EXPERIMENTAL AND NUMERICAL INVESTIGATION OF COMBUSTION CHARACTERISTICS OF DIESEL ENGINE BY BIODIESEL-DIESEL BLEND

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Abstract : The diesel engines are frequently used in transportation, power generation and many other applications including industrial and agriculture sector. The major pollutants from diesel engine are smoke, particulate matter (PM), carbon monoxide (CO), carbon dioxide (CO2), nitrogen oxides (NOX) and un-burnt hydrocarbon (UHC). Due to this major pollution we use biodiesel-diesel blend fuel. This mixture (Bio-Diesel and Diesel) used in Diesel engine without engine modification. The main advantages using mixtures of biofuels in diesel are: the fact that biodiesel is not harmful to the environment and the price of biodiesel is smaller than diesel. It is more energy efficient. We use mixture of biofuel in diesel fuel. This mixture used in Diesel engine without engine modification. IC Engine use in wide area for example domestic purpose, industry, various private sectors etc. Power and fuel consumption plays important role in Diesel Engine. Analysis of this parameter will not be clear from experiment data. Minimize of this problem we use computational fluid dynamics simulation (CFD). The experimental work presented in this Paper is mainly divided into three main parts. In First part, the performance and emission characteristics is evaluated by using pure Diesel, separately, in Single cylinder, four stroke, compression ignition diesel engine at constant speed of 1500 rpm with varying load (0.2,6.1 and 12.1 bar) and compression ratio (16 and 18). The performance parameters selected are brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), and emission parameters as NOx, O2, CO, CO2 and HC. In second part, The performance and emission variables evaluated by using bio- diesel and diesel blend. In third part, The Computational fluid dynamics simulation of four Stroke diesel engine.

***IndexTerms* - CFD (Computational Fluid Dynamics), BD (Biodiesel), BTE (Brake Thermal Efficiency),BMEP (Brake Mean Effective Pressure), BSFC (Brake Specific Fuel Consumption), ICE (Internal Combustion Engines), CIE (Compression Ignition Engine), CO (Carbon Monoxide), FD (Fluid Dynamic), CR (Compression Ratio), HC (Hydrocarbon), NOX (Nitrogen oxides),BP (Brake Power), FP (Frictional Power), IP (Indicated Power), IMEP (Indicated Mean Effective Pressure), ITE (Indicated Thermal Efficiency).**

I. INTRODUCTION

During last decade India has maintained a high growth rate in accepting the improved technological challenges in global scenario. The energy demand is expected to grow. Energy is very important for society as it is used to sustain and improve well-being. It exists in various forms, from many different sources. Now a day we are mostly using petroleum. Petroleum is a naturally occurring, yellow to-black liquid in geological formations beneath the earth's surface. It is mixture of hydrocarbons that occur in the earth in liquid, gaseous, or solid forms. The declining reserves of fossil fuels and the growing environmental concerns have stimulated scientists and industries to search for and evaluate alternative fuels for petrol and diesel engines. Furthermore, an urgent need to reduce dependence on petroleum fuels for better economy and environment is required. One of the best alternative fuels of petroleum is Bio-fuel or Bio-diesel. A Bio-fuel is a fuel that is produce through contemporary biological processes, such as agriculture and anaerobic digestion, rather than a fuel produced by geological processes such as those involved in the formation of fossil fuels. Bio-fuel is renewable resources. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles [2].

➢ THE ADVANTAGES OF BIO-DIESEL USED AS DIESEL FUEL ARE:

- Liquid nature-portability.
- Ready availability.
- Renewability.
- Higher heat content (about 88% of diesel fuel).
- Lower sulphur content.
- Lower aromatic content.

- Bio-diesel has similar Cetane number to diesel fuel; this Indicates a potential for higher engine performance Indicates a potential for higher engine performance Indicates a potential for higher engine performance Close to that of diesel fuelled Engines.
- Their higher flash point makes them safer to store.

- SOME OF THE DRAWBACKS ARE [3]:
  - Bio-diesel tends to affect rubber hoses and gaskets.
  - Possible concerns with engine warranties.
  - Special measures that must be taken to use Bio-diesel in Cold climates.
  - Limited commercial availability.
  - Higher viscosity.
  - Lower volatility.
  - Under certain load conditions Bio-diesel has higher fuel Consumption compared to conventional diesel.

The diesel engines are frequently used in transportation, power generation and many other applications including industrial and agriculture sector. The major pollutants from diesel engine are smoke, particulate matter (PM), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NOX) and un burnt hydrocarbon (UHC).

We use mixture of biofuel in diesel fuel. This mixture used in Diesel engine without engine modification. The main advantages using mixtures of biofuels in diesel are: the fact that biodiesel is not harmful to the environment and the price of biodiesel is smaller than diesel. [5]. IC Engine use in wide area for example domestic purpose, industry, various private sectors etc. Power and fuel consumption plays important role in Diesel Engine. Analysis of this parameter will not be clear from experiment data. Minimize of this problem we use computational fluid dynamics simulation (CFD).

CFD analysis is plays a important role in an structure safety of the component in automobile and aerospace applications. Simulation of IC engine is the most important engineering problems in the computational fluid dynamics field. In the engine development process, CFD modelling of direct injection engine is used to analyses the interaction between the fuel and the motion of the intake air inside the combustion chamber. The scope is to minimize the prototyping time and to identify solutions with high success rate, in an early stage of the project. The success is based on the capability to make numerous studies, including different shapes for the combustion chamber, for the piston, for the admission pipes, in a relatively short time, based on the computational power [5].

