International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 10, October - 2013

CFD Analysis of combustion characteristics of Jathropha in compression ignition engine

Irwin Osmond Toppo

Indian Institute of Science, Bangalore

Abstract

Computational fluid dynamics (CFD) code FLUENT is used to model the complex combustion phenomenon in compression ignition engine. Temperature profile and Nox produced inside the combustion chamber is compared for Jathropha with conventional diesel fuel. Simulation results obtained is validated experimentally for both Jathropha and conventional diesel on test diesel engine. Simulation is carried out in Ansys- fluent using Non premixed combustion model to cater actual in cylinder combustion parameters. Two dimensional combustion chamber with deformation mesh is used for simulation.

Introduction

A lot of experimental data has been published in the past on combustion, performance and emissions for diesel and Biofuel on Diesel engine. Harun Mohamed Ismail [1] successfully predicted in-cylinder parametrs. In terms of pollutants, Nox and Soot formed with diesel is in line with the experimental results for Diesel with slight variations. Experimental work done by G Lakshmi et al [2] using Biodiesel shows decrease in emissions which is good in terms of pollution control however with slight a decrease in power for various reasons like high viscosity which hampers the atomization of the fuel with air leading to incomplete combustion. Another experimental work done by Jinlin Xue et al [3] on the effect on biodiesel on engine performance and emissions reveals that use of biodiesel leads to the substantial reduction in CO (carbon monoxide) emissions accompanying with the imperceptible power loss, the increase in fuel consumption and the increase in Nox emissions on conventional diesel engines with no or fewer engine modification.CFD modeling is broadly used by engine researcher to explore in-cylinder flow fields. CFD investigation on the auto–ignition of diesel fuel using detailed kinetics was successfully conducted by Golovitchev et al [4]. In computation front S.Som et al [5] used Fluent to study the use of Biofuel on performance and emissions characteristics of compression ignition engine by studying the spray behavior of the fuel which govern the air- fuel mixture and is important parameter for combustion.

Combustion Geometry and Modeling

The computational domain dimensions are in line with the actual experimental test engine. Computational domain has been modeled and meshed and preprocessed in Gambit. Two dimensional model of combustion chamber for simulation is designed. Combustion problem is solved as unsteady, first order implicit with consideration of turbulence effect. The numerical methodology is the segregated pressure based solution algorithm. For solving species discrete phase injection and Non Premixed combustion model along with PDF model is used because it predicts the formation of intermediate species. Important parameters like rich flammability limit is obtained experimentally, the first order upwind scheme is

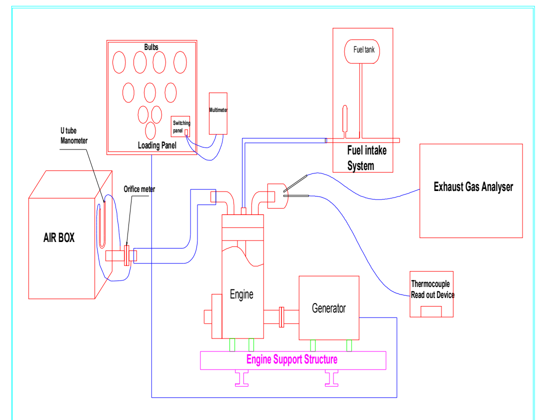
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 10, October - 2013

employed for discretization of the model equations. The governing equation for continuity, momentum and energy equation are used with appropriate initial boundary conditions. Well known RNG K-ε model is used for modeling turbulence. To predict NOx emission transport equation for Nitric Oxide (NO) concentration is solved. The NOx transport equations are solved based on given flow field and combustion solution. The formation of NOx can be attributed to four distinct chemical kinetic processes: Thermal NOx formation, Prompt NOx formation, fuel NOx formation and intermediate N2O.Thermal NOx is produced by the oxidation of atmospheric nitrogen present in the combustion air. Prompt Nox is produced by the high speed reactions at the flame front, the fuel NOx is produced by the oxidation of nitrogen contained in the fuel. At elevated pressure and oxygen rich conditions, NOx may also be formed from molecular nitrogen (N2) Via N2O.Mass transport equation are solved for the NO species, taking into account convection, diffusion , production and consumption of NO and related species. For thermal and prompt NOx mechanisms, only the NO species transport equation is needed.

