772. WE-Heraeus-Seminar

Metrology and Process Safety
for Hydrogen Technologies & Applications
10 Oct - 13 Oct 2022

WILHELM UND ELSE HERAEUS-STIFTUNG

OME$_N$/DIESEL SPRAY INJECTION IN AN RCCI ENGINE; COMBUSTION ANALYSIS IN THE PRESENCE OF HYTHANE

Ali Navid [a,*], Kourosh Ghadamkheir[b], Anna Hasche[a], Javad Zareei[c], Sven Eckart[a], Hartmut Krause[a]

[a] *Institute of Thermal Engineering, TU Bergakademie Freiberg, Freiberg,* ***Germany***
[b] *Mechanical Engineering Department, Ferdowsi University of Mashhad,* ***Iran***, [c] *Biosystems Engineering Department, Ferdowsi University of Mashhad,* ***Iran***

Aim of the work & Objectives

Reactivity controlled compression ignition (RCCI) engine is a dual fuel strategy that uses fuels with different reactivities. In this study, Hythane or HCNG (60% methane and 40% hydrogen) as a low reactivity fuel and diesel or OME with high reactivity are used. Thus, Hythane consists 5% of the incoming air mass, and OME/diesel is sprayed under fully lean condition.

Objectives:

- A comparison between a typical diesel engine and RCCI engine.
- Effect of the chain length on the compbustion process is investigated.
- Emission analysis by changing the fuel configuration.
- Effect of the flame speed on the combustion process.
- Effect of the change in the equivalnce ratio on the combustion process and the flame surface density.

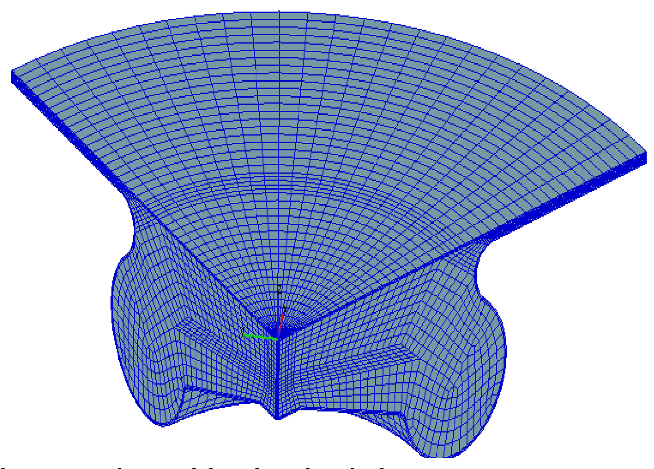

Fig. 1: mesh used for the simulation process at TDC

Engine specifications

Tab. 1: Engine specifications

Description (unit)	Value
Bore × stroke (mm)	82.5×82
Displacement (cm³/cylinder)	438
Compression ratio	19.5:1
Swirl ratio @ IVC	3
Clearance (mm)	0.86
Connecting rod length (mm)	104
Start of injection	4 ˚CA bTDC
Injection duration	11 ˚CA
Injection spray angle	160˚