II. OBJECTIVE OF THE PAPER

1. To find an immediate alternative energy solution for unmodified diesel engine.
2. To evaluate engine performance parameter i.e. Brake Specific fuel consumption (BSFC), Brake thermal Efficiency (BTE) Mechanical Efficiency and emission Parameters i.e. Carbon monoxide (CO), Carbon dioxide (CO_2), Hydrocarbon (HC), Oxide of Nitrogen (NOX), Emission with fuel as blend of biodiesel-diesel in unmodified diesel engine.
3. In order to better comprehend and advance ‘diesel,Biodiesel or Diesel-biodiesel blend’ ignition and Emissions characteristics, CFD methods have been use up to simulate in-cylinder procedures and characteristics With varying degrees of success. CFD Simulation result more exact as compared to actual result.
4. To develop the analytical modelling for predication of response at unperformed levels and optimization of input variables for achieving goal of maximum performance and minimum emission from exhaust gas.
5. Analytical modeling, Simulation and validation.

III. SCOPE OF THE WORK

In view of the large foreign exchange requirement for purchase of petroleum crude and the resulting unabated pollution, the government of India has set up a Committee on Development of Bio-fuel in 2002-03. The target of the mission is production of biodiesel sufficient to blend with high speed diesel to the extent of 20% by the year 2011-2012. Utilization of non-edible vegetable oils for production of biodiesel will prevent further wastage of already existing resources as well as plantation of oilseeds in wastelands, and use of environmentally friendly fuel will create cleaner environment.

The work presented in this Paper is to study of influence on blend of biodiesel and diesel. Also, analytical models developed in effort to reduce experimental conduction cost and time. So, aim of this study is mainly to standardized fuel and conducts engine testing to evaluate performance and emission characteristics with minimum number of experimental trails.

IV. EXPERIMENTAL TECHNIQUE AND METHODOLOGY

In this experimental investigation, KOME is used as a biodiesel as it is easily available and its properties are similar to pure diesel in CI engine. The investigation is based on the results obtained by the various researchers and allows for further investigation in performance parameters and exhaust emissions.

A. *Engine Detail and Experimental Setup*

The experiment is conducted on computerized single cylinder, 4-stroke, direct injection, water cooled compression diesel engine. The schematic test facility is shown in Figure (a) and actual setup is shown in Figure (b) The engine test rig consists of diesel engine, eddy current dynamometer, Exhaust gas analyzer and fuel tank. The research engine technical specification is shown in Table (1) The engine was mounted on the engine bed with suitable connections for lubrication and cooling water supply. The fuel was supplied from a fuel tank at a height of 2 m above the ground. The fuel consumption rate was measured by noting the time taken from a known volume of fuel flow. The engine and the dynamometer are interfaced to a control panel, which is connected to a computer. These signals are interfaced to the computer through an analog to digital converter card PCI-1050 which is mounted on the motherboard of the computer.

TABLE: 1. Technical Engine Specification

Make	Kirloskar oil engine Ltd.
No. of cylinders	Single
No. of strokes	Four
Cylinder diameter	87.5 mm
Stroke length	110 mm
Connecting rod length	234 mm
Orifice diameter	20 mm
Power	3.5 KW at 1500 rpm
Compression ratio range	12:1 to 18:1
Injection point variation	0 to 25^0 BTDC
Method of Cooling	Water Cooled

Table: 1

Experiments are conducted with diesel only and readings recorded. Then test carried with KOME blended with diesel. The blends used for carrying out experiments are B5+ D95 (5% by volume KOME and 95% by volume diesel), BD5+D95, BD10+D90, BD15+D85, BD20+D80, BD100.

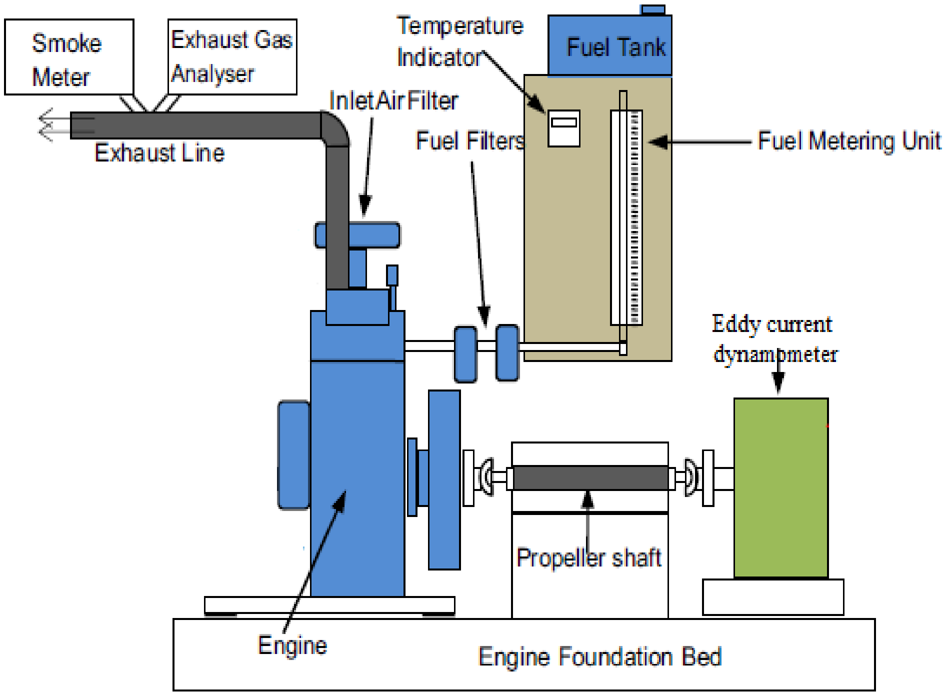

Figure (a) Schematic of experimental setup

Firstly, experiments are conducted with diesel only and readings recorded. Then test carried with combination of Bio-diesel and Diesel. The blends used for carrying out experiments are BD5+D95 (Bio-Diesel 5% and Diesel 95%), BD10+D90, BD15+D85, BD+D80, BD100. In this, speed of engine is kept constant at 1500 rpm and load is varied in range of 0-12 kg. To avoid effect of environmental condition, engine is initially run for 15minutes (for warming) until temperature of exhaust gases and cooling water reached to steady condition. The ICEngineSoft software is used, sample report generated shown in Appendix-II, for taking readings.

