 can produce damaging exotherms on contact with the already hot three-way catalyst.

Blow-through is usually a transient problem during drive cycles and the response time of conventional CO analyzers is often too slow to measure the engine-out CO content. The NDIR500 fast CO&CO_2 analyzer can therefore be of use in this application measuring just upstream of the 3-way catalyst.

Furthermore, the fast CO&CO_2 analyzer can be positioned directly behind one of the exhaust valves to observe the blow-through occurring at first hand.



The figure above shows the position in the exhaust port where the fast NDIR sample probe was positioned to measure the CO&CO_2 content per cycle. The tip of the sample probe is approximately 20mm from the exhaust valve stem. Below is the data recorded at this position:



There are several things to note from the results as indicated in the above graph:

A) The blown-through air is trapped in the exhaust port (being measured by the fast analyser) for the remaining parts of the cycle (intake, compression and power strokes) and only moved on at the next exhaust valve opening event. The deep troughs in CO_2 caused by the displacement of burned gas by blown-through air is clear following the valve timing switch.

B) There is a rich transient during the valve switch period which only lasts for about ½ second but is clearly visible with this instrument.

C) The short-duration spikes in the CO signal correspond to the first-out rich combustion products from each exhaust event. The engine-out universal exhaust gas oxygen sensor was indicating λ=1.05 (lean) but the peak CO of approx. 1.5% corresponds to a combustion λ of approximately 0.95 (rich). This allows the calibrator to identify the combustion λ as opposed to the UEGO-indicated exhaust λ.