$$\frac{\partial}{\partial t}(\rho Y_{\mathrm{NO}}) + \nabla \cdot (\rho \vec{v} Y_{\mathrm{NO}}) = \nabla \cdot (\rho \mathcal{D} \nabla Y_{\mathrm{NO}}) + S_{\mathrm{NO}}$$

Experimental Set up

Experiment was conducted in a single cylinder four stroke air cooled vertical diesel engine of 5.9 kW rated power and 1500 rpm rated speed. Accurate measurements of exhaust temperature, fuel flow rate was done. Emissions of Bio Diesel and Diesel were measured using Gas Analyzer. Constant speed load test was conducted on the engine and the measurements above mentioned were taken under different load.



Schematic of the Experimental Set up

Experiment schematic is shown above. Set up consists of Air box of size approximately 500 times the volume of engine cylinder. The idea is to make the air inflow free from any pulsation. The engine shaft is attached to the AC generator .Electrical loading is applied to the engine using AC generator. Temperature and emissions of the exhaust gas are measured using thermocouple and Gas analyzer respectively. While conducting experiment room conditions have been kept constant, proper ventilation have been provided to make the ambient free from exhaust emission which may affect the emission reading.

Results & Discussion

Simulation results shows temperature contours inside the combustion chamber at different crank angle for Jathropha and Diesel .

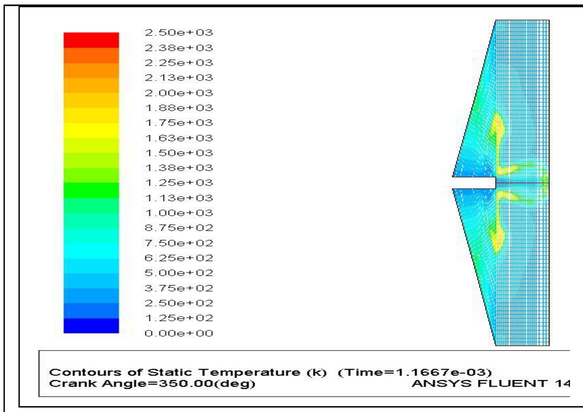


Fig-1.a: Contour of Static temperature for Diesel

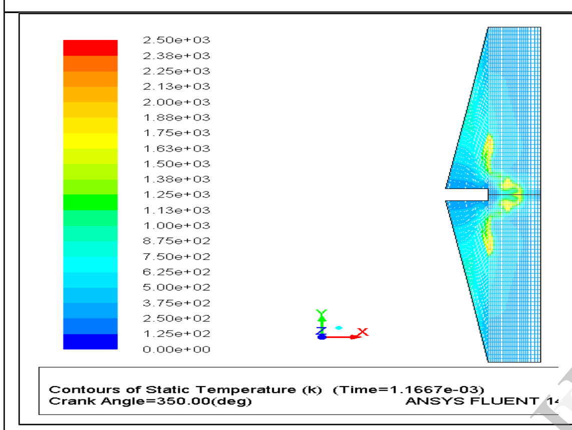


Fig-1.b: Contour of Static temperature for Jathropha.

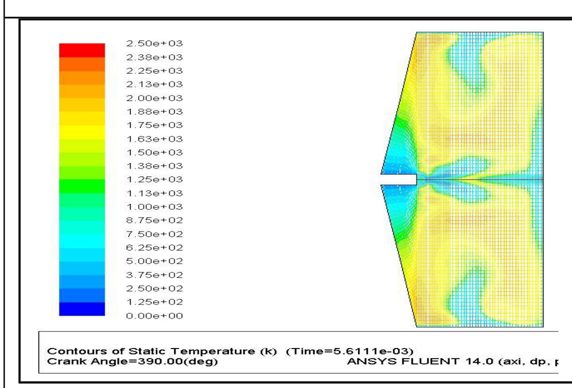


Fig-2.a: Contour of Static temperature for Diesel.

