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Computer Simulation of a D.I C.I Engine for Performance Analysis using Diesel-Biodiesel Blends

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Abstract

The investigation concerning the performance of a four strokes compression ignition diesel engine, which is powered by alternative fuels in the form of diesel and biodiesel blends of Calophyllum Inophyllum oil and Rubber seed oil, has been described in the present work. The combustion simulation model developed done by using C language. The developed simulation model used to estimate the engine performance such as cylinder pressure, brake thermal efficiency and engine emissions of Nox, CO and HC. In this paper, prediction of combustion parameters has used Honerberg's equation heat transfer model and Zero dimensional combustion model. Experiments were performed in a single cylinder direct injection diesel engine fuelled with blend of Calophyllum Inophyllum oil and Rubber seed oil for the proportion of B10, B20 and B30 by volume with diesel fuel for validation of simulated results. It was observed that there is a good agreement between simulated and experimental results which reveals that the simulation model developed predicts the cylinder pressure, brake power, thermal efficiency and emissions such as Nox, CO and HC characteristics of biodiesel fuel and engine specifications given as input. HC emission is decreased by about 3% when compared to the predicted by the simulation model.

Keywords— *Bio diesel, Simulation, Performance, Emission*

1. Introduction

In the field of Engineering & Technology there is intense research efforts are being carried out to identify the potential biodiesel to develop less polluting and more efficient engines. The process of making numerical simulation was preferred to study the combustion behavior and emission of C.I diesel engine because the experimental investigations were time consuming and costly affair. Computer simulations by computer based mathematical model have been proposed in the present work to study and understand the performance and emissions exhaust. The models proposed are one zone and multi zone models. In this paper the analysis of progressive combustion (PCS) using zero-dimensional single-zone model is used and assumed the entire combustion chamber is considered as single zone. In order to analyze the engine intake and exhaust by gas exchange processes are. This analysis is called Actual Cycle Simulation (ACS). In this analysis the intake and exhaust processes using fluid dynamic equations, heat transfers and friction are included by means of empirical equations. By means of this step-by-step approach of simulation, the values of pressure, volume and temperature at salient points in the cycle are calculated. Output is evaluated along with thermal efficiency. To check the compatibility of other properties produced biodiesel is tested. It has provided one more choice for alternative energy and commercialization.

2. Literature Review

The computer simulation is the process of formulating a mathematical model of a physical system using differential, algebraic and integral equations representing actual processes and analyzing by using a computer. Ganesan (1996) is the first who introduces Momani *et al*. (2009) the computer simulation in simplified way. It considerable reduces the time-consuming tests by narrowing down the variables that must be studied. It also helps in optimizing the engine design for a particular application, thereby reducing cost and time. This technique can be used partially; in some conditions oxygen can be feed into the combustion chambers to increase the engine performance. The effects on air-fuel ratios can be tested with the combination another fuel additives or mixtures. The first person who introduces computers to simulate the flow through engine gas exchange system is Heywood (1988). Kumanan and Raja (2008) the engine performance has simulate and analyzed by using Petri net aided software, a PETRI-PM. Heywood (1998) and Whitehouse and Benson (1979) analyzed Heat release rate based on first law of thermodynamics and state equation. They had proposed to use more easy models for the gas properties before, during and after combustion with accurate heat transfer model. Jung and Assanis (2001) have examined the effects of biodiesel on performance and emissions in diesel engine combined with a two zone combustion model to calculate performance and emission and optimize the engine operating parameters.

Rao and Ganesan (2010) the investigation has been carried out using the software STAR-CD. The bath tub, shallow and flat piston bowl shapes effect, for compression ratios of 11.2, 12 and 12.5, for intake port geometries like helical, tangential and straight for different engine speeds 1500, 2000, 2500 and 3000 rpm on the turbulence kinetic energy and swirl ratio has been studied. From the analysis of the flow field, shallow bowl seems to be preferable from the point of swirl ratio at lower compression ratio, but at higher compression ratio flat bowl shape is preferable (Kaliravna*et al*., 2010). Through statistical tools it is easy to interpret that what were the values of certain parameters when customers rated that particular engine as good, average or bad. Some of these tools used here are Standard Deviation (SD), Coefficient Of Variance (COV) and Lowest Normalized Value (LVN). The Standard Deviation (SD) and Lowest Normalized Value (LNV) of Indicative Mean Effective Pressure (IMEP) are determined through the analysis of in-cylinder pressure data of the engine. It has been observed that with second camshaft value of SD and LNV of IMEP is improved significantly which in turn shows improved combustion stability at idling in both fuel modes, Najafi*et al*. (2007) An Artificial Neural Network (ANN) was developed based on the collected data of this work.

