International Journal of Research in Engineering, Science and Management
Volume-1, Issue-11, November-2018
www.ijresm.com | ISSN (Online): 2581-5792

CFD Simulation of Reactivity Control Diesel and Gasoline Engine

Prakash Shakti[1], J. Raval Dhruv[2], Rana Rajveersinh[3], Panchal Deepkumar[4]
[1]*Assistant Professor, Department of Automobile Engineering, KJIT, Vadodara, India*
[2,3,4]*UG Student, Department of Automobile Engineering, KJIT, Vadodara, India*

***Abstract*: As we all know about diesel engine is capable to get power and torque but it increases environment pollution such as high emission of oxides of nitrogen (NOx) and particulate matter (PM). The objective of Reactivity Controlled Compression Ignition (RCCI) engine is to get better combustion of fuel, lower the emission and to achieve higher thermal efficiency.**

***Keywords*: Dual Fuel, RCCI, Diesel, Gasoline, Carburetor, Fuel Injector.**

1. Introduction

- Diesel engine are widely used for transportation and power generation applications because of their high fuel efficiency. However, diesel engine can cause environmental pollution owing to their high NOx and soot emissions.
- Accordingly, reduction of NOx and soot in-cylinder has been investigated by many researchers. Most of the current strategies can be placed in the category of premixed Low Temperature Combustion (LTC).
- Lower combustion temperature result in NOx reduction due to the high activation energy of the NO formation reactions.
- In effort to reduce NOx and soot emissions in-cylinder, while maintaining high thermal efficiency, many new compression ignition combustion strategies have been proposed.
- One of the simplest method of achieving low NOx and soot emission in a CI engine is HCCI combustion. Although HCCI combustion appears to be thermodynamically attractive, the controllability challenge raised by the HCCI concept over conventional engines, which results from the near constant volume combustion, leads to very rapid rates of heat release and hence a very rapid rates of pressure rise

A. Some of the problems which introduce RCCI engine

- HCCI has drawn tremendous attention of engine researchers due to its ideal combustion and emission performance. The fundamental idea of HCCI is to combine the advantages of SI and DICI engines while to avoid their disadvantages, as SI engine features low soot emission but low thermal efficiency, DICI engine employs high thermal efficiency but high level NOx-soot trade-off relation.
- However, some challenges in HCCI design and control keep it from to be commercialized and play its role as in car engine combustion to save energy and reduce pollutants. The most challenging problems facing HCCI commercialization are combustion phasing control and high pressure rise rate. To address this issue, RCCI was recently proposed by Kokjhon.
- It employs port-injection with low reactivity fuel (i.e. gasoline) and direct-injection with high reactivity fuel (i.e. diesel) to hopefully control the combustion by changing premixed fuel ratio and direct injection timing.
- To commercialize RCCI, a large amount of design and calibration with various fuel and different controlling strategies should be conducted.

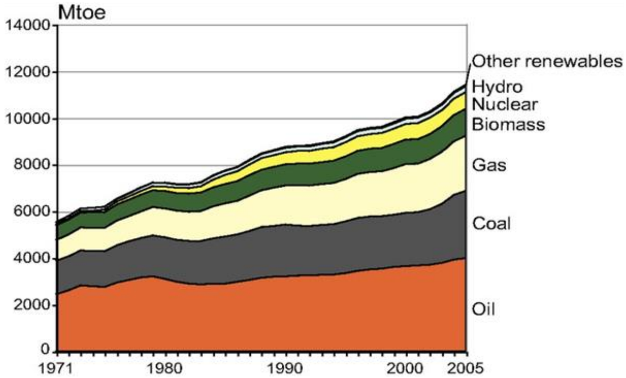


Fig. 1. Global Energy demand by fuel type

B. Project details

RCCI combustion has been investigate on Heavy duty (HD) and light Duty (LD) engines. This invention relating generally to reduction of emission such as particulates and NOx in internal combustion engine and more specifically to emission reduction in compression ignition (CI or Diesel) engines.

Common pollutant arising from the use of internal engine are nitrogen oxides (NOx) and particulates. NOx is generally associated with high temperature engine conditions and may be reduced by use of measures such as exhaust gas recirculation (EGR), where in engine intake air is diluted with relatively inert exhaust gas. This reduce the oxygen in the combustion region and obtains a reduction in maximum combustion temperature, thereby deterring NOx formation.