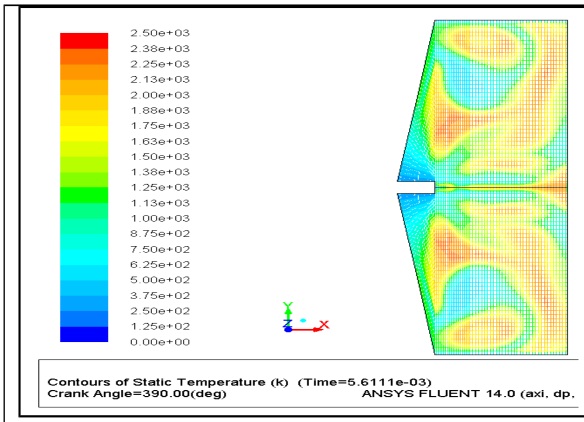


Fig-2.b: Contour of Static temperature for Jathropha.

Distribustion of temperature inside the combustion chamber represent the combustion.Fuel is injected into the combustion at 340 degree before top dead center. Maximum temperature is reached at 20 degree and 30 dergee after Top dead center for diesel and jathropha.

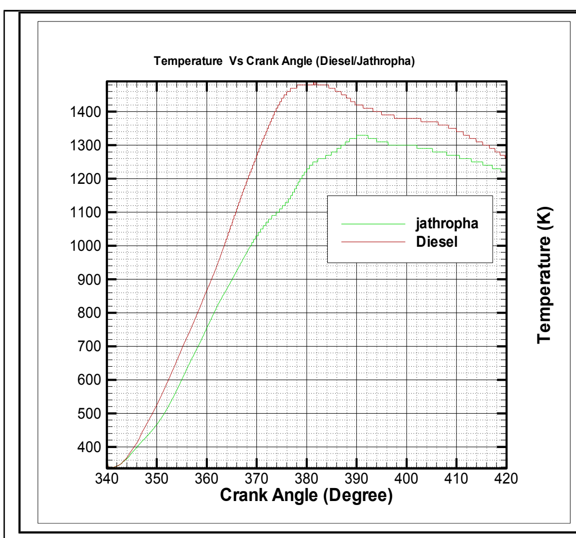


Fig-3 :Temperature Vs Crank Angle for Diesel and Jathropha

NOx formation

Nitric Oxid (NO) and Nitrogen dioxide (NO2) are grouped together as NOx emissions. The principal source of NO is the oxidation of atmospheric nitrogen which is present in air (Oxidizer). The high temperature and high oxygen concentration result in high NO formation rates. Nox forms wherever high temperature and high pressure burned gases equivalence ratio formed during combustion is close to stoichiometric. NOx formation is highly depended on temperature and fuel /air equivalence ratio of already burned gases. NOx formed for Jatropha is more compared to Diesel, one of the possible reasons for this is extra oxygen which Jatropha carries which combines with nitrogen to form NO Not having enough oxygen left to combine with nitrogen during combustion for diesel could be the reason for less NO formation in diesel combustion. As combustion proceeds in Jehropha the local burned gases equivalence ratio become leaner (closer to Stoichiometric) which is favorable condition for Nox Formation.

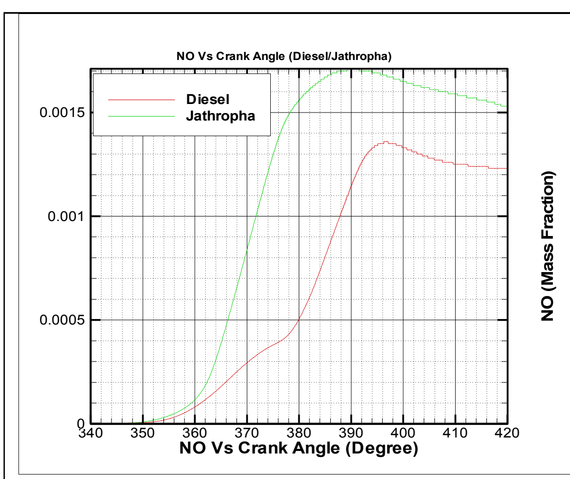


Fig-4: NO(Mass fraction) Vs Crank Angle for Diesel and Jathropha

Experimental and Simulation studies were performed to compare the performance and emission of Jatropha (Biofuel) in comparison to commercial Diesel. Experimental results shows that there is considerable increase in NO (28%) using Jatropha and simulation result shows increase of NO(29%).

