Computational methods in combustion

Simulation of gaseous combustion in Diesel-type engine

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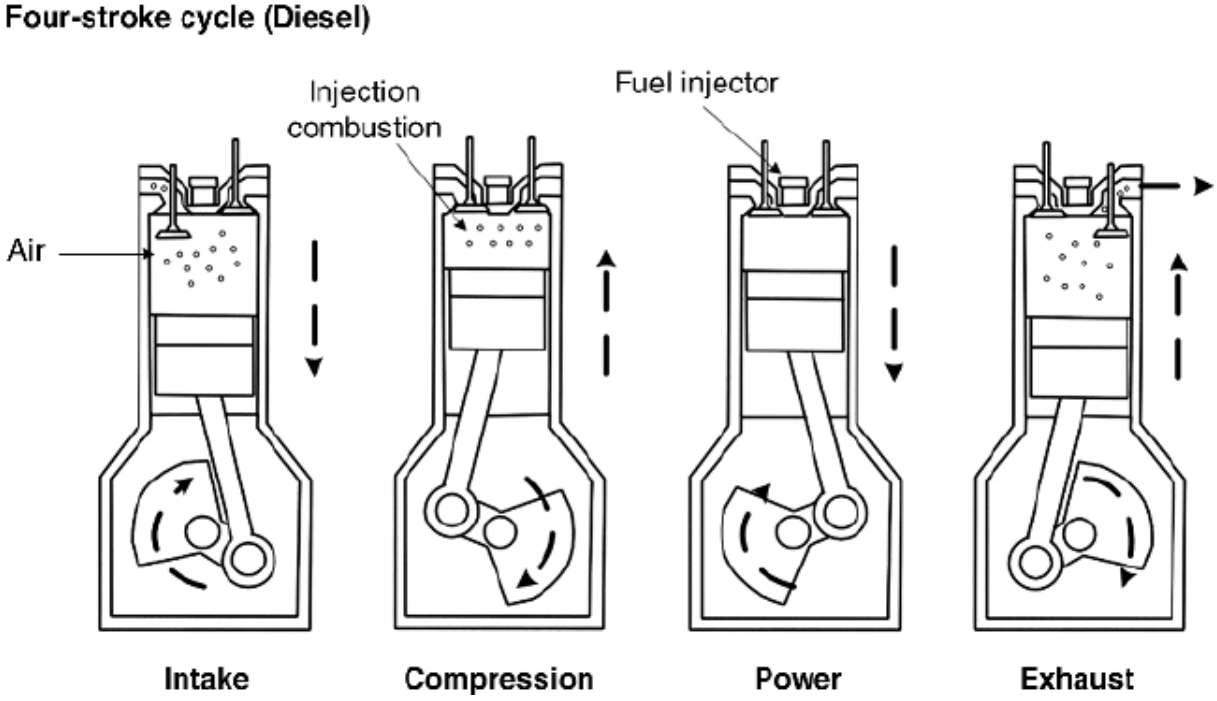
1. Introduction

In this project there is simulation of combustion in Diesel-type engine. In this simulation as a fuel is used dodecane, hydrocarbon with twelve atoms of carbon. Simulation is of course an approximation and it is more simple than in real. Obtained parameters from this simulation are heat release per one cylinder, expansion power per cylinder, estimated efficiency and estimated CO emission. Moreover there will be some plots, ex. pressure and temperature in function of crankshaft angle.

Below is a brief reminder of how a compression ignition four-stroke engine works.



[Pic.1] Picture of four-stroke cycle.

Intake – this stroke of the piston begins at top dead center and ends at bottom dead center. In this stroke the intake valve must be in the open position while the piston pulls an air-fuel mixture into the cylinder.

Compression – this stroke begins at bottom dead center or just at the end of the suction stroke (intake), and ends at top dead center. In this stroke the piston compresses the air-fuel mixture in preparation for ignition during the power stroke.

Combustion – at this point the crankshaft has completed a full 360 degree revolution. While the piston is at top dead center the compressed air-fuel mixture is ignited by heat generated by high compression. This stroke produces mechanical work from the engine to turn the crankshaft.

Exhaust – the piston, once again, returns from bottom dead center to top dead center. This action expels the spent air-fuel mixture through the exhaust valve.

2. Model

First to be mentioned are main ambient and fuel parameters such as temperature and pressure.

Ambient parameters :

- T = 293 K
- p = 1013,25 hPa

Fuel parameters (injector) :

- T = 300 K
- p = 1600 bar

Secondly the parameters of the model, so the engine and its cylinders.