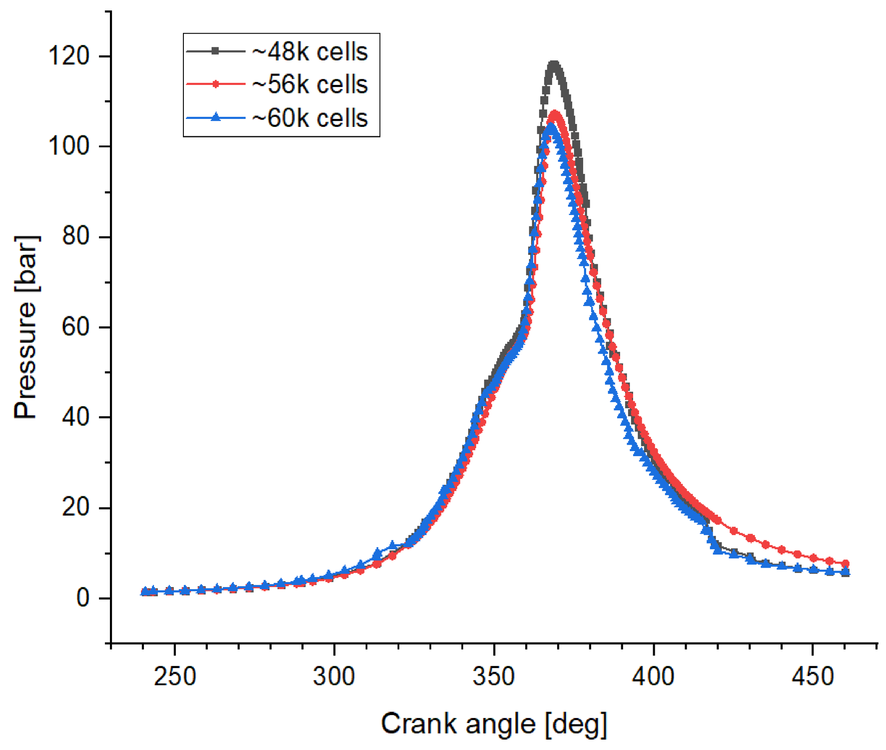

Fig. 2: mesh independence with three different cell sizes for pressure under 1250 rpm and full load condition.

A Ford 1.8 L DI (direct injection) diesel engine equipped with a prototype Lucas CAV HPCR (high-pressure common rail) system, and an allied Signal VGT (variable geometry turbocharging) is used. The VGT mechanism optimizes the air flow based on engine conditions and it depends on the engine speed and engine load.

Numerical Simulation

Tab. 2: Models used for the simulation process

Description	Model
Combustion	ECFM-3Z [1]
Turbulent model	k-zeta-f [2]
Auto ignition model	Two stage
NO_x model	Extended Zeldovich + prompt [3]
Soot	Kennedy/Hiroyasu/Magnussen
Breakup model	Wave
Drag law model	Schiller Naumann
Evaporation model	Dukowicz
Wall interaction model	Walljet 1

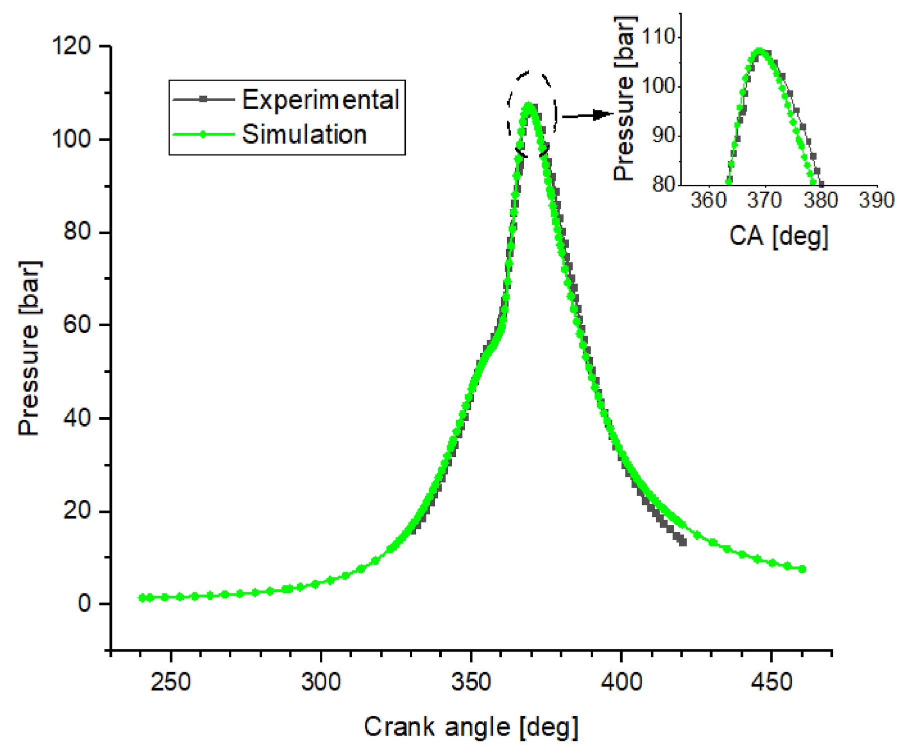

Fig. 3: validation of numerical results with 56k cells for the baseline diesel engine for pressure at 1250 rpm and full load condition

Since there is no spark, only one-fourth of a cylinder is simulated which is due to axisymmetric condition. Due to the high coincidence and computation simplicity, the middle mesh (~56k) is used as the reference mesh. In order to make a fair comparison, the volume of the injected fuel for base engine (diesel) is the same for all cases and based on the OMEn density, the injected mass is variable (14.15 mg/cycle for diesel). However, Hythane mixture is the same for all RCCI cases.

