POSIBILITIES TO IMPROVED HOMOGENEOUS CHARGE IN INTERNAL COMBUSTION ENGINES, USING C.F.D. PROGRAM

Alexandru-Bogdan Muntean*, Anghel,Chiru, Ruxandra-Cristina (Dica) Stanescu, Cristian Soimaru

Transilvania University of Brasov

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ABSTRACT – This study shows the current trends to achieve homogeneous mixtures in S.I. engines, impediments that arise in their implementation, and solutions to improve the mixture formation.

Performance indicators for a complete combustion process are emissions of C_mH_n, PM (which must tend to 0), in strict accordance with the auto-ignition-delay period. Also these performances are influenced by type of charge which enters the combustion chamber.

In order to realise an optimization of those processes will be used virtual models based on C.F.D. (Computational Fluid Dynamics) software.

Thus, the paper wishes to highlight (in terms of virtual simulation) jet fuel dependence, the degree of turbulence and optimize it.

INTRODUCTION

The more and more stringent emission regulations and the need to reduce fuel consumption in particular with regard to limited resources and global warming effects induce the need of new advanced combustion systems for internal combustion engines. HCCI is a combustion process which provides as high efficiencies as conventional compression ignition direct injection (CIDI) diesel engines without having the drawback of high nitrogen oxide (Knox) and particulate matter (PM) emissions (1).

DEFINITION

The homogeneous combustion is defined as a process in which a 3D-ignition (volumetric) of the homogeneous (premixed) charge is followed by simultaneous (no flame front) heat release in the whole combustion chamber volume characterized by a homogenous temperature field. (2)

TARGETS

For realizing HCCI combustion, the main challenges are:

- the homogenization of fuel, air, and recycled burnt gases prior to ignition,
- the control of ignition and combustion timing, and
- the control of heat release rates

METHODS TO RELISE HCCI

An effective mixture formation and the avoidance of fuel-wall interactions are crucial for achieving high fuel efficiency. Regarding the mixture formation and homogenization of fuel and air, two main categories, the external and the internal mixture formation, can be distinguished.(3)

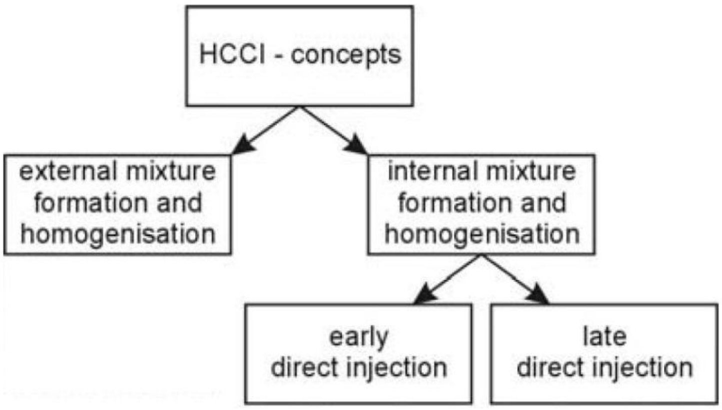

Fig. 1 Mixture formation concepts for HCCI-engines (Adapted from **(3)**)

The simplest way of achieving a homogeneous in-cylinder mixture is the introduction of fuel upstream of the intake valves (external mixture formation). The mixture enters the cylinder during the intake stroke. This method is also known as port injection.

In the case of heavy fuels with reduced volatility, the port injection results in poor evaporation as well as increased wall impingement, HC and CO emissions, fuel consumption and oil dilution. This injection is mainly attractive for gaseous and liquid fuels with high volatility, but not for diesel fuel.

Besides the problem of homogeneous mixture formation, the control of ignition timing has a strong influence on efficiency and operating range.

A stable combustion can be realized at low and partial load for lean fuel-air ratios and an increase in load towards stoichiometric values results in a significant increase in heat release rates and in knock-like combustion.

Combustion phasing and the control of ignition in H.C.C.I. is affected by:

- the auto-ignition properties of the fuel,
- the fuel-air ratio,
- the volatility of the fuel,
- the EGR rate, the temperature and the reactivity of the recycled gas,
- the mixture homogeneity,
- the compression ratio of the engine,
- the intake temperature, and
- the heat transfer to the engine.