Name of parameter [unit]	Symbol	Value
Engine speed [rpm]	n	3500
Displacement volume [m^3]	V_s	$0{,}5 \cdot 10^{-3}$
Compression ratio [-]	ε	20
Piston diameter [m]	D	0,082

[Tab.1] Main engine parameters.

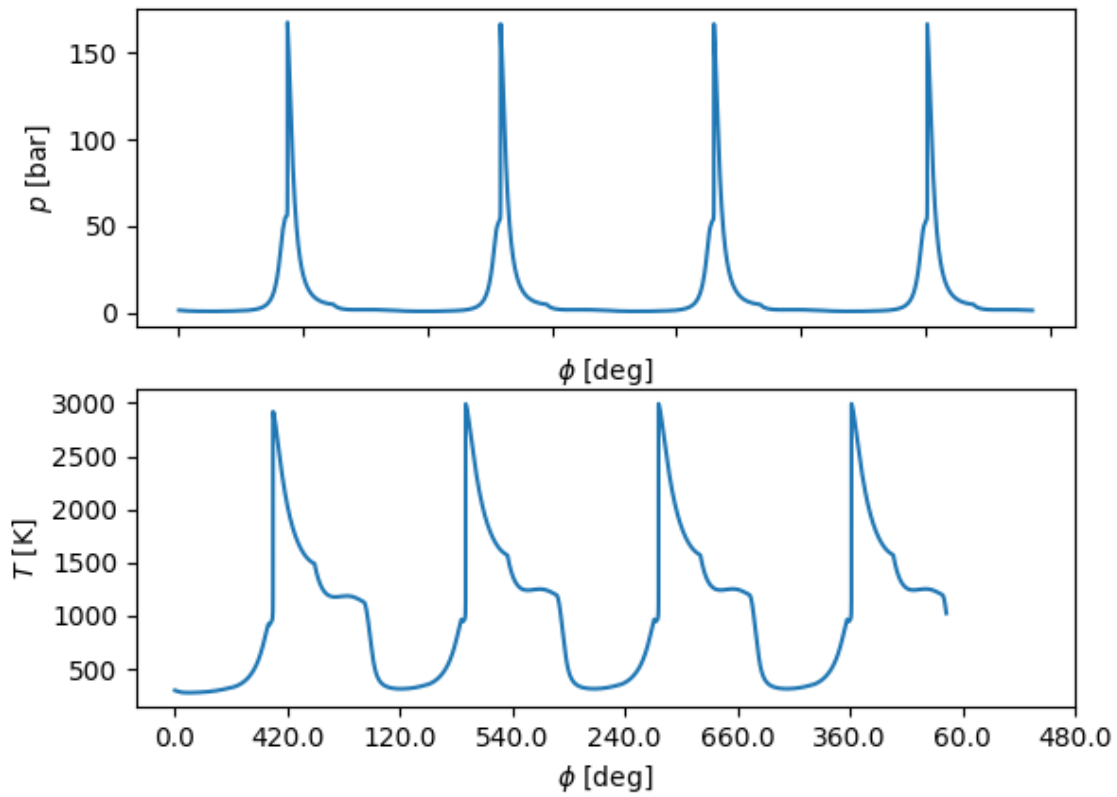
Stoichiometric equation representing dodecane-air combustion is given as followed :

$$C_{12}H_{26} + 18{,}5(O_2 + 3{,}76N_2) \rightarrow 12CO_2 + 13H_2O + 69{,}56N_2$$