Particulates includes a variety of matter such as elemental carbon, heavy hydrocarbons hydrated sulfuric acid, and other large molecules, and are generally associated with incomplete combustion. Particulates can be reducing by increasing combustion and/or exhaust temperature, or by providing more oxygen to promote oxidation of soot particles.

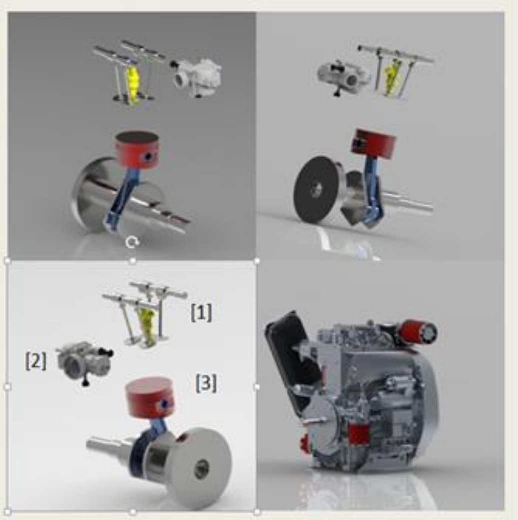
Unfortunately, measure which reduce NOx tend to increase particulate emission and measures which reduces particulates tends to NOx emission resulting in what is often termed the soot- NOx trade-off.

There are two different types of fuel required for the RCCI engine, where fuel required would be one primary fuel and other will be secondary fuel. Where the primary fuel required for the RCCI engine, where fuel required would be one low reactivity fuel (i. e. Gasoline) and secondary fuel will be high reactivity fuel (i. e. Diesel) to fulfill requirement of engine.

The primary fuel will be used through port-injection with low reactivity fuel (i.e. Gasoline) and secondary fuel will be used through direct-injection with high reactivity fuel (i. e. Diesel).

2. Engine design and specification

A. Design of engine



1: Inlet Valves, Exhaust Valves & Injector 2: Carburettor 3: Crankshaft & Piston Connecting Rod
Fig. 1. Engine Design

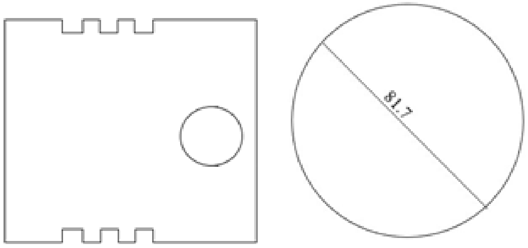


Fig. 2. Piston and cylinder design

Diameter of Cylinder is 81.7mm

Table 1
Engine Specifications which will be used in project

Engine Type	Direct injection, Air cooled
No. of cylinder	1
Displacement CC	435 CC
Material	Aluminum
Max. Power	6 KW @ 3600 rpm
Max. Torque	21 Nm @ 2000-2400 rpm
Weight (Kg)	50 kg
Bore/ Stroke	78 mm/ 68 mm
Compression Ratio	18:1
Oil sump Capacity (litre)	1
Lub. Oil consumption (gm/hr)	13 ltr
Dry weight (Kg)	43 kg

B. Design of air intake system from carburetor and calculation detail

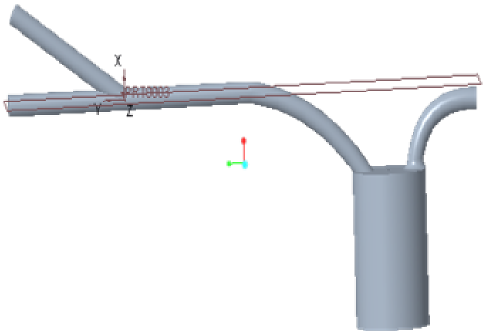


Fig. 3. Design of combustion chamber

Table 2 (a)
Data input for calculation

Air Fuel motion (flow)	
3 Fuels	Gasoline, Diesel and Air
Air velocity	0.6 m/s
Diesel	0.7 m/s
Petrol	0.9 m/s

Table 2 (b)