In order to control combustion phasing, two main groups of approaches can be distinguished:

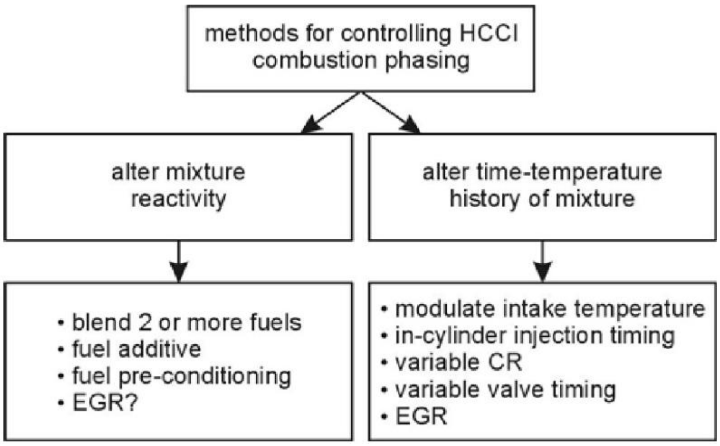

Fig. 2 Methods for controlling HCCI combustion phasing (Adopted from **(3)**)

In the following steps will be presented effects of in-cylinder injection timing, and valve timing on the fuel-air mixture, at different speeds of the crankshaft.

SIMULATION WORK

Steps which were made to realise the simulation model include:

- building the geometry of the single cylinder components (piston, cylinder, valves, walls)
- building the mesh of the simulated components
- set up the numerical mode (select appropriate physical model, define material properties, prescribe operating condition, prescribe boundary conditions, provide initial solution, set up solver control)
- compute the solution
- examine the results

DESCRIPTION OF INPUT DATES

For simulation work, it was used Fluent 6.3 version, C.F.D. software. (5)

The input parameters to the model refer to:

- Engine parameters (stroke, bore, displacement, connecting rod, compression ratio, etc.)
- the injection process (mass flow rate, injection timing),
- to the liquid fuel properties (type, temperature, min. diameter, max. diameter)
- To the domain properties (density, viscosity, temperature).

The effects of engine parameters on HCCI mixture formation were investigated using a port injection single cylinder engine. The virtual model engine had a bore × stroke = 83mm× 90 mm, a displacement of 487 cc and a compression ratio of 6.7. Length of the connecting rod is 150 mm. Investigation of air-fuel mixture was made using several engines speed, starting to 1000 rpm to 6000 rpm.

Cold flow simulation was started, using n-heptanes fuel (C_7H_{16}) which was injected in the air and vaporized. The injected mass flow rate was different for each engine speed but the injection timing and valve timing remained the same for all engine speeds. This input dates are presented below:

Engine Speed (rpm)	Total Flow Rate (kg/s)
1000	0.000979
1500	0.001469
2000	0.001958
2500	0.002448
3000	0.002937
3500	0.003427
4000	0.003916
4500	0.004406
5000	0.004895
5500	0.005385
6000	0.005874