Figure (b) Actual test Setup

B. Properties of Fuels

TABLE 2 Properties of Fuels

Fuel	Density (kg/m3)	Calorific value (KJ/kg K)
Diesel (DE)	840	43790
Bio-Diesel	870	36870
BD5+D95	805	41250
BD10+D90	810	41850
BD15+D85	830	42380
BD20+D80	835	42580

Table: 2

C. Computational Fluid Dynamics Simulation (CFD) Method

CFD analysis is plays a important role in an structure safety of the component in automobile and aerospace applications. Simulation of IC engine is the most important engineering problems in the computational fluid dynamics field. In the engine development process, CFD modeling of direct injection engine is used to analyses the interaction between the fuel and the motion of the intake air inside the combustion chamber. The scope is to minimize the prototyping time and to identify solutions with high success rate, in an early stage of the project.

Computational fluid dynamics simulation of a direct injection single cylinder engine using diesel, biodiesel, or different mixture proportions of diesel and biodiesel. There is use of various software to CFD simulation.

1. ANSYS SOFTWARE
2. AVL FIRE SOFTWARE
3. CONVERGE CFD

In this paper we use Ansys software to CFD simulation. There are various step to CFD simulation by using Ansys Workbench. Some basic instructions for using ICE in Workbench. Applications that can be accessed from Workbench include: ANSYS Design Modeler (for geometry creation); ANSYS Meshing (for mesh generation); ANSYS Fluent (for setting up and solving computational fluid dynamics (CFD) simulations); and ANSYS CFD-Post (for post processing the results). In Workbench, a project is composed of a group of systems. The project is driven by a schematic workflow that manages the connections between the systems. From the schematic, you can interact with workspaces that are native to Workbench, such as Design Exploration (parameters and design points), and you can launch applications that are data-integrated with Workbench. Data-integrated applications have separate interfaces, but their data is part of the Workbench project and is automatically saved and shared with other applications as needed. This makes the process of creating and running a CFD simulation more streamlined and efficient. In addition, Workbench also allows you to copy systems in order to efficiently perform and compare multiple similar analyses. Workbench also provides parametric modeling capabilities in conjunction with optimization techniques to allow you to efficiently investigate the effects of input parameters on selected output parameters.

➢ Simulation Procedure

Ansys software to use for CFD simulation. There are various step to CFD simulation by using Ansys Workbench.

- Launch IC Engine system.
- Read an existing geometry into IC Engine.
- Decompose the geometry.
- Define mesh setup and mesh the geometry.
- Define the solver setup.
- Run the simulation.
- Examine the results in the report.

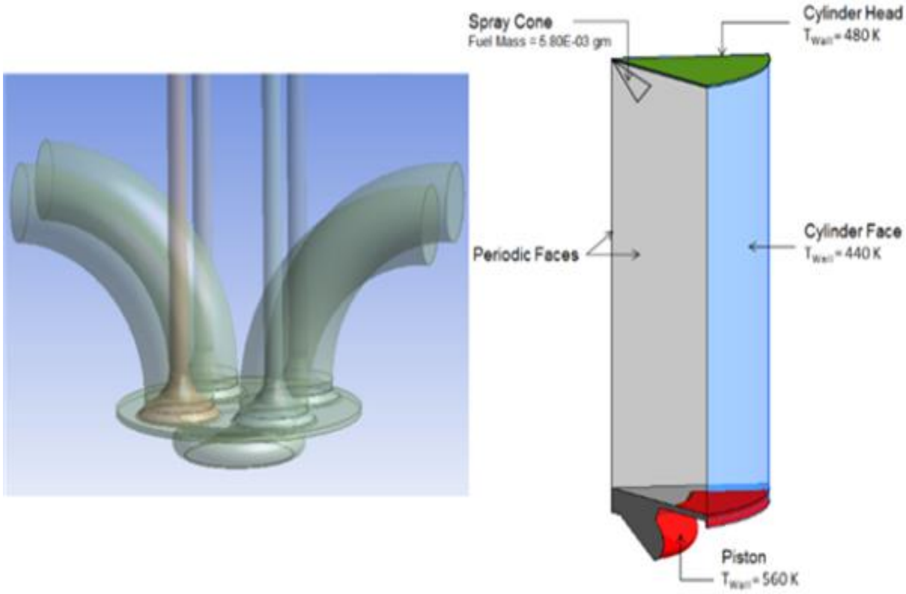

Figure (C) Problem Schematic

V. RESULTS AND DISCUSSION

Experimental results for performance and emission parameter with blend of Bio-Diesel and diesel as fuel.