Combustion (Input Data) Gasoline	
Air Speed	2 m/s
Fuel Speed	80 m/s
Composition- Gasoline	1% fuel
Air consumption (Oxygen)	0.23%

Table 2 (c)

Combustion (Input Data) Diesel	
Air Speed	2 m/s
Fuel Speed	80 m/s
Composition- Diesel	97.5% fuel
Air consumption (Oxygen)	0.23%

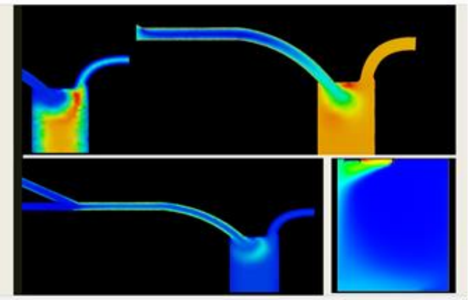


Fig. 4. Simulated gasoline and diesel combustion

3. Calculated result

Table 3
Fuel properties used in RCCI engine

Property	Unit	Diesel	Gasoline
Density	(Kg/m^3)	820	682
Octane/Cetane Number		45-55	85-95
Lower heating value	(MJ/Kg)	42.31	42.4
Viscosity	(cSt)	2.87	0.44
Final Boiling point	(°C)	369.8	78
Molar mass		104	109
Stoichiometric (A/F) mass		14.6	14.7
Stoichiometric mixture density	(Kg/m^3)	1.46	1.42
L.H.V.	(MJ/Kg)	42.7	43.5
L.H.V. of Stoichiometric mixture	(MJ/Kg)	2.75	2.85
Combustion Energy	(MJ/m^3)	36	42.7
Flammability limit in air	(vol% in air)	1-6	1.4-7.6
Flame Propagation speed	(m/s)	-	0.5
Adiabatic Flame temperature	(°C)	2054	2150
Auto-ignition temperature	(°C)	316	258
C%	(W/W)	86	85
H%	(W/W)	12.935	15
S%	(W/W)	1	-

1) Eddy Viscosity

Eddy Viscosity is a coefficient that relates the average shear stress within a turbulent flow of water or air to vertical gradient of velocity.

- Maximum eddy viscosity will be 2.089 $Pa{\cdot}S$.
- Minimum eddy viscosity will be 1.441 $Pa{\cdot}S$

2) Pressure Analysis

Pressure is a continuous physical force exerted on or against an object by something in contact with it.

- Maximum pressure will be 5.134 Pa.
- Minimum pressure will be 4.913 Pa

3) Turbulence Kinetic Energy

Turbulence kinetic energy means kinetic energy per unit mass associated with turbulent flow.

- Maximum turbulence kinetic energy will be 3.599 $m^2{\cdot}s^2$.
- Minimum turbulence kinetic energy will be 1.800 $m^2{\cdot}s^2$

4) Velocity during intake valve open

Velocity is the speed at which something moves in a particular direction.

- Maximum velocity will be 1.665 m/s^2.
- Minimum velocity will be 1.294 m/s^2.

5) Velocity during exhaust valve open

Velocity is the speed at which something moves in a particular direction.

- Maximum velocity will be 3.342 m/s^2.
- Minimum velocity will be 1.791 m/s^2.

6) Velocity till intake port

Velocity is the speed at which something moves in a particular direction.

- Maximum velocity will be 1.816 m/s^2.
- Minimum velocity will be 0 m/s^2.

A. Analysis of different gases during combustion and exhaust

1) CO_2 mass fraction

- In Ordinary Diesel engine CO is generated when the Lean mixture is entered in the cylinder.
- Approximate 12% of CO is generated in Diesel engine.
- In RCCI Engine CO is not generated much, as compared to normal engine.
- In RCCI engine the generation of CO will decreases up to 25% than normal Diesel engine.
- In RCCI engine generation of CO will be Approximate 8.5 – 9%.

2) H_2O mass fraction

- In normal Diesel engine the generation of H2O is approximate 12%.
- The H_2O will generate in exhaust manifold by mixing oxygen and hydrogen.
- In RCCI engine the generation of H2O will be approximate 15%-17%.