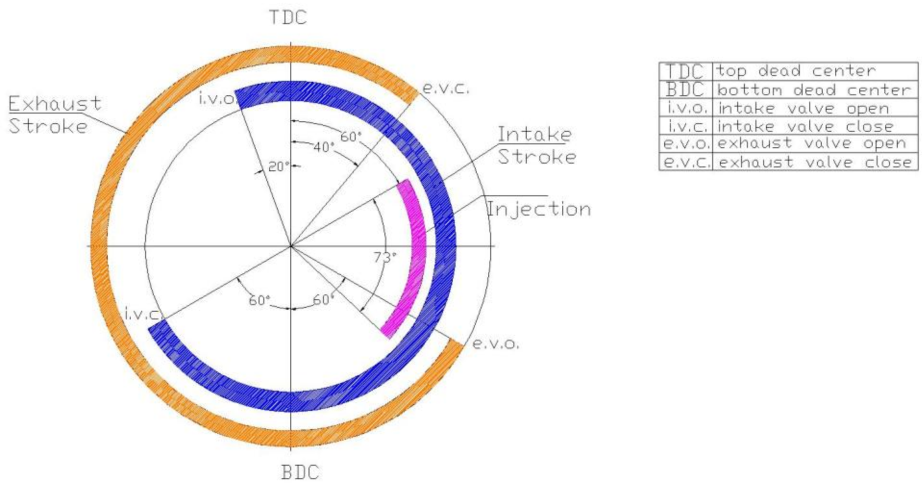

Fig. 3 Valve timing chart

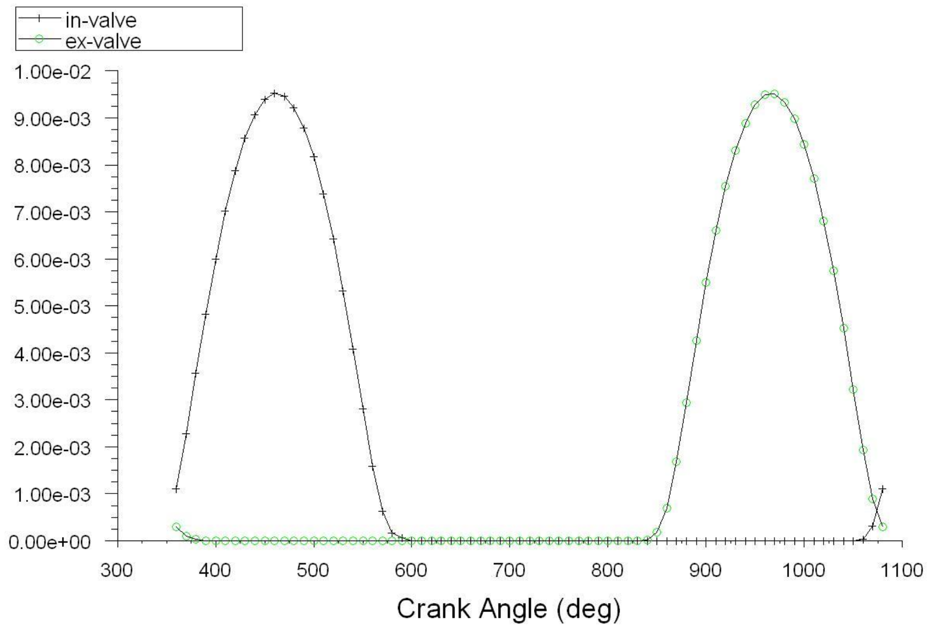

Fig. 4 Valve lift chart

Temperature of fuel injected was 310 K, and the temperature of intake air flow 318 K.
The goal of this simulation was to establish the predicted $C_7 H_{16}$ mass fraction distribution in the cylinder, and the velocity magnitude. In order to realize this, it was proposed a 2D model which was used to measure the velocity and mass fraction in one point of combustion chamber.(see Fig.5)

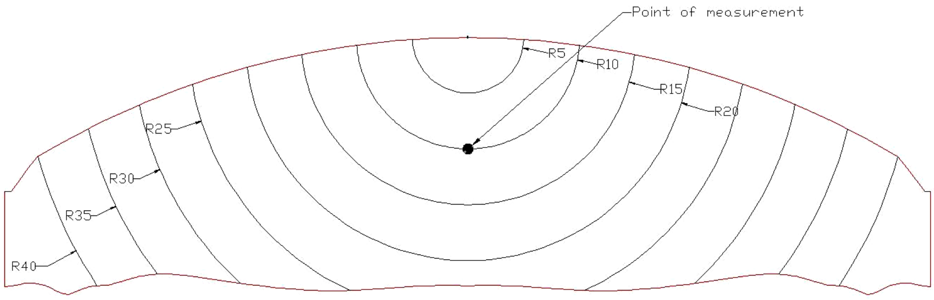

Fig. 5 Combustion chamber of the simulated model

Other followed aspects were, how the mass fraction and velocity of the air are influenced by the position of the piston. In that case, we propose two position for observing the mass fraction (10^{o} BTDC and 5^{o}BTDC), and three position of the piston for observing the velocity (10^{o} BTDC, 5^{o}BTDC and TDC).

RESULTS

The next figures shows the results of the simulation work, on the condition previously established.