Multi-Layer Perceptron network (MLP) was used for nonlinear mapping between the input and the output parameters. Kannan and Udayakumar (2009) based on the model description a computer program is developed using C program for the diesel cycle simulation to predict the cylinder pressure for the complete cycle and performance parameters can be effectively evaluated. A CFD studies on combustion and emission of diesel engine using Fluent is required to evaluate the emission data. The present work aims to develop a single zone zero dimensional model for direct injection diesel engines running with biodiesel – diesel blends, to predict the engine performance and emission characteristics. For experimental work conducted in a 4-stroke single cylinder compression ignition engine and compared with simulated results. The experimental results was very good were compare to simulation model developed.

3. Theoretical Prediction

3.1 Fuel injection rate

During the end of the compression stoke the fuel injected at the particular rate is calculated using the relation:

$$mf_i = Cd\,(p/4)\,dn^2\,(2DP_n/\rho f)^{0.5} \quad (1)$$

The first law of thermodynamics is used for the calculation of numerical model.

$$dQ - dW = dE \quad (2)$$

From the characteristics gas equation the pressure at each crank angle can be calculated using the relation:

$$pV = M\,R_{mol}\,T \quad (3)$$

The volume at each crank angle Vtheta is calculated using the relation:

$$V(THETA) = vdisp*[cr/(cr-1)-(1-\cos\Theta)/2+l/s-1/2*\sqrt{[(2l/s)^{\wedge}2-\sin^2\Theta]}$$

(4)

3.2 Heat transfer process

Heat transfer coefficient is one of the important parameter of the simulation which is between cylinder gases and wall. The calculation of heat transfer coefficient has used Hohenberg's correlation. It is given below,

h_{t1} = *pow (69626.179688*0.001/1000000,-0.06);*
h_{t2} = *PATM*(VPHT+1.4);*
h_{t3} = *pow (h_{t2}, 0.8);*
h_{t4} = *pow (Temp,-0.4);*
h_{tc} = *0.13* h_{t1}* h_{t3}* h_{t4};*

(5)

3.3 Combustion duration

The time taken of combustion varies according to the revolution of engine. It is given by empirical expression as below,

*Combustion duration=40 + 5 * (RPM / 600 - 1) + 166 * (ycc / y - 1.1)* ^{2}

(6)

3.4 Combustion model

Using wiebe heat release model the heat release rate has been calculated. Assuming that all the fuel is injected before the end of ignition delay period:

ROHR (dQc/dΘ) =a(m+1)*(Qav/COMBDUR)^m*[(Θ-SOC)/COMBDUR] ^m*exp [-a*(Θ-SOC)/COMBDUR] ^(m+1)]*
Where:
A = 6.908, M = 2& Qav = QP2
(Energy Release at Constant Pressure)
*QP2= (hrp1+N1*282800)*sf2*

(7)

3.5 Ignition delay

Ignition delay time has been calculated as the difference between the times at which combustion starts and the time at which injection starts. Ignition delay is function of mixture temperature, pressure, Air fuel ratio and fuel properties. The correlation proposed by wolfer's relation is used in the model:

*Ignition delay = [0.44*exp (4650/AT2)] / (AP2^1.19)*

(8)

3.6 NOx formation

The calculation of formation of nitric oxide inside each zone, a chemical equilibrium is used to calculate the concentration of various components under equilibrium conditions. In the present work extended Zeldovich mechanism is used for calculation of NOx formation. NOx formation is strong dependant on temperature and oxygen concentration:

$$d(NO)/dt = 6*10^6/T^{0.5} \exp(-69090/T)[O2]e^{0.5}[N_2]_e$$

(9)

The concentration of oxygen and nitrogen in the burned zone are given by:

$$[O_2]\ e = fO_2\ (P, T)\ [N_2]\ e = fN_2\ (P, T)$$

(10)

