UNIVERSIDAD POLITECNICA DE VALENCIA

motores térmicos

Student research project

Theme:

Study on the Cold Start Behaviour of a Single-Cylinder DI Diesel

The project will consist of a basic study to understand the phenomena that take place in a single-cylinder DI diesel engine during the cold-start phase. Relevant parameters for engine evaluation will be measured, and this information will be processed and analysed. The project results will help the definition of control strategies for the optimisation of engine performance under such conditions.

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Area of expertise: CMT - Motores Térmicos

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Preamble:

I would like to thank for the support of my project at the department “Centro de Mantenimiento y Transporte (CMT) - Motores Térmicos” at the Universidad Politécnica de Valencia. Also I would like to thank the director of this project Mr. Jose Maria Garcia Oliver, CMT group head Prof. Francisco Payri and Univ.-Prof. Dr.-Ing. Klaus Augsburg from the department “Kraftfahrzeugtechnik” of the Technical University of Ilmenau for the acceptance of this project at my home university.

Declaration:

Herewith I affirm you, that I made my project autonomous and that I give all used sources and devices in the index.
For my knowledge, this project doesn´t exist in this or a similar version.

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Manuel Kleinke Valencia 2006-06-30

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Mathematical symbols:

α = angle

A_DHRL_{max} = crankangle where the maximum heat release rate occurs

AQ25 = crankangle position at 25% of total heat realeased

AQ50 = crankangle position at 50% of total heat realeased

AQ75 = crankangle position at 75% of total heat realeased

$CALMEC_p$ = Parameter how is explained on page 25

DHRL = Heat Release Rate

H_P = Fuel heating power

HRL=FQL = Heat Release Law, integral of DHRL

m_f = fuel mass

P_{inj} = injection Pressure

Abbreviations:

CAD = Crank Angle Degree

ECU = electronic control unit

EVO = exhaust valve opening

FIS = Fuel injection system

inj = injection

Main = main injection

Pilot 1 = first pilot injection

Pilot 2 = second pilot injection

Rep. = Repetition

SOC = Start of Combustion

SOE = Start of Energizing

SOI = Start of Injection

SOL = Start of Luminosity

TDC = top dead center (In a piston engine, TDC is the position of a piston in which it is furthest from the crankshaft)

tot = total

1. Introduction:

Due to a bad efficiency of an Otto-Engine the engineer Rudolf Diesel developed together with the companies „Maschinenfabrik Augsburg" and "Krupp" an engine much more efficient. In 1892 he applied his Diesel engine for a patent.

Until the 80´s, the engines efficiency was being continuously improved. In the mid 80´s the development path split in two directions - the efficiency and the pollutant emission trade-off. Because of higher demands, there are more developments, now. Plenty of effort is put on the understanding of the combustion process, which has a direct implications on both efficiency and pollutant formation.

CMT (a research group in the Polytechnic University of Valencia/Spain (UPV)) is carrying out an extensive work on the cold start behaviour of direct injection Diesel engines.
In especial, the combustion during the cold start should be analysed.

1.1 Problem description:

A cold start at low temperatures in current D.I. direct engines is a problem which has not been properly solved yet. The key factors which lead to a proper cold start process depend on the particular characteristics of the engine. Efforts on optimisation of the cold start process, are mainly based on a "try and error" procedure, and the influence of some of the parameters governing the ignition process are still unknown.

It seems clear that the temperature of the in-cylinder air and of the surfaces of the combustion chamber are key factors, but they are not the only parameters governing the cold start process, since a proper explanation for misfiring can not be provided considering only these factors.

When a cold diesel engine is started (cold start), the heat of compression is the only energy source available to heat the gas in the combustion chamber to a temperature that will initiate the spontaneous combustion of the fuel (about 400°C). Since the walls of the combustion chamber are initially at ambient temperature rather than operating temperature, they are a significant heat sink rather than a heat source. And since cranking speed is slower than operating speed, compression is also slower, which allows more time for the compressed air to lose heat to the chamber walls. (A glow plug provides an additional source of heat in indirect-injection diesel engines.)

A fuel that combusts more readily will require less cranking to start an engine. Thus, if other conditions are equal, a higher cetane number(1) fuel makes starting easier. As the compression temperature is reduced by variables like lower compression pressure, lower ambient temperature, and lower coolant temperature, an engine requires an increasingly higher cetane number fuel to start easily.

(1) Cetane Number is a measure of how readily the fuel starts to burn (autoignites) under diesel engine conditions. A fuel with a high cetane number starts to burn shortly after it is injected into the cylinder; it has a short ignition delay period.

Research indicates that fuels meeting the ASTM Standard Specification D 975 cetane number requirement of a minimum of 40 provide adequate cold starting performance in modern diesel engines.
At temperatures below freezing, starting aids may be necessary regardless of the cetane number of the fuel.

Even after the engine has started, the temperatures in the combustion chamber may still be too low to induce complete combustion of the injected fuel. The resulting unburned and partially burned fuel is exhausted as a mist of small droplets that is seen as white smoke (cold smoke). This situation normally lasts for less than a minute, but the exhaust is irritating to the eyes, and can be objectionable if a number of vehicles are started together in an enclosed space. A fuel with a higher cetane number can ameliorate the problem by shortening the time during which unburned fuel is emitted to the atmosphere.

1.2 General objective:

The general objective in this project is to improve understanding on the influence of the main parameters controlling the cold start process, on the basis of systematic experiments in an optical engine where the effect of the main parameters can be isolated. This should provide guidelines for cold start optimisation in any engine.

1.3. Project methodology:

A set of fundamental studies will be performed in an experimental facility allowing the reproduction of in-cylinder air conditions similar to those of an engine at low temperature, whilst providing optical access for visualisation of the ignition process. Although the cold start process is clearly unsteady, the only way to visualise and analyse the phenomenon of fuel ignition under controlled conditions is to motor the engine at the desired engine speed and perform single injections to determine whether fuel ignites or not under each operating condition. Once determined the critical conditions where ignition occurs, parametric studies will be performed modifying every single parameter, with detailed visualisation of the ignition process (pre-reactions leading to fuel combustion) trying to identify the phenomena controlling the fuel ignition process in the case of using a heating plug (hot spot ignition) or an electrical heater in the intake (ignition controlled by fuel evaporation and mixing).

In all cases, special care will be taken to ensure the independence of the different parameters to be investigated.