CFD Simulation of GM 2.0 Liter HCCI Engine

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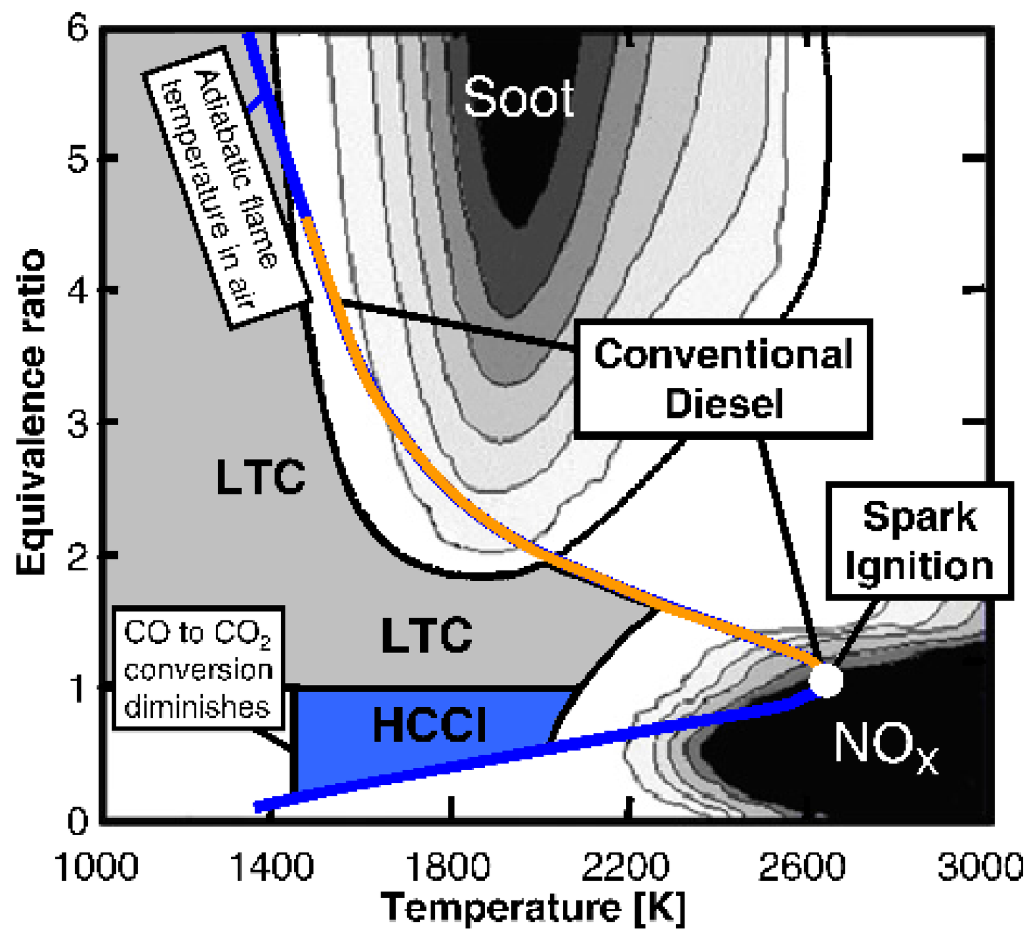
Introduction

- HCCI is a combination of gasoline spark ignition (SI) and diesel compression ignition (CI) technology
- Similarly to SI, HCCI has a homogeneous mixture which prevents soot formation
- Due to lean operation, like CI engine, HCCI has high efficiency
- Lean HCCI prevents formation of NO_x due to low burned gas temperatures



Methodology

- CFD is used to convert 3-D Navier-Stokes PDE equations into a set of algebraic equations

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho v_i)}{\partial x_i} = 0 \quad \text{Conservation of Mass}$$

