This thesis is based on experimental and numerical studies on the use of dimethyl ether (DME) in the homogeneous charge compression ignition (HCCI) combustion process. The first paper in this thesis was published in 2007 and describes HCCI combustion of pure DME in a small diesel engine. The tests were designed to investigate the effect of engine speed, compression ratio and equivalence ratio on the combustion timing and the engine performance. It was found that the required compression ratio depended on the equivalence ratio used. A lower equivalence ratio requires a higher compression ratio before the fuel is burned completely, due to lower in-cylinder temperatures and lower reaction rates. The study provided some insight in the importance of operating at the correct compression ratio, as well as the operational limitations and emission characteristics of HCCI combustion. HCCI combustion process is governed mainly by chemical kinetics. To understand the combustion process therefore requires detailed knowledge of the dominating reaction paths in lean premixed combustion of DME. The reactions were studied by running simulations of HCCI combustion in CHEMKIN II [1] with a detailed reaction mechanism for DME developed at Lawrence Livermore National Laboratory in 2004 [2]. The dominating reactions paths were then identified and used to create a simple reaction mechanism containing 55 reactions only. It contains just enough reactions to successfully predict ignition as well as low and high temperature reactions with reasonable similarity to the original mechanism. By reducing the mechanism to its essential reactions it becomes more useful to CFD models of HCCI combustion. The number of elementary reactions has a great influence on computational demands and computing time, so the use of a simple mechanism greatly reduces both. Reaction paths for methanol and methane were included amongst the elementary reactions, since these two fuels are commonly used to control the radical behavior in the initial phase of combustion and hence the combustion phasing of the fuel in an engine, as well as enabling an increase in engine power. The use of methanol for combustion phasing control was tested successfully in a large diesel engine with common rail, in which the piston bowls were widened to give a compression ratio of 14.5. This compression ratio still allows DI CI operation with DME, but requires a substantial combustion delay in HCCI operation with DME to achieve post TDC combustion. By adding methanol to the inlet port during HCCI combustion of DME, the engine reached 50 percent of its full DI CI load capability without engine knock at 1000 rpm and somewhat less at 1800 rpm. The engine also had EGR capability which was used to demonstrate the effect on HCCI combustion phasing of increasing EGR ratios. The EGR percentage which is limited to about 30 percent in DI CI operation, could be increased to 70 percent in HCCI operation. The large amount of EGR delayed combustion almost to TDC. These tests were performed in Tokyo in 2008 and are described in the second paper in appendix. One of the limitations with HCCI combustion is combustion knock which increases with the equivalence ratio. The higher concentration of fuel leads to higher rates of reaction, and as the reaction is not spatially uniform, higher pressure gradients result from the combustion. These pressure gradients cause strong acoustic resonance in the combustion chamber. Part of the energy from this resonance is transferred to the cylinder liner and further through the engine block. The engine vibrates both as a result of direct transmission, as well as having its natural resonance frequencies exited. The sound pressure around the engine caused by the high frequencies can reach levels of more than 110 dB. The third paper describes the testing of various geometries of piston crowns for their ability to reduce the acoustic resonance in the combustion chamber and hence the noise emitted from the engine. The study showed that minimum exposure of the cylinder liner is critical in reducing the transmitted noise. The effect of splitting the chamber into smaller volumes was tested, by shaping piston crowns with cavities. It was found that piston crowns with cavities embedded in the piston performed much better in terms of noise reduction than those with cavities formed between the piston and the cylinder liner. The most notable result was the difference between two common geometries: the flat piston crown and the DI CI bowl-type crown. The latter provided the largest noise reduction of all tested. The combustion efficiency was however reduced by a very large crevice volume in the bowl-type crown. The physics behind the initial pressure gradients causing the resonance is largely unknown and hence difficult to include in a model. There is however indications that the large pressure gradients are caused by detonations. In some cases at least, explosions alone can not account for the observed pressures, which oscillate at values above those otherwise possible in a constant volume reaction. Detonations may develop in the wake of pressure waves that are sent out from local explosions. Even though the detonation may not develop to its steady state condition, it may still create a pressure wave of significant magnitude. While the steady state condition may be calculated, it is of higher interest to see if the detonation will develop at all under given circumstances. This was formed the basis of a CFD study. The objective of this study was to see if detonations would occur in CFD simulations of constant volume combustion with a lean premixed charge of DME in atmospheric air. STAR-CD [3] was used in conjunction with the reduced mechanism for DME combustion developed earlier. Detonation waves are known to be planar (when propagating in tubes) and hence the simulation could be set up in one dimension only, which saves computational time while allowing an excellent resolution in the direction of propagation. The studies revealed that with proper time stepping, spatial discretion and a temperature gradient across the domain, detonations will naturally be initiated and develop in a transient solution. The most important implication of this is perhaps that common CFD models may be used to test if certain conditions are more likely to provoke detonations than others.

**General information**

Publication status: Published  
Organisations: Fluid Mechanics, Department of Mechanical Engineering  
Contributors: Pedersen, T. D.  
Publication date: May 2011  

**Publication information**