Application of Dimethyl Ether in Compression Ignition Engines

This study has its roots in two separate events at the Department of Mechanical Engineering at DTU. In 1995 the first attempt to operate a diesel engine on dimethyl ether (DME) was successfully concluded. In 2004 the department decided to compete in the vehicle fuel efficiency competition Shell Eco-Marathon.

The diesel engine test results from 1995 showed that DME is a superb diesel fuel. DME is easy to ignite by compression ignition and it has a molecular structure that results in near-zero emission of particulates when burned. These are features of a fuel that are highly desirable in a diesel engine. The challenges with DME as a diesel engine fuel are mainly related to poor lubricity and incompatibility with a range of elastomers commonly used for seals in fuel injection systems. This means that although DME burns well in a diesel engine designing a fuel injection system for DME is challenging. Since then studies have revealed that the injection pressure for DME does not have to be as high as with diesel to achieve satisfactory performance. This opens for a larger range of possibilities when designing injection systems.

In the period from 2004 to 2009 the DME engine was perfected for use in the car DTU was racing in the Shell Eco-Marathon. The car won the competition in 2007 and 2009. The concept was to use a direct injected two-stroke engine operating with an injection pressure of only 150 bars. A piston pump operating without metal-to-metal contact had been developed to supply that pressure. The elastomer seals that provided the sealing instead of the metal-to-metal contact could do that because of the low injection pressure.

The engine developed in this way was based on a 50cc Peugeot two-stroke engine. The fuel injector used was a Bosch HDEV originally developed for direct injection of gasoline in automotive engines at up to 200 bars pressure. This injector was too large to provide for normal diesel engine operation on an engine of only 50cc. Although DME ignites easily all the fuel was injected before combustion started due to the high flow rate. Attempts to find a smaller injector that was also able to deal with the required injection pressure and also DME were not fruitful. Despite the fact that this combustion mode was more a result of necessity than choice the engine efficiency was higher than 30% which is good for an engine of this size. Up until this stage engine design and testing work was done with a focus on efficiency not emissions.

The objective of this study was to investigate the combustion mode and the emissions of the engine and to investigate possible improvements. It has been shown that the engine operates in a partially premixed mode. It does so with emissions of NOx that are an order of magnitude lower than for traditional automotive diesel engines. Emissions of carbon monoxide and unburned hydrocarbons were quite high though. Experiments with an oxidation catalyst revealed that carbon monoxide could effectively be converted to carbon dioxide but the low exhaust temperature did not allow for full oxidation of the unburned hydrocarbons.