4. Experimental Description

The engine test rig is equipped with a Electrical dynamometer, used to apply the load on the engine. A adjustable depth of immersion electrode was provided for water rheostat with an to dissipate the power generated. At various loads starting from no load to full load condition at a constant rated speed of 1500 rpm the tests are conducted. At each load condition, the fuel flow rate and constituents of exhaust gases such as Hydrocarbon, Carbon Monoxide and Nitrogen Oxides, were measured with a 5 gas MRU Delta exhaust gas analyzer. The analyzer uses the principle of Non- Dispersive Infrared for the measurement of CO and HC emissions while NOx measurement was by means of electrochemical sensors. Combustion analysis were carried out by means of an AVL pressure pick-up fitted on the cylinder head and a TDC encoder fixed on the output shaft of the engine. The pressure and crank angle signals were send to computer.

Various combustion parameters like peak pressure and its acquaintance were obtained using data acquisition system. The properties of the fuel at various volumetric proportions as specified in Table.2. The engine was first operated with diesel oil to generate the baseline data followed by Calophyllum Inophyllum oil and Rubber seed oil methyl esters and their blends such as RSO 10, RSO 20, RSO 30 and CIO 10, CIO 20 and CIO 30 blends.

A. *Notation:*

BTHE : Brake thermal efficiency
BSFC : Brake specific fuel consumption
RSO : Rubber seed oil
CIO :Calophyllum Inophyllum oil
RSO 10 , CIO 10 : 10% of RSO, CIO and 90% of diesel
RSO 20, CIO 20 : 20% of RSO, CIO and 80% of diesel
RSO 30, CIO 30 : 30% of RSO, CIO and 70% of diesel

Table 1 Engine specifications

S.No	Make Kirloskar	Model TAF 1
1	Type Direct injection,	air cooled
2	Bore × stroke (mm)	87.5×110
3	Compression ratio	17.5:1
4	Cubic capacity	0.661 lit
5	Rated power	4.4 KW
6	Rated speed	1500 rpm
7	Start of injection	24° bTDC
8	Connecting rod length	220 mm
9	Injector operating pressure	220 bar

Table 2 Properties of CIO biodiesel

S.No	Properties	Testing Procedure	CIO 10	CIO 20	COI 30
1	Specific gravity	ASTM D4052	0.860	0.867	0.872
2	Calorific value MJ/kg	ASTM D240	37.50	38.25	39.20
3	Flashpoint °C	ASTM D445	120	112	108
4	Viscosity mm^2/s @ 40^oC	ASTM D93	5.35	4.97	4.83

Table 3 Properties of RSO biodiesel

S.No	Properties	Testing Procedure	RSO 10	RSO 20	RSO 30
1	Specific gravity	ASTM D4052	0.874	0.876	0.878
2	Calorific value MJ/kg	ASTM D240	36.50	37.15	37.80
3	Flashpoint °C	ASTM D445	114	109	102
4	Viscosity mm^2/s @ 40^oC	ASTM D93	5.81	5.23	4.89

5. Results and Discussion

The engine various performances including combustion and emission parameters are predicted using simulation model. The developed simulation model can be useful for both diesel and biodiesel blends. The simulation model serves as a versatile tool for a better understanding of the variables involved and their effect on engine performance and also it helps in optimizing the engine design for reducing cost and time. The test has conducted experimentally with various compression ratio, injection pressure and injection timing at constant speed of engine. It is list out in Table 1.

At injection timing of 21°bTDC and 24°bTDC and compression ratio of 17.5:1 and 16:1 also injector opening pressure of 200bar and 220bar and were tried for as RSO 10, RSO 20, RSO 30 and CIO 10, CIO 20 and CIO 30 blends. But from the investigation, the performance of the engine has very poor. Hence the engine were set to run at higher compression ratio of 19:1,advanced injection timing of 27°bTDC and higher injector opening pressure of 240bar. It arrives at the optimum range operating parameters for CIO 30 and RSO 30. It was observed that for CIO 30 and RSO 30 gives better performance for the optimized operating parameters. Finally the theoretical results of cylinder pressure, brake power, thermal efficiency and pollutants such as nitric oxide, carbon monoxide and hydrocarbon are validated with experimental results. The simulation model predicted results of performance and emissions have in close with experimental results.