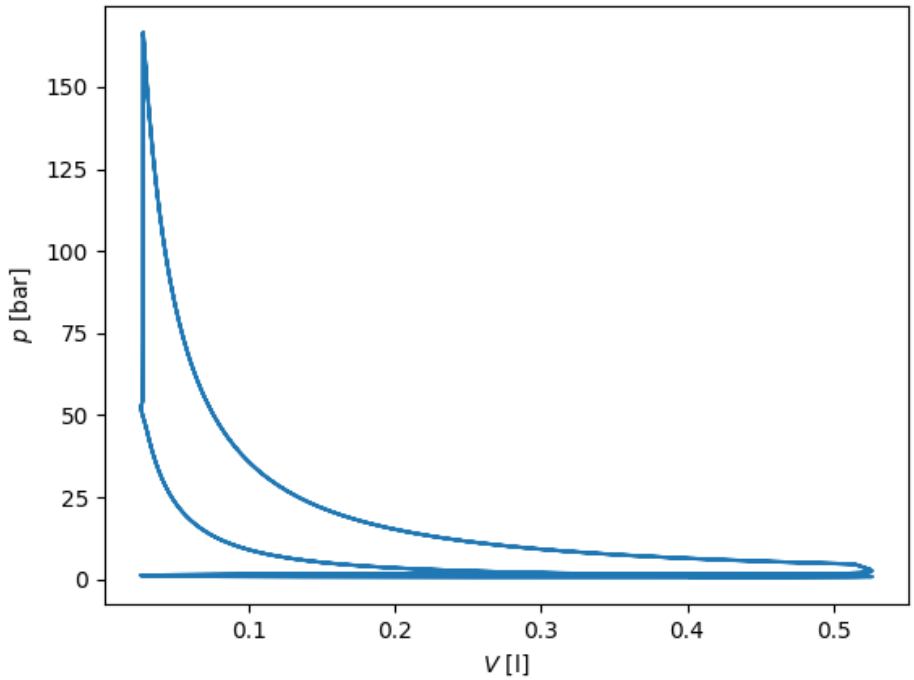
In this simulation piston is modeled as a planar wall.

3. Results

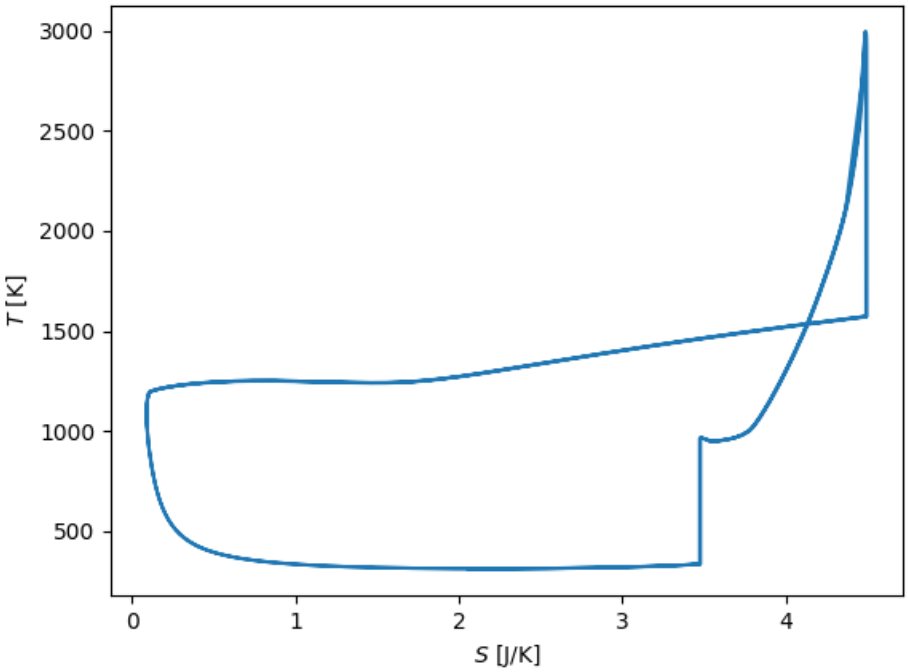
The simulation results consist of five diagrams and four parameter values describing the properties of the engine.



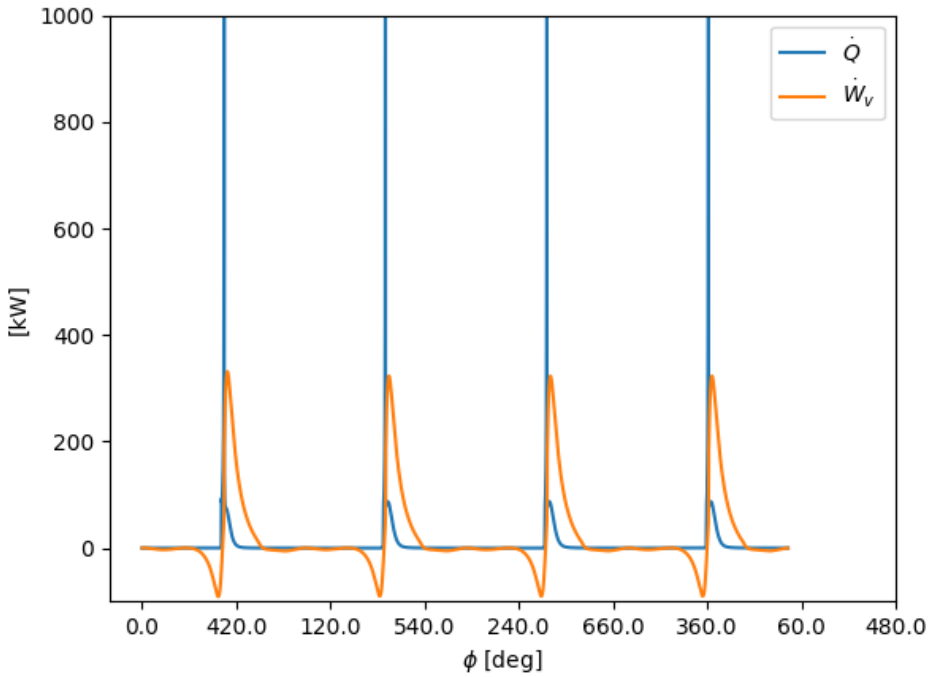
[Fig.1] Figures of pressure and temperature in function of crankshaft angle.