The experiments were conducted on single cylinder, four stroke CI diesel engine at constant speed of 1500 rpm. The performance and emission characteristics of engine are determined for different blends. The variation of BTE with load for BD100, D100 and BD5+D95, BD10+D90, BD15+D85, BD20+D80, and blends at compression ratio (a) 16 and (b) 18 and found out HC(PPM), CO(%), CO2 (%), O2 (%), NOX (PPM) with varying load 0.2, 6.1 and 12.1. Gas emission used for whole process. Smoke Meter used for find out smoke (%) with varying load 0.2, 6.1 and 12.1.

A. Gas Emission and Smoke Emission

A.1. Gas Emission Analyzer At "CR (Compression Ratio) 16 & Load 0.2"

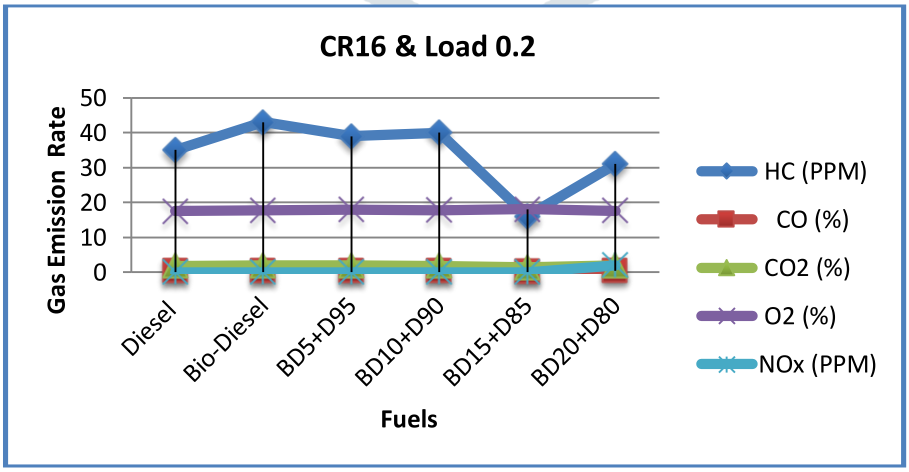

Chart A.1

In This Chart A.1 shows Gas Emission result at CR16 & Load 0.2 with using different blends (BD5+D95, BD10+D90, BD15+D85, BD20+D80).Blend BD15+D85 More effective as compare to other blends.

A.2. Gas Emission Analyzer At "CR (Compression Ratio) 16 & Load 6.1"

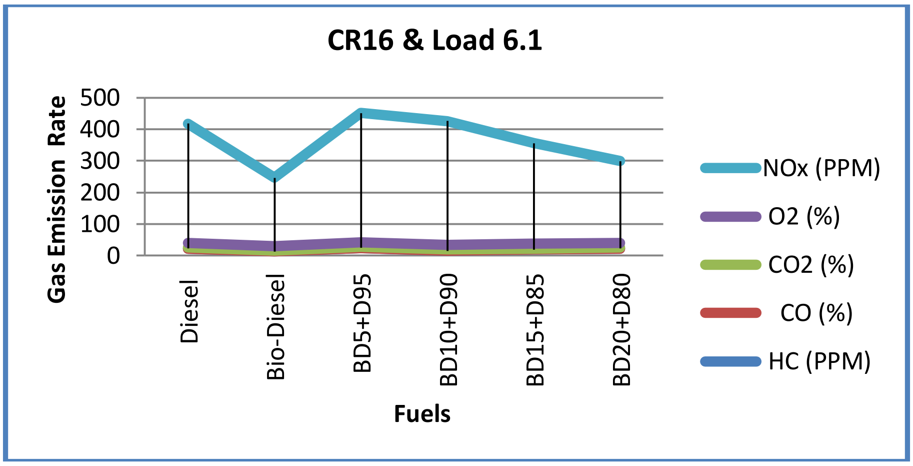

Chart A.2

In This Chart A.2 shows Gas Emission result at CR16 & Load 6.1 with using different blends (BD5+D95, BD10+D90, BD15+D85, BD20+D80).Blend BD15+D85 More effective as compare to other blends.

A.3. Gas Emission Analyzer At "CR (Compression Ratio) 16 & Load 12.1"

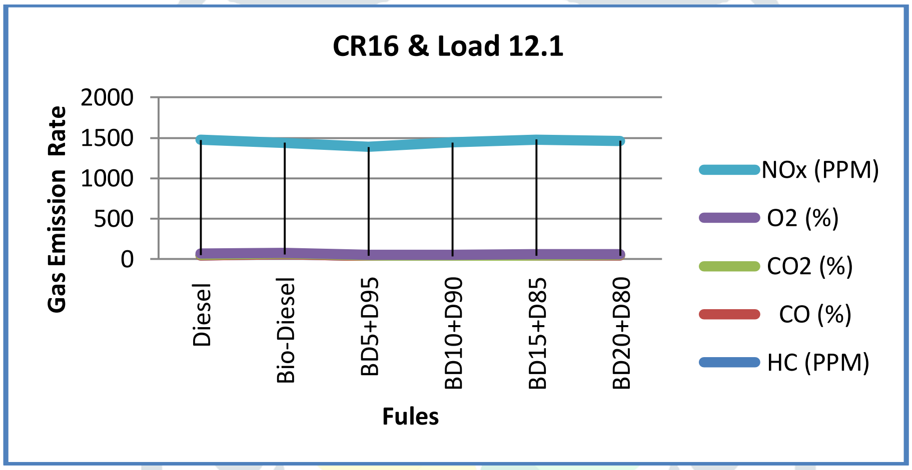

Chart A.3

In This Chart A.3 shows Gas Emission result at CR16 & Load 12.1 with using different blends (BD5+D95, BD10+D90, BD15+D85, BD20+D80).Blend BD10+D90 More effective as compare to other blends.