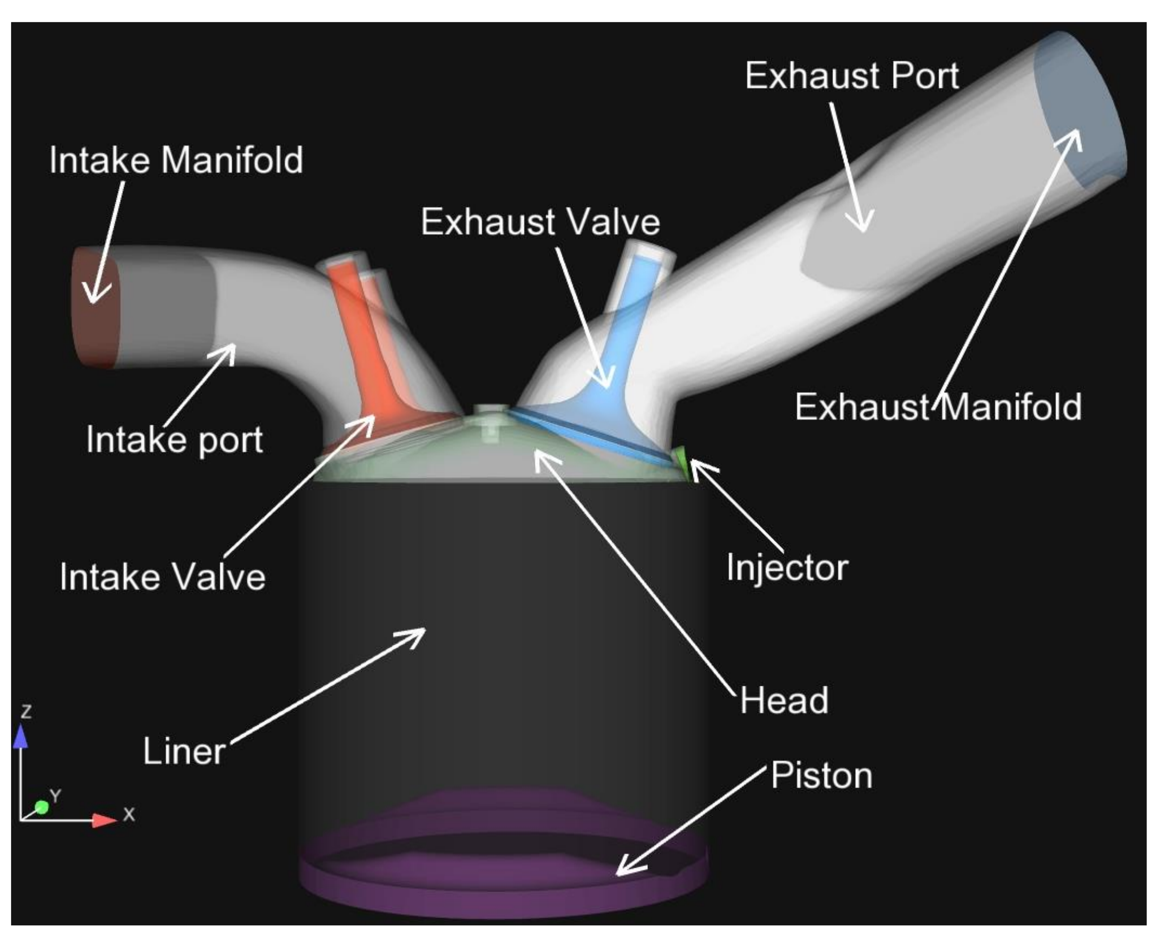
$$\frac{\partial \rho v_i}{\partial t} + \frac{\partial(\rho v_j v_i)}{\partial x_j} = \frac{\partial \tau_{ij}}{\partial x_j} - \frac{\partial p}{\partial x_i} \quad \text{Conservation of Momentum}$$

$$\frac{\partial(\rho E)}{\partial t} + \frac{\partial(\rho v_j E)}{\partial x_j} = \frac{\partial}{\partial x_j}\left(k\frac{\partial T}{\partial x_j}\right) + \frac{\partial}{\partial x_j}(\tau_{ij} v_i) \quad \text{Conservation of Energy}$$