Refrences

[1] Harun Mohamed Ismail,Hoon Kiat Ng, Suyin Gan . Evaluation of non-premixed combustion and fuel spray model for in-cylinder diesel engine simulation. ELSEVIER, Applied energy 90(2012),271-279

[2] Shaik Magbul , Dr. B.Sudheer Prem Kumar , Dr. K. Vijaya Kumar Reddy .CFD analysis of Combustion and emissions to study the effect of Compression ratio and Biogas substitution in a diesel engine with experimental verification.International Journal of Engineering Science and Technology ,ISSN :0975-5462 , Vol.4 No.2 February 2012

[3] G Lakshmi Narayana Rao, S Sampath , K Rajagopal. Experimental Studies on the Combustion and Emission Characteristics of a Diesel engine Fuelled with used cooking Oil Methyl ester and its Diesel blends. International journal of Engineering and Applied Sciences 4:2 2008

[4] Golovitchev VI , Tao F, Chomiac J. Numerical evaluation of soot formation control at direct-like conditions by reducing fuel injection timing , SAE paper,1998,1999-01-3552

[5] S.Som ,D.E. Longman , A. I. Ramirez , S.K. Aggarwal. A comparison of injector flow and Spray Characterstics of Biodiesel with Petrodiesel .Fuel 89(2010)4014-4024

[6] Hoon Kiat Ng, Suyin Gan. Combustion performance and exhaust emission from the Non-pressurised combustion of palm oil biodiesel blends.

ELSEVIER,Applied Thermal Engineering 30(2010)2476-2484

[7] Jinlin Xue,Tony E. Grift, Alan C. Hansen .Effect of biodiesel on engine performances and emissions.ELSEVIER,Renewable and Sustainable energy Reviews 15(2011) 1098-1116.

[8] Umakant V. Kongre, Vivek K. Sunnapwar. CFD Modelling and Experimental Validation of Combustion in direct ignition fueled with diesel. INTERNATION JOURNAL OF APPLIED RESEARCH , DINDIGUL Volume 1, No 3,2010

[9] Heywood JB. Internal Combustion engine fundamental .New York, Mcgraw –Hill, 1989

[10] Reitz RD, Spray Technology Short course, University of Wisconsin,1996

[11] Han Z, Uludogan A, Greogory JH, Reitz RD. Mechanism of Soot and Nox emission reduction using multiple –injection a diesel engine.SAE paper (1996) 960633

[12] Ali M .Poukhesalian 1, Amir H. Shamekhi, Farhad Salimi . Alternative fuel and gasoline in an SI engine . A comparative study of performance and emissions characteristics. ElSEVIER , Renewable and Sustainable energy reviews.

[13] K. Pramanik. Properties and use of Jatropha Curcas oil and diesel fuel blends in compression ignition engine.Renewable Energy,2003, vol 28, Iss 2,239-248

[14] Philipp A, Lang o, schutz R. and Weng V, 2002 .CFD Simulation of diesel injection and combustion, SAE,2002-01-0945

[15] Reitz R.D. and Rootland C.J. ,1998, Development and Testing of diesel engine CFD Model. Prog combust. Sci. Vol 21 , pp 173-196

[16] J-H Ng, Ng , S. Gan . Advances in biodieselfuel for application in compression ,ignition engines , Clean technology and Enviromental Policy (2009), doi:10.1007/s10098-009-0268-6

[17] A.K. agarwal . Biofuels (Alcohols and Biodiesel) applications as fuels for internal combustion engines, progress in energy and combustion science 33(3) (2007) 1772-16780

[18] Y. Ali, M.A. Hanna , LI. Leviticus, Emissions and Power characteristics of diesel engines on methyl soyate and diesel fuel blends, Bio resource technology 98(2)(2007) 241-246

[19] Golovitech VI, Yang J. construction of combustion models, for rapeseed methyl ester bio-diesel fuel for internal combustion engine applications. Biotechol Adv 2009,27: 641-55.

[20] Fluent 6.3.26 Documentation, User Guide. Fluent Inc: 2007

[21] Jinlin Xue,Tony E. Grift , Alan C. Hansen . Effect of biodiesel on engine performances and emissions. Renewable and Sustainable energy reviews 15 (2011) 1098-1116