Figure1 shows that the comparison of experimental and predicted cylinder pressure for CIO 30 and RSO 30 biodiesel blends and diesel fuel with respect to crank angle for various engine operating conditions. The predicted values and experimental values of cylinder pressure are at satisfactory level.

Figure 2 shows that the comparison of experimental and predicted brake thermal efficiency for CIO 30 and RSO 30 biodiesel blends with respect to brake power. The simulated values of brake thermal efficiency for all biodiesel blends are similar experimental brake thermal efficiency.

Figure 3 shows that the calculated and measured NOx (in ppm) with respect to the loads. NOx emissions are greatly dependant on the engine temperature. It is seen from the figure that the full load emission of NOx for diesel is 820 ppm and that of biodiesel blend with diesel is 120 ppm increases predicted by the simulation model. The experimental values are 1150 ppm for CIO 30 and 1160 ppm for and RSO 30 blends with diesel at 75% load.

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Figure 4 shows that the calculated and measured CO (in % vol) with respect to the loads. CO emissions are greatly dependant on the air fuel ratio relative to stoichiometric proportions. It is seen from the figure that the full load emission of CO for diesel is 0.49% and that of biodiesel blend with diesel is 0.2% predicted by the simulation model. Due to better combustion of biodiesel blends with diesel, CO emissions present in the exhaust are reduced.

Figure 5 shows that the load predicted by the simulation model and the experimental one. The biodiesel blend decreases the HC values increase of load as shown in Fig 5. HC emission is decreased by about 3%, estimated by the simulation model. Chain and substituted types of aromatic compounds in diesel, burns more slowly and produces higher amounts of unburnt hydrocarbons. The biodiesel blends is reduced the HC emission, due to better combustion of the fuel.

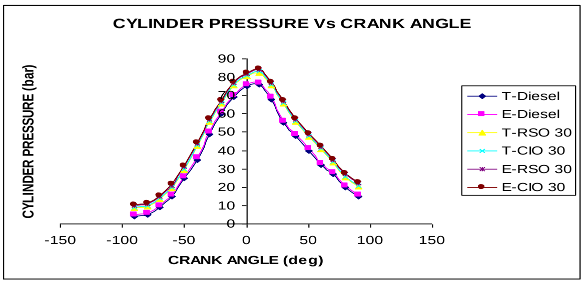

Fig.1 Comparison of experimental and predicted cylinder pressure for Diesel, RSO 30 and CIO 30 with respect to crank angle

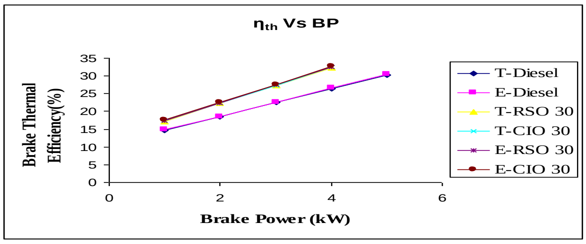

Fig.2 Comparison of experimental and predicted brake thermal efficiency for Diesel, RSO 30 and CIO 30 with respect to brake power

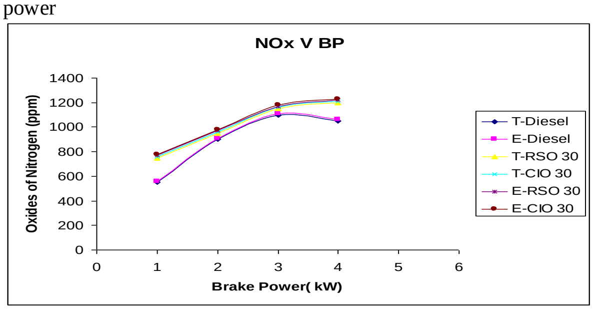

Fig.3 Comparison of experimental and predicted oxides of nitrogen for Diesel, RSO 30 and CIO 30 with respect to brake power