A.4. Gas Emission Analyzer At "CR (Compression Ratio) 18 & Load 0.2"

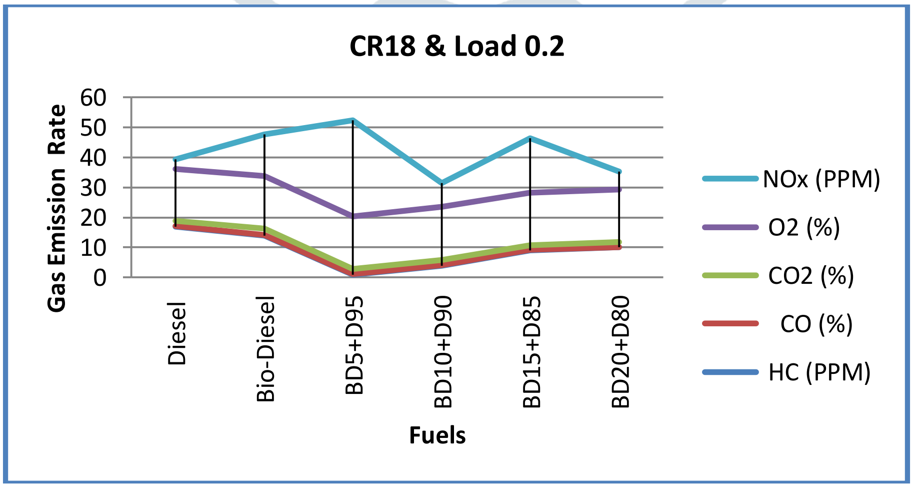

Chart A.4

In This Chart A.4 shows Gas Emission result at CR18 & Load 0.2 with using different blends (BD5+D95, BD10+D90, BD15+D85, BD20+D80).Blend BD5+D95 More effective as compare to other blends.

A.5. Gas Emission Analyzer At "CR (Compression Ratio) 18 & Load 6.1"

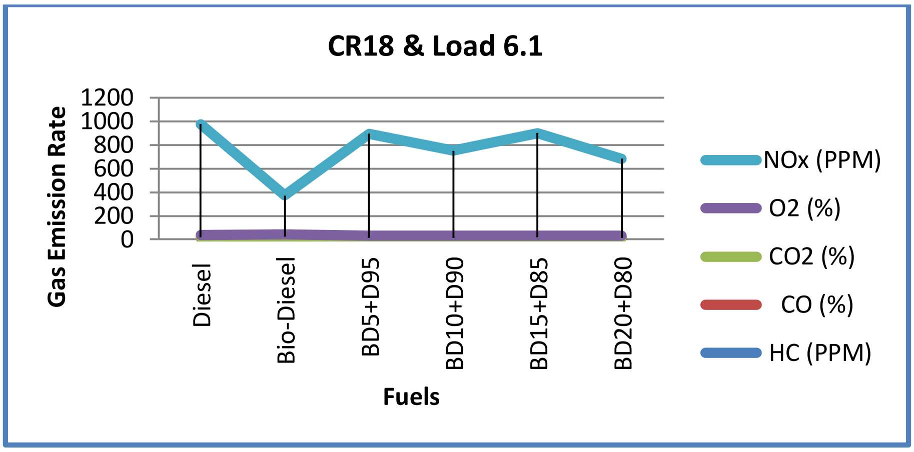

Chart A.5

In This Chart A.5 shows Gas Emission result at CR18 & Load 6.1 with using different blends (BD5+D95, BD10+D90, BD15+D85, BD20+D80).Blend BD20+D80 More effective as compare to other blends.

A.6. Gas Emission Analyzer At "CR (Compression Ratio) 18 & Load 12.1"

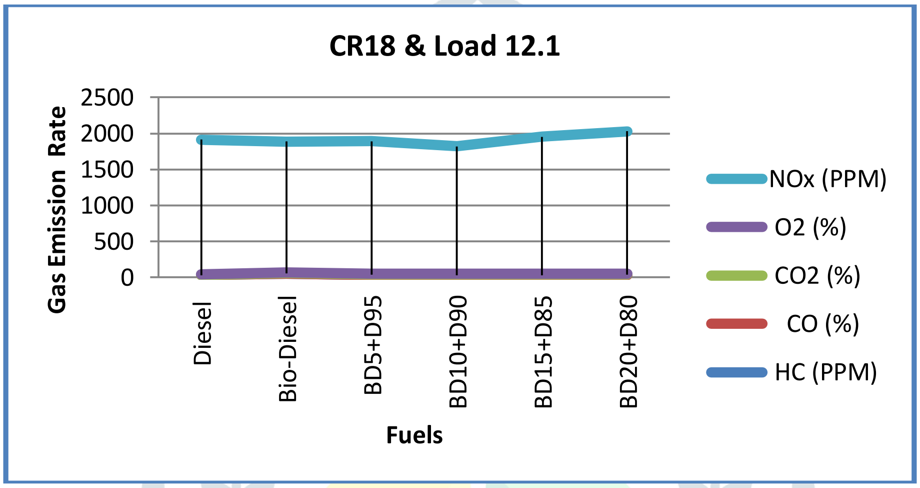

Chart A.6

In This Chart A.6 shows Gas Emission result at CR18 & Load 12.1 with using different blends (BD5+D95, BD10+D90, BD15+D85, BD20+D80).Blend BD10+D90 More effective as compare to other blends.