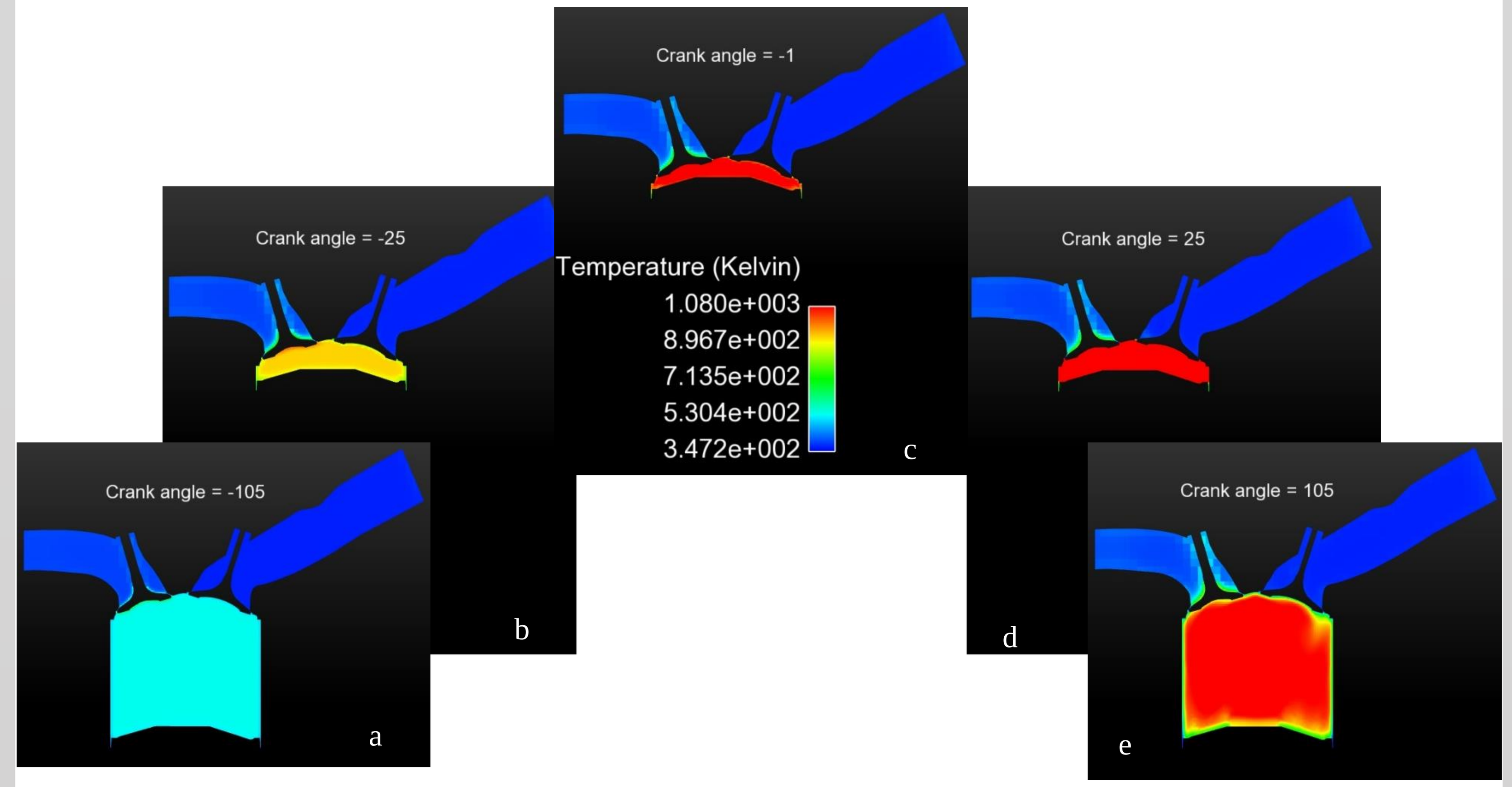
- CFD also solves for chemical reactions through a chemical kinetic mechanism file
  The i^{th} species mass fraction transport equation:

$$\frac{\partial}{\partial t}(\rho Y_i) + \frac{\partial}{\partial x_j}(\rho u_j Y_i) = \frac{\partial}{\partial x_j}\left(\rho D_i \frac{\partial Y_i}{\partial x_j}\right) + R_i + S_i$$

- CONVERGE CFD performs 3-D simulations to provide insight into engine combustion
- It uses different sub-models for combustion, heat transfer, turbulence, and injection