3) N_2 mass fraction

- In Diesel engine the percentage of generation NOx is Approximate 70%.
- NOx is generated when High temperature combustion of fuels is held, where the temperature riches at (above 1300ºC-2370ºC).
- In RCCI engine the NOx will reduces at max. To 25%.
- The NOx will be generated by RCCI at Approximate 43% to 48%.

4) Mass fraction of pollutant NO

- In Diesel engine the percentage of generation NOx is Approximate 70%.
- NOx is generated when High temperature combustion of fuels is held, where the temperature riches at (above 1300ºC-2370ºC).
- In RCCI engine the NOx will reduces at max. to 25%.
- The NOx will be generated by RCCI at Approximate 43% to 48%.

B. Purpose of choosing this project

- As we all know that we don’t get 100% of anything, if we try to get better efficiency then we are unable to get proper power or torque as per requirements.
- So we are try to get both the things at the same time in the same engine where we are able to achieve the better efficiency and power all from the same engine.

- Some researchers are trying to get the same things but by different fuels such as rice oil + diesel, biodiesel + diesel, so we thought that what if we try to put petrol in diesel engine by some minor proposition of petrol from 1.56 to 10.5% with diesel into the diesel engine.

Table 4
Results

	Before	After
Compression Ratio	18:1	16.1:1
C %(w/w)	86	26.7
H %(w/w)	12.935	14.096
S %(w/w)	1	1.125
NO	77 %	43-48 %
N_2	70	42.5-45.7 %
H_2O	12 %	15-17 %
CO_2	12 %	8.5-9 %
Soot Particles	1.37 mg/(10 mins)	0.41 mg/(10mins)

4. Advantages

RCCI permits optimization of HCCI and Premixed Controlled Compression Ignition (PCCI) type combustion in diesel engines, decreasing emissions without the need for after-treatment methods. By suitably choosing the reactivity's of the fuel charges, their comparative amounts, timing and combustion can be custom-made to achieve optimal power output (fuel efficiency), at controlled temperatures (controlling NOx) with controlled correspondence ratios (controlling soot). Key benefits of the RCCI engine include:

- Lowered NOx and PM emissions
- Reduced heat transfer losses
- Increased fuel efficiency
- Eliminates need for costly after-treatment systems
- Fulfils with EPA 2010 emissions guidelines without exhaust after treatment

5. Conclusion

Experimental work on a single-cylinder HD diesel engine with the dual fuel strategy and a "single fuel" strategy were presented, comprising low load to high load operation. A review of experimental and modeling work in the field of high efficiency, low emissions engines has been conducted. Dual fuel reactivity-controlled compression ignition combustion in HD and LD diesel engines was focused on, due to its demonstrated superior control, compared to other strategies with discussion of the operating range, thermal efficiency and emission benefits. This work further demonstrates that uses two fuels with different reactivity's. The present study used PFI of commercially available diesel fuel. The RCCI concept has been shown to provides improved control over the combustion process and to allow high-efficiency and low emission operation over a wide range of speeds and loads. The improved control over the start- and end-of-combustion was highlighted by exploring adiabatic operation with the CFD modelling. It was found that when HT is removed the RCCI combustion process converts 14 per cent more of the recovered HT energy into useful work than conventional diesel operation.

References

[1] Reitz RD. Directions in internal combustion engine research. Combust flame 2013; 160(1):1-8.
[2] Kokjohn SL, Hanson RM, Splitter DA, Reitz RD. Experiment and modelling of dual-fuel HCCI & PCCI combustion using in-cylinder fuel blending, SAE Int I Engines 2010; 2(2); 24-34.
[3] Kokjohn SL, Hanson RM, Splitter DA, Reitz RD. Fuel reactivity controlled compression ignition (RCCI), a pathway to controlled high-efficiency clean combustion. INT I Engines 2011; 12(3); 209-39.
[4] Kokjohn SL, Reitz RD. Characterization of dual-fuel PCCI combustion in a light-duty engines, in: USA: international multidimensional engines modelling user's group meeting at the SAE congress, 2010.
[5] Reitz RD, Ganesh Duraisamy. Review of high efficiency & clean reactivity controlled compression ignition (RCCI) combustion in internal combustion engines, Elsevier Ltd. 2015; 46(15) 12-71.
[6] Study on RCCI (reactivity-controlled compression ignition) engine by means of statistical exp. Design.