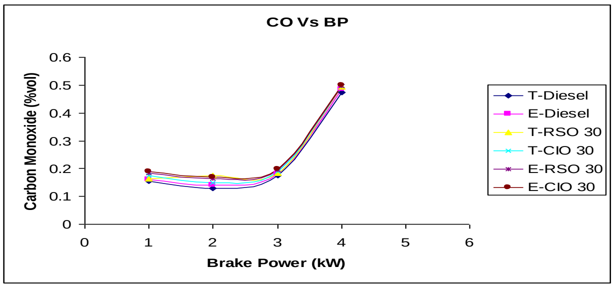

Fig.4 Comparison of experimental and predicted carbon monoxide for Diesel, RSO 30 and CIO 30 with respect to brake power

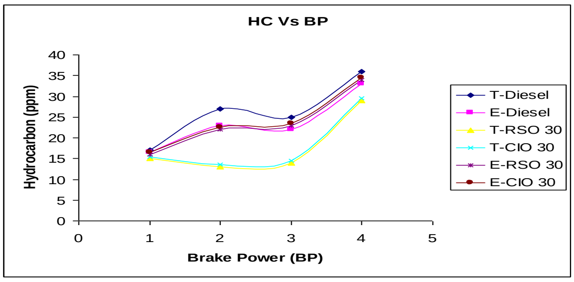

Fig.5 Comparison of experimental and predicted hydro carbon for Diesel, RSO 30 and CIO 30 with respect to brake power

6. Conclusion

In the present work a single zone zero dimensional model for direct injection diesel engine has been developed to predict the performance characteristics of D.I C.I single cylinder engine. The predicted results of performance and emissions have been in close with experimental results. The computer simulation model developed appears to be a useful tool for analyzing the diesel engine combustion accurately. Thus the developed computer model can predict the various performance and emission parameters of any vegetable oil esters with minimum inputs such as density, calorific value, chemical formula and engine specification. For the developed model has to be considered as a tool to calculate the effect of engine operating parameters such as injection pressure, injection timing and compression ratio. Finally the predictions revealed fair agreement with experimental results. Hence the C-programming language used to develop model is validated of given vegetable oil esters of Rubber seed and Calophyllum Inophyllum seed at various operating parameters of diesel engine.

References

[1]. Benson R.S., Whitehouse N.D., Internal combustion engines,Pergamon: Oxford, (1979).

[2]. Ganesan, V., Computer Simulation of Compression Ignition Engine Processes. 1st Edn. Published by University Press India Limited- Hyderabad, ISBN-10: 8173710155, pp: 231 (1996).

[3]. Jung, D. and D.N. Assanis, Multi zone DI Diesel spray combustion model for cycle simulation studies of engine performance and emissions. SAE 2001-01-1246, pp: 1-23 (2001).

[4]. Kaliravna, J.S., M. Nimbalkar, N.K. Jain and V.Ganesan, Combustion quality measurements at idling in a bi-fuel engine using statistical tools. Int. J. Green Energy, Energy Manage 1 (2010)

[5]. Kannan, K. and M. Udayakumar, Modeling of nitric oxide formation in cylinder direct injection diesel engine using diesel-water emissions. Am. J. Applied Sci., 6: pp 1313-1320 (2009).

[6]. Komintarachat, C. and S. Chuepeng, Methanolbased transesterification optimization of waste used cooking oil over potassium hydroxide catalyst. Am. J. Applied Sci., 7: 1073-1078 DOI: 10.3844/ajassp.2010.1073.1078 (2010).

[7]. Kumanan, S. and K. Raja, Modeling and simulation of projects with petri nets. Am. J.Applied Sci., 5: 1742-1749 (2008).

[8]. Momani, W., S. Abu-Ein, M. Momani and S.M. Fayyad, Effects of oxygenated gasoline on fuel and air mass flow rates and air-fuel ratio. Am. J. Applied Sci., 6: 974-977. DOI: 10.3844/ajassp.2009.974.977 (2009)

[9]. Ramadhas A .S., Jayaraj. S and Muraleedharan.C, "Theoretical modeling and experimental studies on biodiesel-fueled engine", Renewable Energy 31, pp.1813–1826 (2006).

[10]. Whitehouse, N. D. and Benson R.S., Internal Combustion Engines: A Detailed Introduction to the Thermodynamics of Spark and Compression Ignition Engines, their Design and Development, Volume 2. 1st Edn., Published by Pergamon Press,England, ISBN: 0080227171, pp: 430 (1979).