A.7.Smoke Emission Analyzer (Smoke %) At "CR (Compression Ratio) 16"

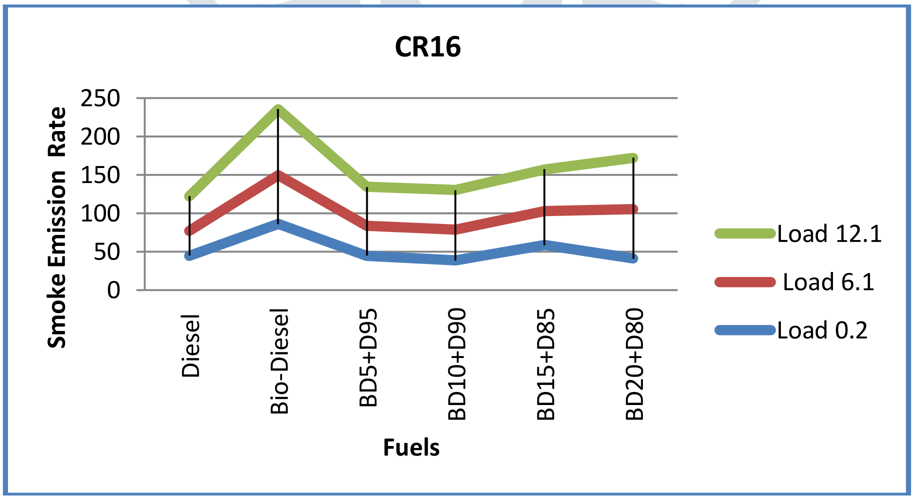

Chart A.7

In This Chart A.7 shows Smoke Emission result at CR16 & Loads 0.2,6.1 and 12.1 with using different blends (BD5+D95,BD10+D90,BD15+D85, BD20+D80).Minimum Smoke Emission by Blend BD10+D90 at load 0.2 ,Diesel 100 at load 6.1 and load 12.1.

A.8. Smoke Emission Analyzer (Smoke %) At "CR (Compression Ratio) 18"

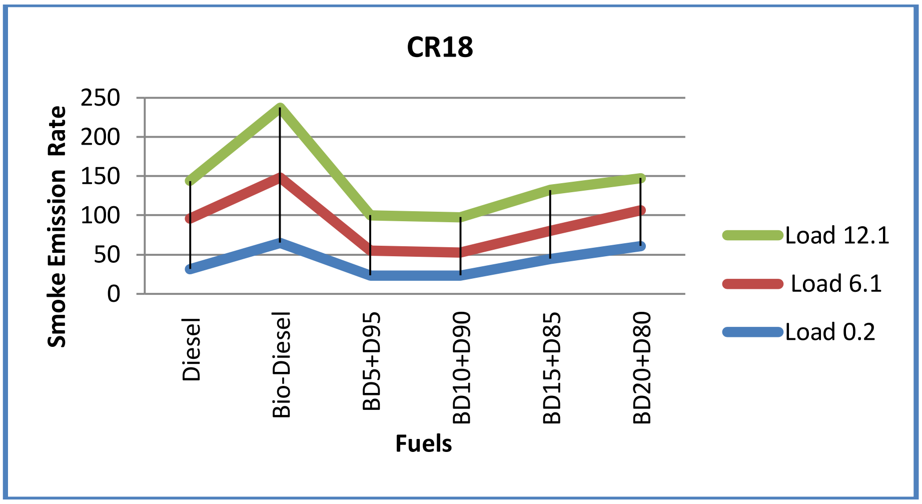

Chart A.8

In This Chart A.8 shows Smoke Emission result at CR18 & Loads 0.2, 6.1 and 12.1 with using different blends (BD5+D95,BD10+D90,BD15+D85, BD20+D80).Minimum Smoke Emission by Blend BD5+D95 at load 0.2 , BD10+D90 at load 6.1 and BD20+D80 load 12.1.

B. Performance Result

B.1. Performance Result at "CR16"