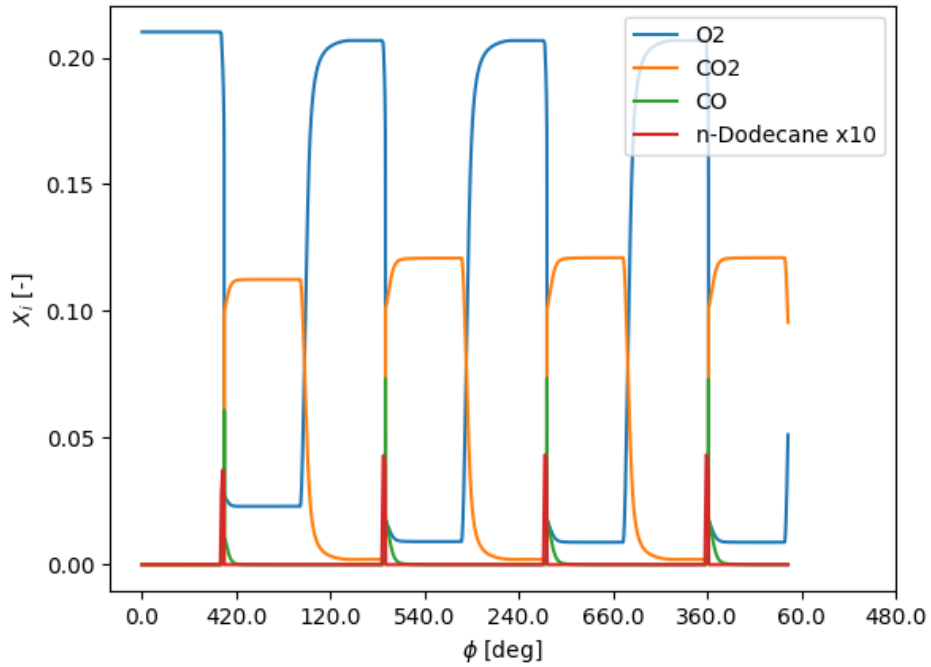
[Fig.2] Figure of pressure in function of volume.



[Fig.3] Figure of temperature in function of entropy.



[Fig.4] Figure showing heat of reaction and expansion work in function of crankshaft angle.



[Fig.5] Figure of gas composition in function of crankshaft angle.

Below there is a table consisting values of obtained parameters during this simulation :

Name of parameter [unit]	Symbol	Value
Heat release rate per cylinder [kW]	$\dot{Q}$	41.7
Expansion power per cylinder [kW]	$\dot{W}_v$	21.0
Efficiency [%]	η	50.3
CO emission [ppm]	-	46.0

[Tab.2] Table of obtained parameters.

4. Summary

The results seem to be a good illustration of the behaviour of the main gas parameters while the engines is running, despite some simplifications. We can observe the rapid increase in pressure and temperature in combustion stroke after ignition and repeatability of this process. Figure p(V) depart from theoretical Diesel cycle figure, but the major shape is remaining and what is important it is more similar to real one. Figure T(s) depart much more from theoretical one. Figure with heat of reaction and expansion work also have well-placed peaks comparing with crankshaft angle. In last figure we can observe when the inlet and outlet valves are open, while looking at increasing blue (O_2) and orange (CO_2) lines.

5. Bibliography

[1] https://cantera.org/tutorials/python-tutorial.html [access : 26.05.22]

[2] M. Gieras “Spalanie – Wybrane zagadnienia w zadaniach” , Warszawa 2011

[3] https://en.wikipedia.org/wiki/Four-stroke_engine [access : 26.05.22]