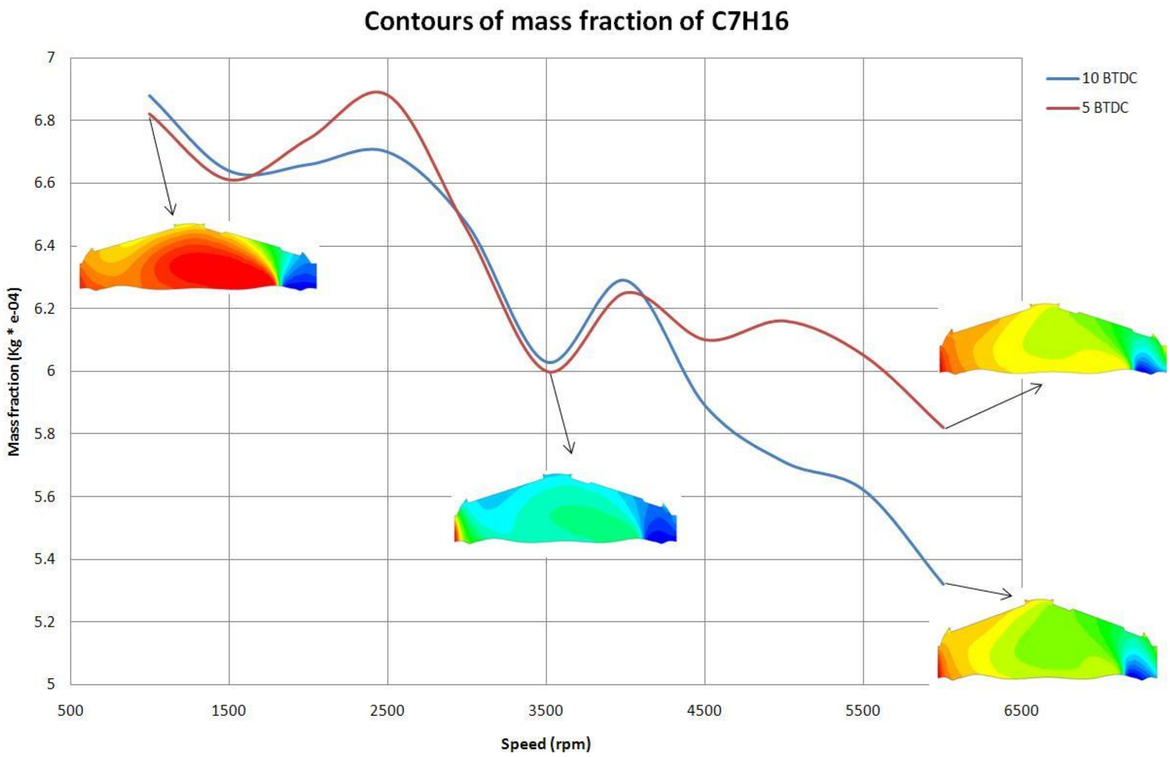

Fig. 6 Predicted C_7H_{16} mass fraction distribution

2D time dependent simulations demonstrate an intense turbulence profile that has to be optimized correlate with other running parameters.

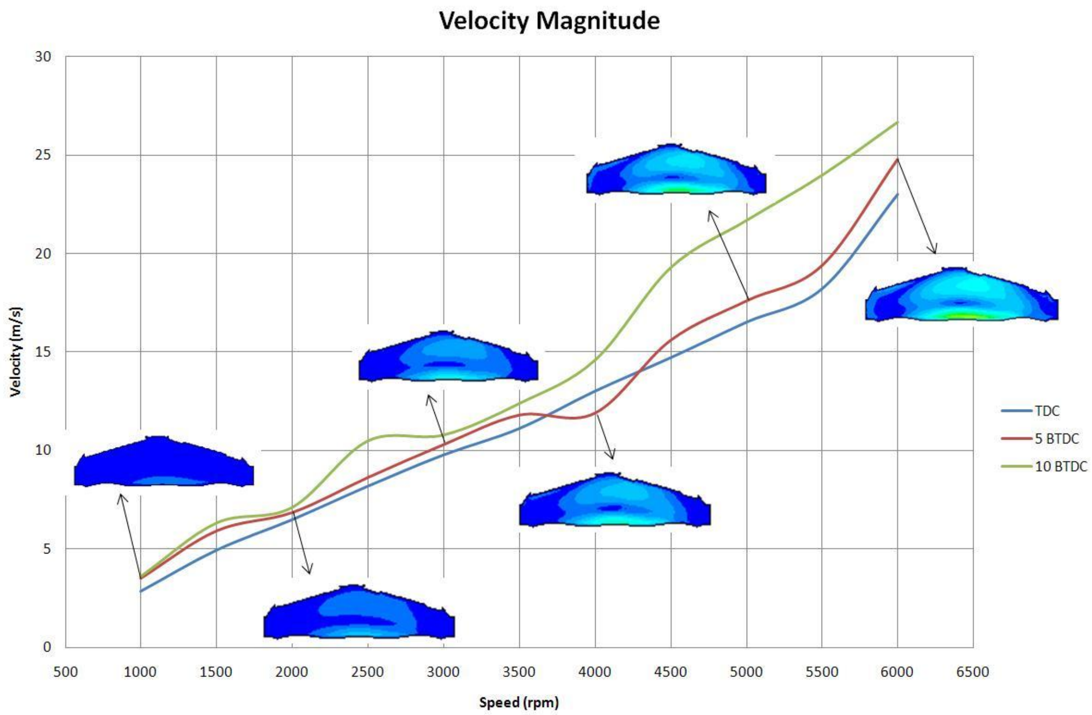

Fig. 7 Predicted velocity magnitude

CONCLUSIONS

In order to realise a homogeneous air-fuel mixture in cylinder, it is necessary to synchronize more parameters of engine cycle like: injection strategies, fully variable valve timing, temperature of the intake air, compression ratio, geometry of the combustion chamber,

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