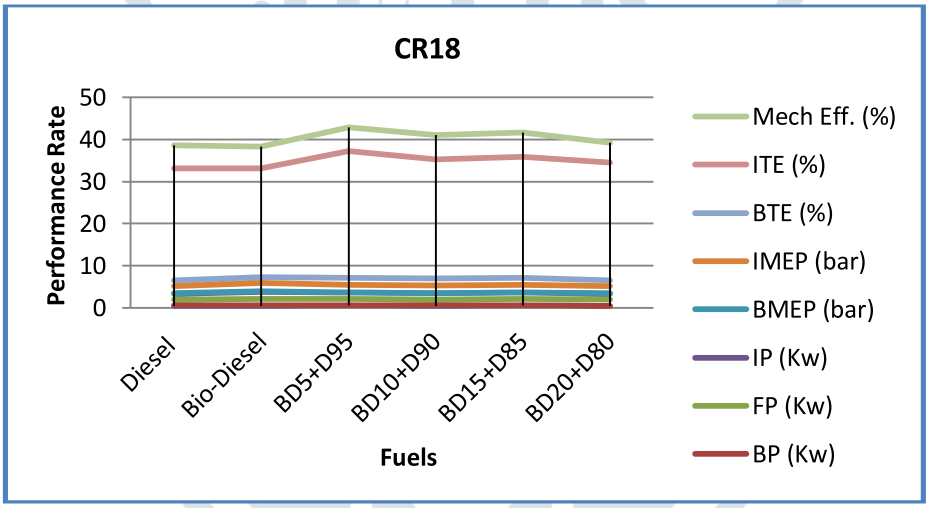

Chart B.1.1

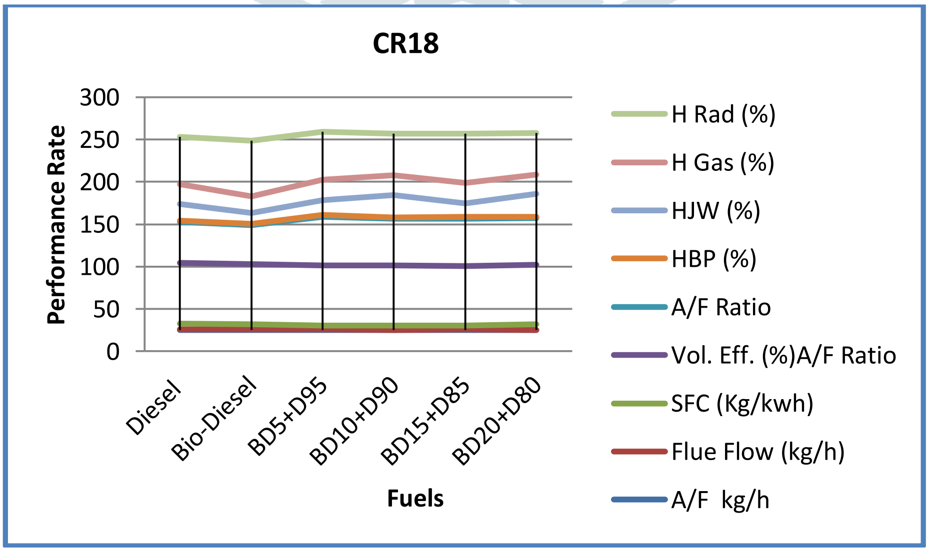

Chart B.1.2

B.2. Performance Result at "CR18"

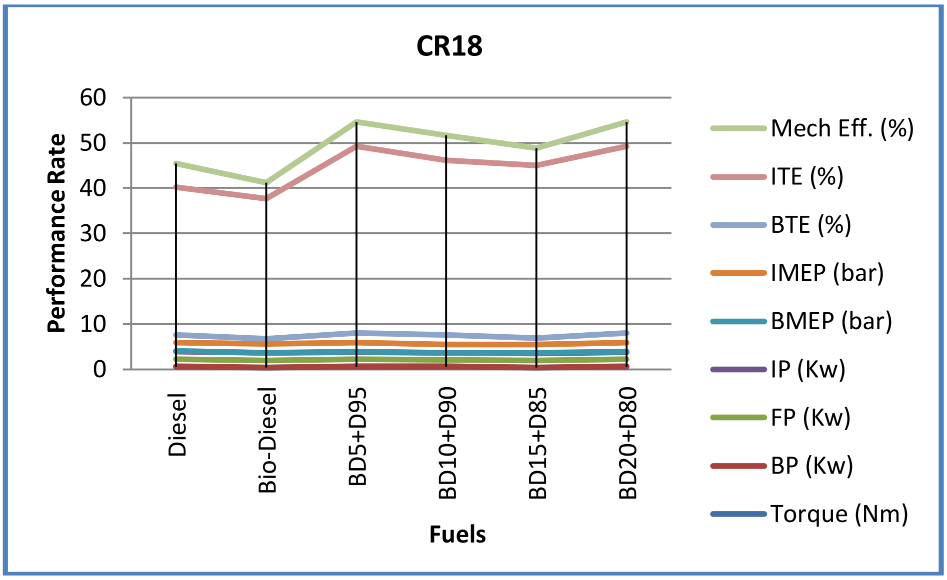

Chart B.2.1

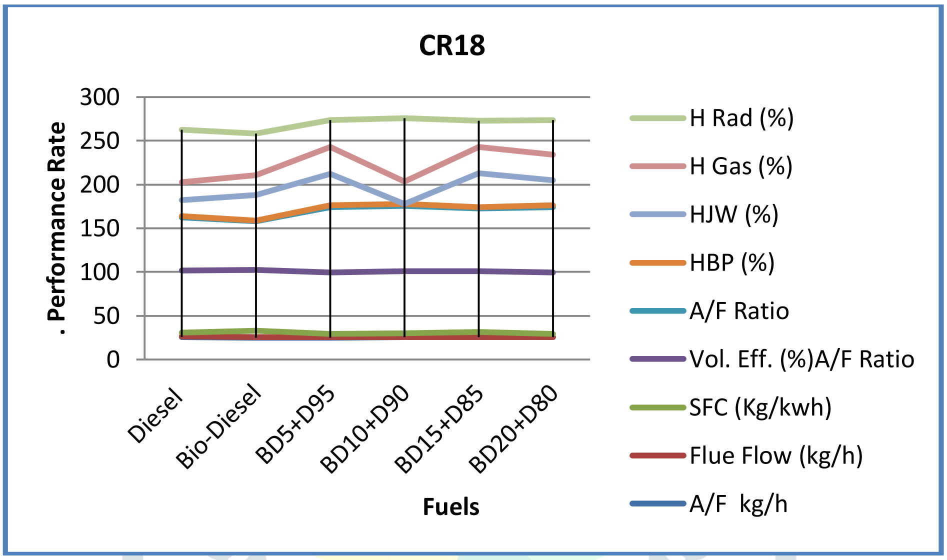

Chart B.2.2

C. Computational Fluid Dynamics Simulation

C.1 Gas Emission Chart for C7H16 (Diesel 100 Fuel)

