The Effect of Swirl on Air/Fuel Mixing in a 4 Valve GDI Engine

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Abstract

The requirement of reducing greenhouse gas emissions, in particular Carbon Dioxide, from vehicles, is one of reducing fuel consumption. One strategy for realising this is through the reduction of pumping losses in the engine cycle. Variable valve timing can be used as a method for partial load control in an IC engine since minimising the use of the throttle leads to a reduction in losses due to pumping work. Furthermore, it is also possible to employ valve de-activation and leave one of the inlet valves closed during induction, hence giving some load control and also introducing a swirling motion into the cylinder as opposed to the usual tumble motion.

Introduction

Two single cylinder engines, one thermodynamic and one optical, each with the same cylinder head geometry, inlet and exhaust systems have been used to study the effects of this swirling motion on the engine performance. The thermodynamic engine was used to measure the fuel consumption and emissions from the engine, at part load and, using single inlet valve operation with a low lift, to give partial control of the engine load. The results from these measurements showed significant differences in the levels of emissions and fuel consumption, dependent on which valve was opened.

This study aims to investigate the mixing phenomena occurring for the opposing swirling flows generated by the operation of the independent inlet valves. To investigate these effects, measurements were performed on the optical engine having a fully variable valve system, the Lotus AVT system. The air flows generated were measured using PIV, for the two inlet valves being operated independently. Mie imaging was used to study the effects of these swirling flows on the fuel spray during the injection period.

The detailed head geometry has the injector closer to one inlet valve, and this leads to significant differences of the effect of the inlet flow on the injected fuel. It is believed that these differences are responsible for the fuel consumption and emissions results due to the degree of mixing generated by the injector position and the detailed air flow into which the injector sprays the fuel.

Results and Discussion

The results can be broadly split into three distinct components, the air flow measurements from the PIV, the spray morphology from the Mie imaging and the fuel consumption and emissions data from the thermodynamic engine. It is the combination of these results from the different experiments that leads towards an explanation of the engine performance under the different valve strategies employed. Examples of the flow fields generated by opening only one inlet valve are shown in figures 1 and 2, for each valve. These results show the expected change in flow direction dependent on which valve is being operated. The effects of these flow fields on the injected spray can be seen from the images in figures 3 and 4. It can be observed that the mixing process is already showing differences even during the injection period, from the different sprays structures which are being developed.

The engine data shown in figures 5 and 6 show fuel consumption and NOx emissions plotted against time of injection for the two valve strategies. All data here was collected at one specific engine load of 2.7 bar IMEP. The differences in fuel consumption between the two valves indicates that the mixing produced when valve 3 is operated is better than for valve 1 leading to better combustion and therefore less fuel. The emissions data in figure 6 supports this idea, as NOx is formed at a high combustion temperature, which tends to only happen when there is a good and reasonably fast combustion event. This being the case, then it is expected that in general the event from valve 1 operating will produce less NOx, due to poorer combustion and therefore lower peak in-cylinder temperatures. The previous experimental results described above allow for an explanation of the engine data from the differences seen in the spray images, indicating different mixing regimes, which in turn can be explained by the differences observed in the measured in-cylinder flow fields.

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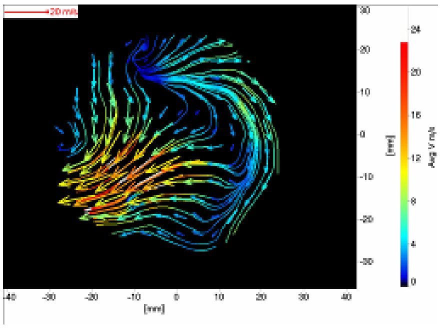

Figure 1. Flow field from valve 1

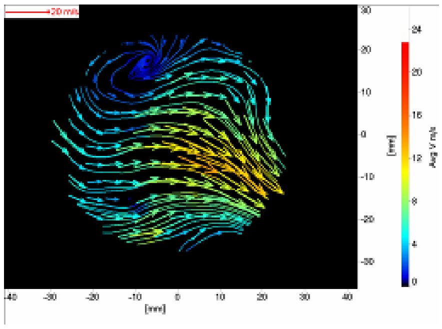

Figure 2. Flow field from valve 3

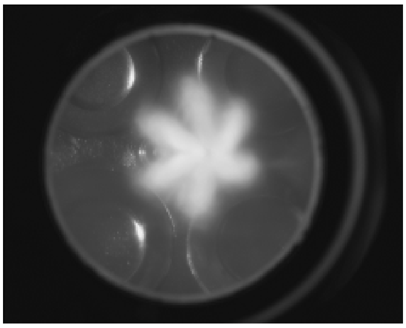

Figure 3. Fuel spray with valve 1

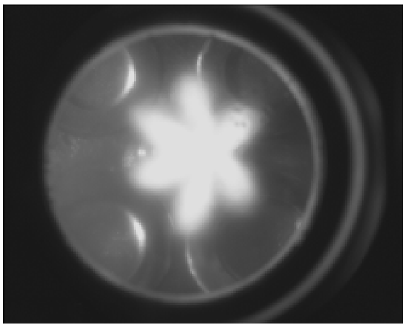

Figure 4. Fuel spray with valve 3

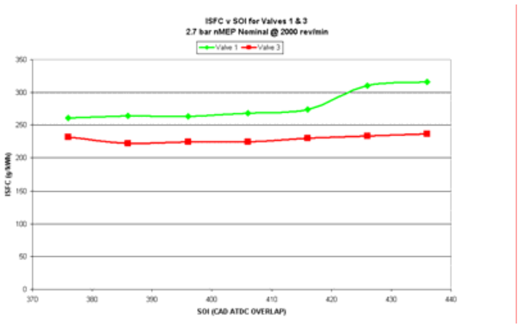

Figure 5. Indicated specific fuel consumption

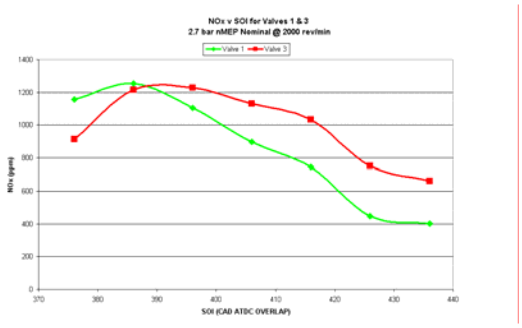

Figure 6. NOx emissions

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