Results

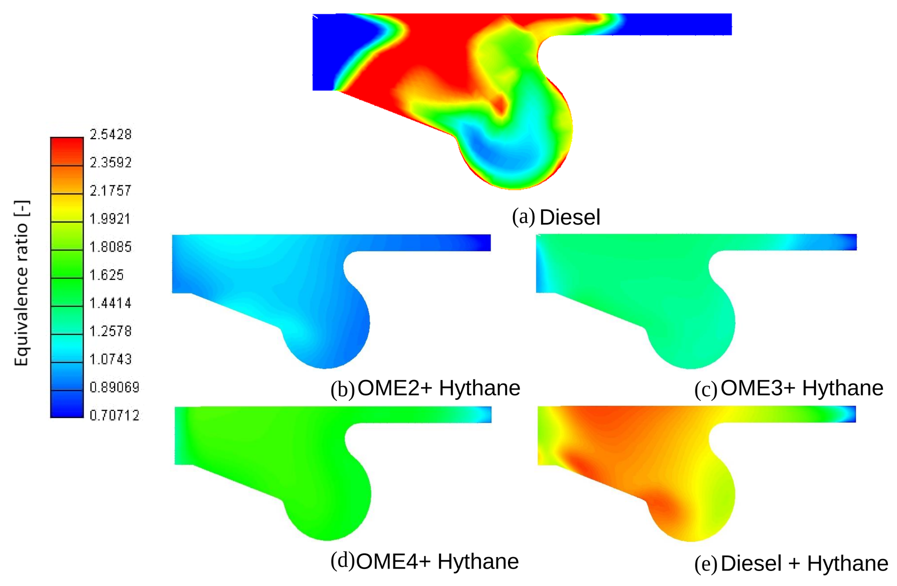

Fig. 4: Equivalence ratio ϕ at 372 °CA for (a) diesel, (b) OME2+ Hythane, (c) OME3+ Hythane, (d) OME4+ Hythane, and (e) diesel + Hythane

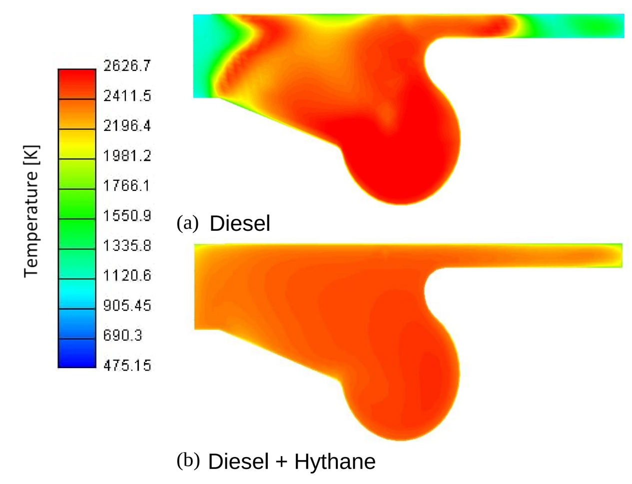

Fig. 5: Temperature distribution at 372 °CA for (a) diesel, and (b) diesel + Hythane