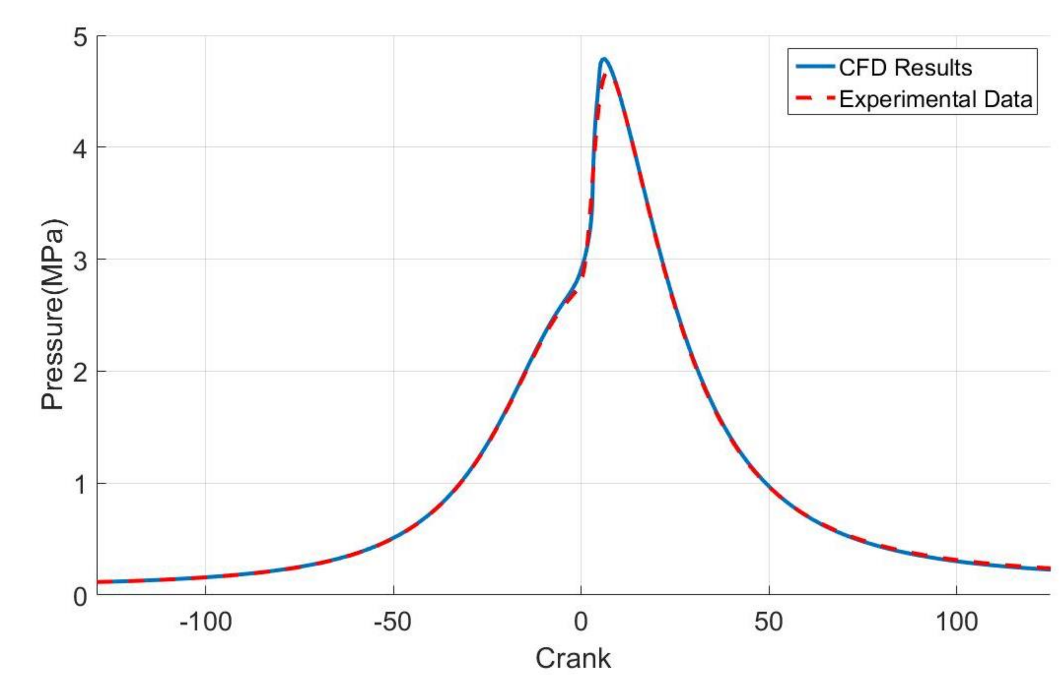


Results

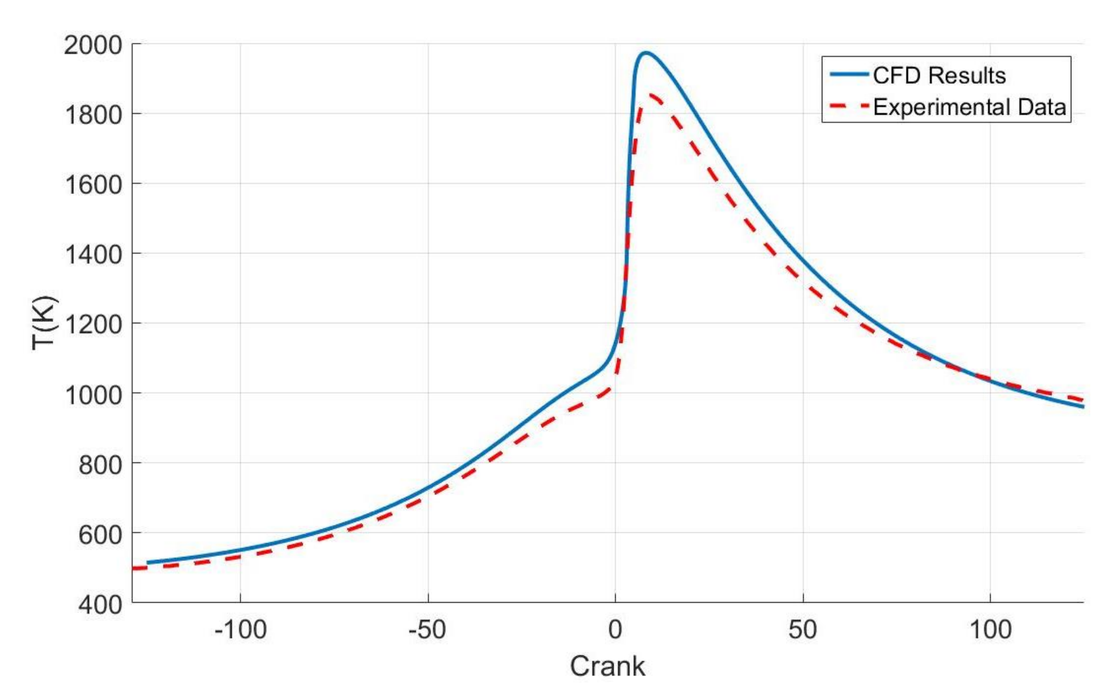


- In the above picture, the temperature distribution inside the cylinder can be seen during compression and expansion (power) stroke
- Temperature increases due to compression, then due to combustion, before decreasing during expansion

