Direct Injection Gasoline Engine Particulate Emissions

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Abstract

Direct fuel injection technology is increasingly being applied to the spark ignition internal combustion engine as one of the many actions required to reduce the CO_2 emissions from road transport. Whilst the potential for CO_2 reductions is compelling, the technology is not without disadvantages. Early examples typically emitted over an order of magnitude more Particulate Matter (PM) than vehicles with conventional spark ignition engines. Consequently, future revisions to European and North American exhaust emissions legislation are likely to regulate the particulate emissions from vehicles with direct injection gasoline engines.

This thesis undertakes to investigate a) instrumentation capable of simultaneously resolving the number concentration and size distribution of particles in the 5-1000 nm size range and b) the factors affecting the PM emissions from spark ignition engines with direct fuel injection. The first objective is achieved by evaluation and comparison of a differential mobility spectrometer; photo-acoustic soot sensor; condensation particle counter and electrical low pressure impactor. To address the second question, a differential mobility spectrometer is applied to quantify the PM emissions from a number of direct injection gasoline engines, together with investigation of their dependence on various calibratable parameters, operating temperature and fuel composition.

The differential mobility spectrometer showed good agreement with the other more established instruments tested. Moreover, it exhibited a faster time response and finer resolution in particle size. The number weighted size distribution of the PM emitted was typically lognormal with either one or two modes located between 20 and 100 nm. Chemical analysis of PM samples showed the presence of elemental carbon, volatile organic material and sulphates.

Transient PM measurements enabled short time-scale events such as mode switching between homogeneous and stratified mixture preparation to be identified. PM number concentrations in stratified mode exceeded those in homogeneous mode by a factor of 10-100. Dynamometer based experiments showed that PM emissions increase for rich air fuel ratios, retarded fuel injection and advanced ignition events. They also demonstrated a strong dependence on fuel composition: the highest PM emissions were measured with an aromatic fuel, whereas blending alcohols such as methanol or ethanol tended to suppress PM emissions, particularly in the accumulation mode size range.

These measurements are amongst the first of their kind and demonstrate the applicability of the differential mobility spectrometer to the measurement of ultra-fine particulate emissions from engines with direct fuel injection systems. Numerous explanations are put forward to describe the data obtained, together with suggestions for future work on PM control and abatement.

Please note that only the abstract of this thesis can currently be made available in the Oxford University Research Archive. Much of the content has been published by the Society of Automotive Engineers and is available from www.sae.org.

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