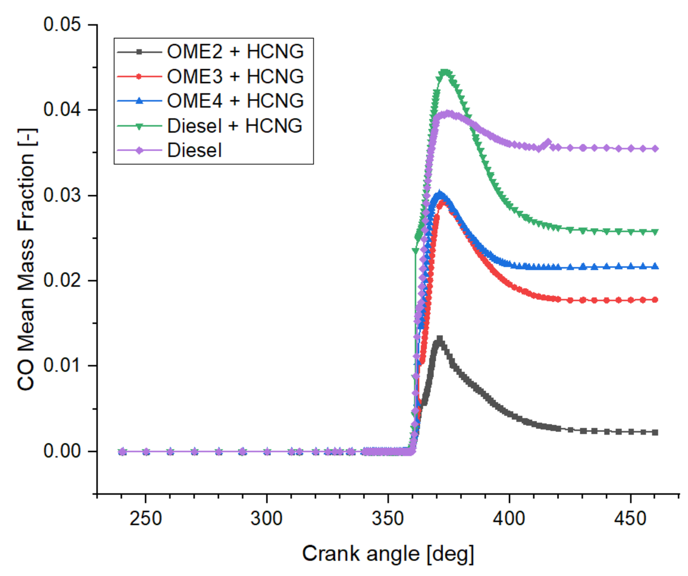

Fig. 6: CO emission for different fuel configurations

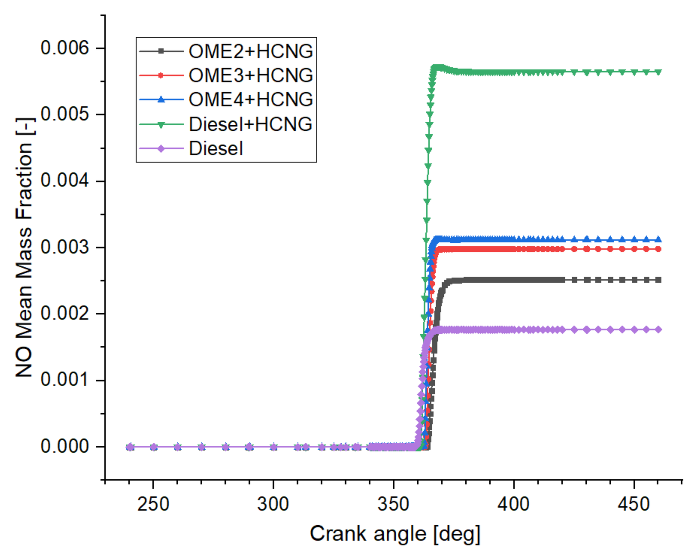

Fig. 7: NO mean mass fraction for different fuel configurations

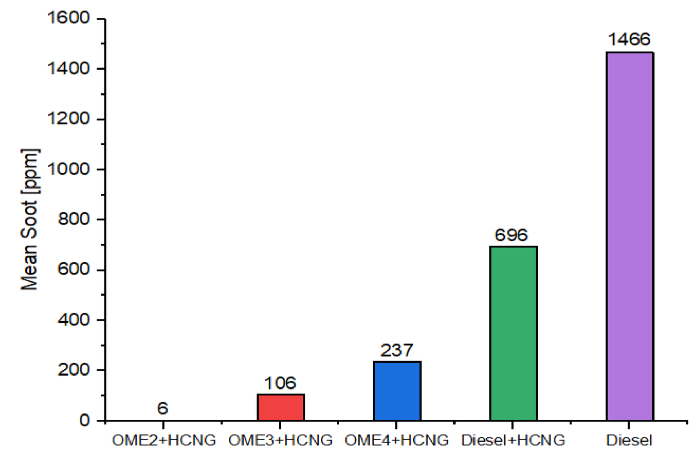

Fig. 8: Mean Soot production for different fuel configurations at final point

- Workflow manager module of AVL Fire is used for the simulation.
- Temperature distribution is uniform in diesel RCCI rather than a typical diesel.
- CO mean mass fraction is the highest in a typical diesel engine.
- Diesel RCCI has produced the most NO emission and the typical diesel has the lowest.
- Soot particles are produced much more in a typical diesel engine rather than RCCI ones.

Conclusions and Outlook

- By increasing OME chain length, the heat release duration in the diffusion combustion becomes longer.
- Hythane in OME$_n$ and diesel fuel leads to a homogenous charge in the combustion chamber and finally leads to a complete combustion.
- The amount of CO extremely increases by lengthening OME chain length due to the reduction in H/C ratio. However, the presence of Hythane has a positive effect on the reduction of CO compared to the diesel case.
- The soot mean production extremely decreases with adding Hythane to diesel fuel and OME. The presence of Hythane has a noticeable effect on H/C increase in RCCI configurations. Moreover, lack of C-C bonds in OME fuels is effective, too.

References

[1] Mobasheri R. Analysis the ECFM-3Z Combustion Model for Simulating the Combustion Process and Emission Characteristics in a HSDI Diesel Engine. International Journal of Spray and Combustion Dynamics 2015;7(4):353–71.

[2] Hanjalic, K., Popovac, M., Hadziabdic, M., "A Robust Near-Wall Elliptic-Relaxation Eddy-Viscosity Turbulence Model for CFD," International Journal of Heat and Fluid Flow, Vol. 25, 2004, pp. 1047-1051

[3] Miller, R., et al. "A super-extended Zel'dovich mechanism for NO x modeling and engine calibration." SAE transactions (1998): 1090-1100.

M.Sc. Ali Navid
TU Bergakademie Freiberg | Institute of Thermal Engineering
Gustav-Zeuner-Straße 7| 09599 Freiberg | Germany
Phone: +49 3731 39 3754 | ali.navid@iwtt.tu-freiberg.de | www.gwa.tu-freiberg.de