CFD Model Validation Against Experimental Data



- The CFD model and simulation results have been validated against experimental data showing good agreement between the CFD and experimental results
- There are some discrepancies between temperature of the simulation and experimental data which is due to slight inaccuracies of chemical kinetic mechanism

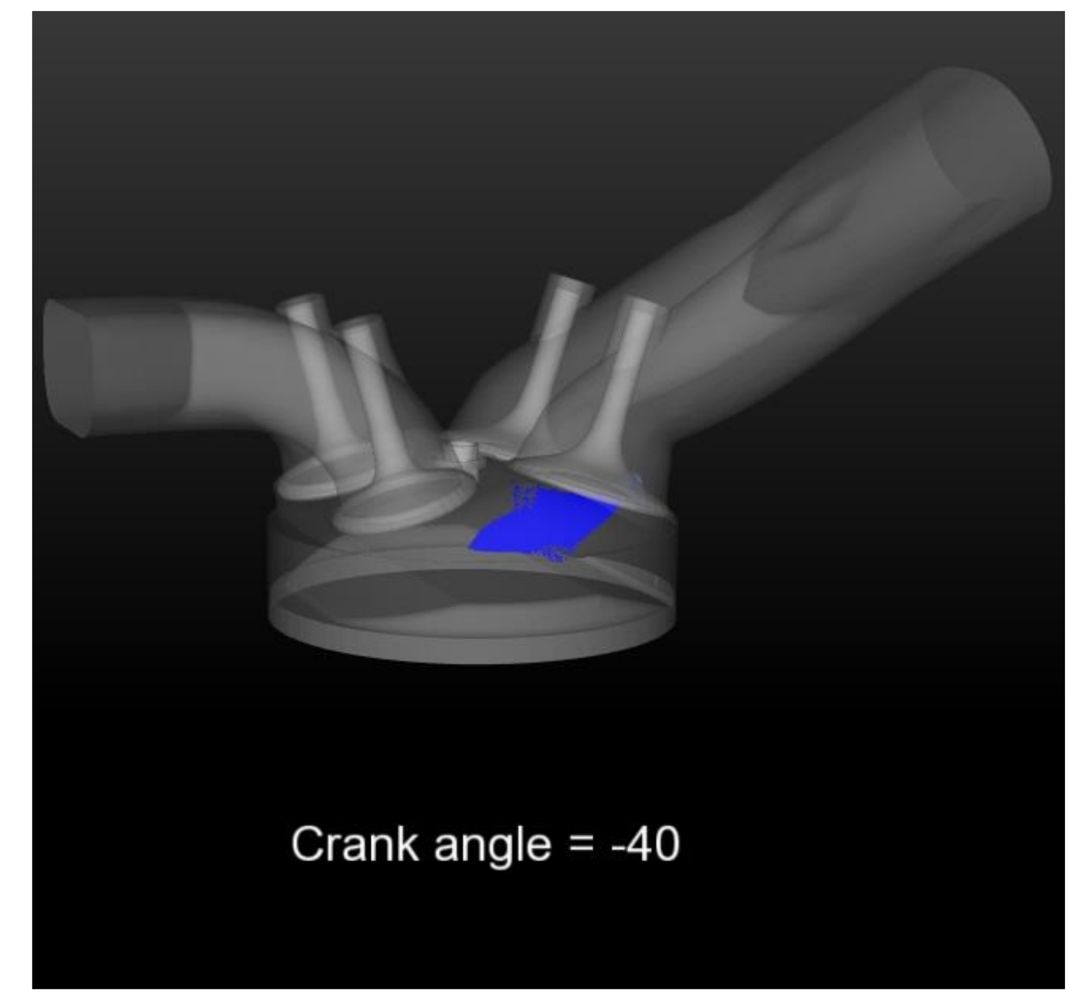


Conclusions

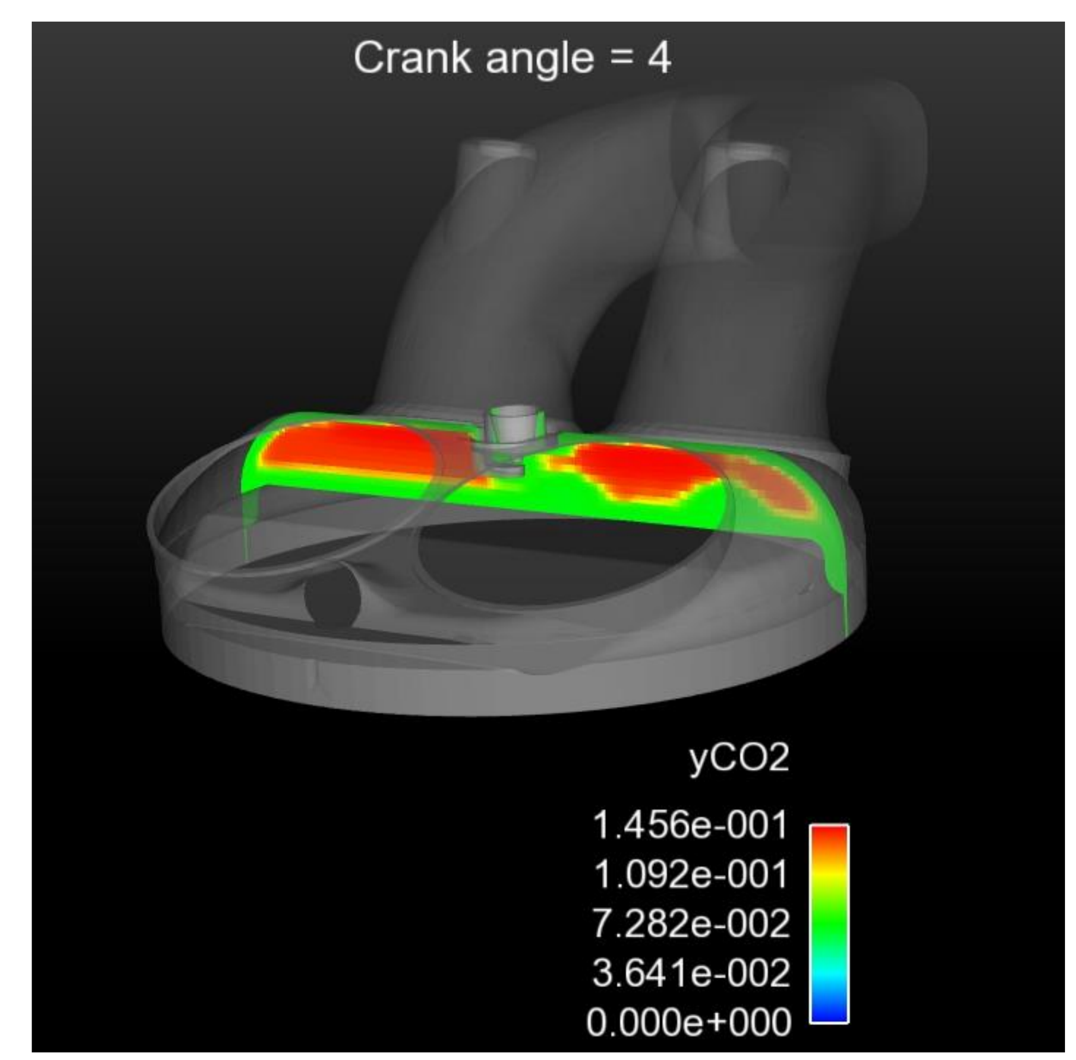
- HCCI offers many advantages over conventional SI and CI including less soot and NO_x emissions and higher efficiency
- A series of experimental tests that were performed on a 2.0 liter GM engine, were used to validate the CFD model and simulation results obtained in CONVRGE

Future Work

- In the future water injection will be added into HCCI engine in order to:
1. Control the start and rate of combustion/energy release
2. Expand the range of operation in HCCI engine to enable high load operation
- The effect of water injection amount and start of injection timing on HCCI combustion will be studied with CFD simulations



- Water is injected at -50 crank angle degree to absorb energy and control heat release
- It evaporates later due to high temperature inside the cylinder



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