# Analysis of Combustion Processes in HCCI Engine using LES

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**Abstract**

The Homogeneous Charge Compression Ignition (HCCI) is still a promising concept to optimize internal combustion (IC) engines with respect to emissions and particulate matter. Having the potential of both providing high efficiency that is similar to diesel engine combustion and also producing ultra-low emission characteristics of NOx and particulate matters the HCCI features combustion properties different from the two well-known, namely the premixed combustion mode in SI gasoline engines and diffusion flames in diesel engines. However in HCCI combustion processes the cycle-to-cycle variations of in-cylinder flow play an important role and can lead to combustion instability due to the lean as well as knock combustion conditions. In this paper, multi-cycle Large-Eddy Simulation (LES) based analysis is carried out on a single cylinder, four-stroke IC-engine with two vertical valves in order to characterize the unsteady effects of HCCI combustion processes. For this purpose, LES simulation of HCCI combustion based on fully premixed iso-octane and early-direct spray injection has been carried out for 40 and 25 engine cycles obtained on coarse and fine grid, respectively. In order to reach the sufficient number of statistically independent samples a parallelization strategy has been used allowing perform LES of cyclic fluctuations in HCCI IC-engine with reasonable statistical accuracy. The effects of cycle-to-cycle velocity fluctuations on the resulting HCCI combustion processes are pointed out. In particular, a qualitative analysis of the intensity of cyclic fluctuations of in-cylinder velocity, temperature and pressure is provided in terms of mean and standard deviation. A verification based on mesh refinement study has been done in the present paper.

The effects of cycle-to-cycle velocity fluctuations on HCCI combustion processes are discussed. As an example, Figure 1 shows the cycle-to-cycle variations of velocity and temperature in the cross section of the combustion chamber for 25 consecutive engine cycles at 15 crank angle degree (CA) before top dead centre (TDC). Figure 2 demonstrates the cycle-to-cycle variations of the temperature obtained in the perpendicular sections of the combustion chamber for 4 consecutive engine cycles at CA = 5° before TDC for fully premixed HCCI combustion. There is only effect of velocity cyclic fluctuations which are initialized during the intake engine stroke taking into account. The initial and boundary conditions were kept identical for all considered cycles.

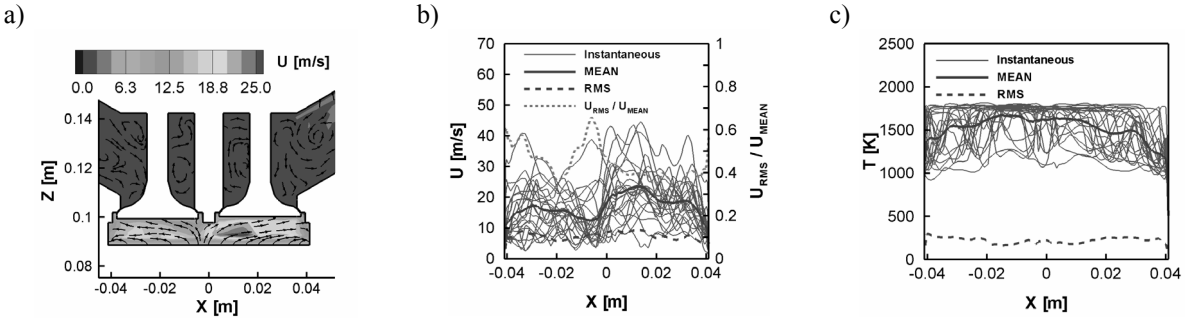


Fig. 1. Contour plots (a), instantaneous profiles and standard deviation of velocity (b) and temperature (c) in the cross section of the combustion chamber. Data obtained for 25 engine cycles at top dead centre for homogeneous autoignition at CA = 15° BTDC, fine grid.

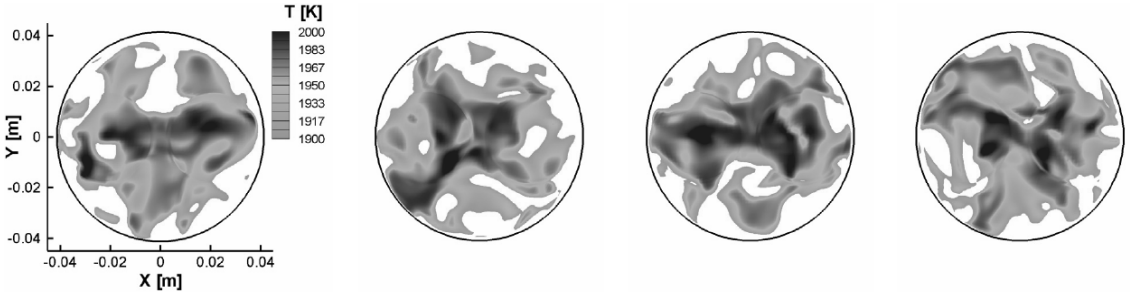


Fig. 2. Cyclic variations of temperature field for premixed HCCI combustion, 4 consecutive engine cycles. XY plane (z = 0.095 m) of the combustion chamber, CA = 5° before TDC, fine grid.