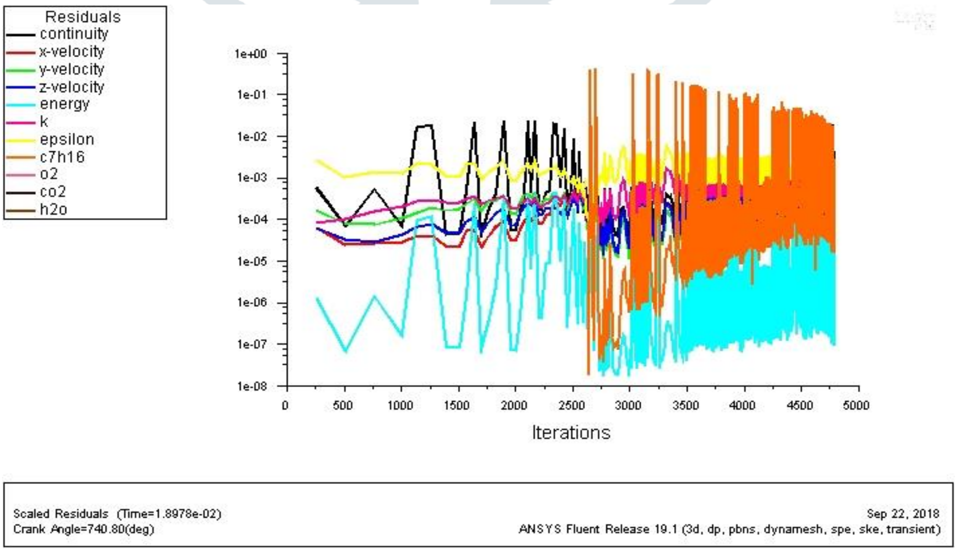

Figure C.1.1

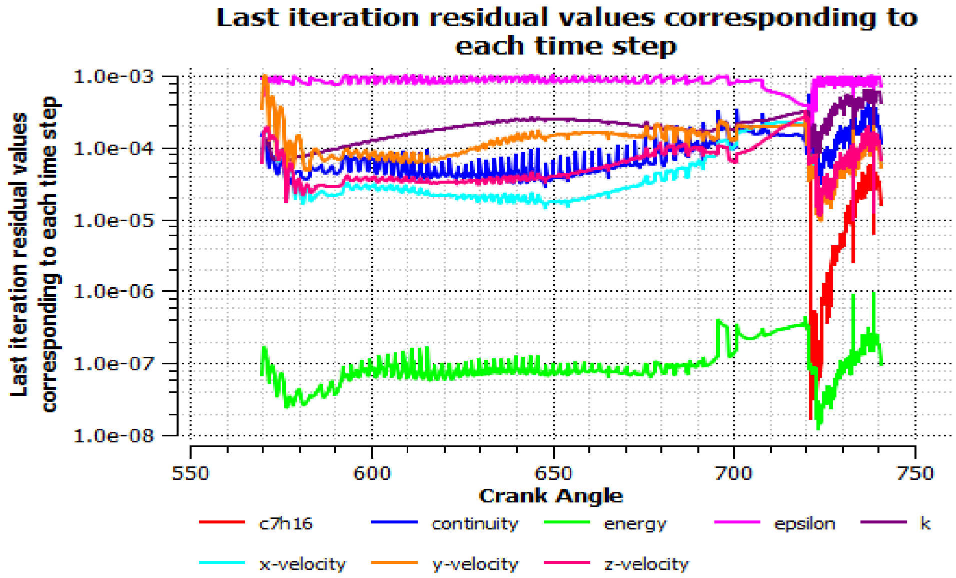

Figure C.1.2

C.2. Gas Emission Chart for C8H18

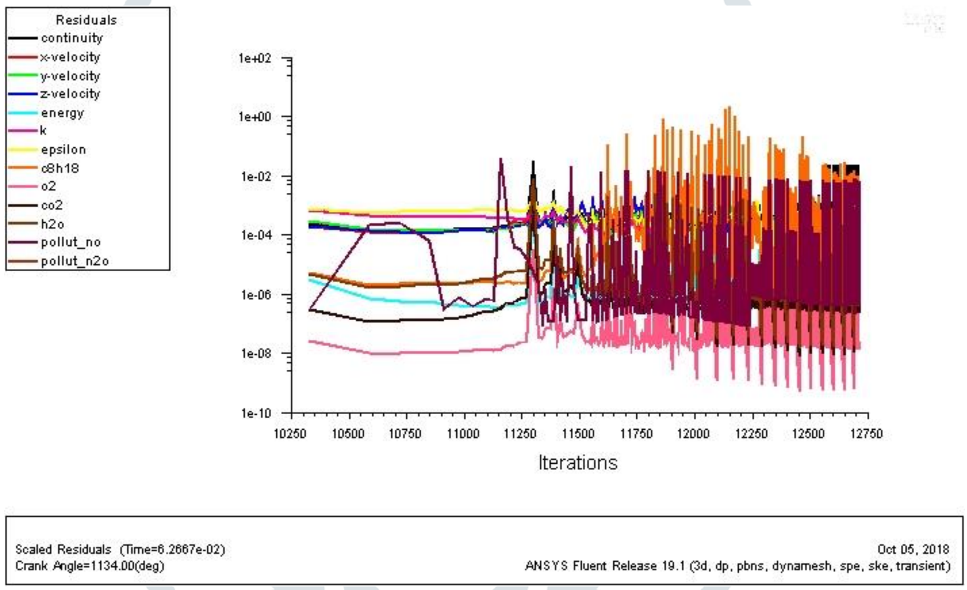

Figure C.2.1

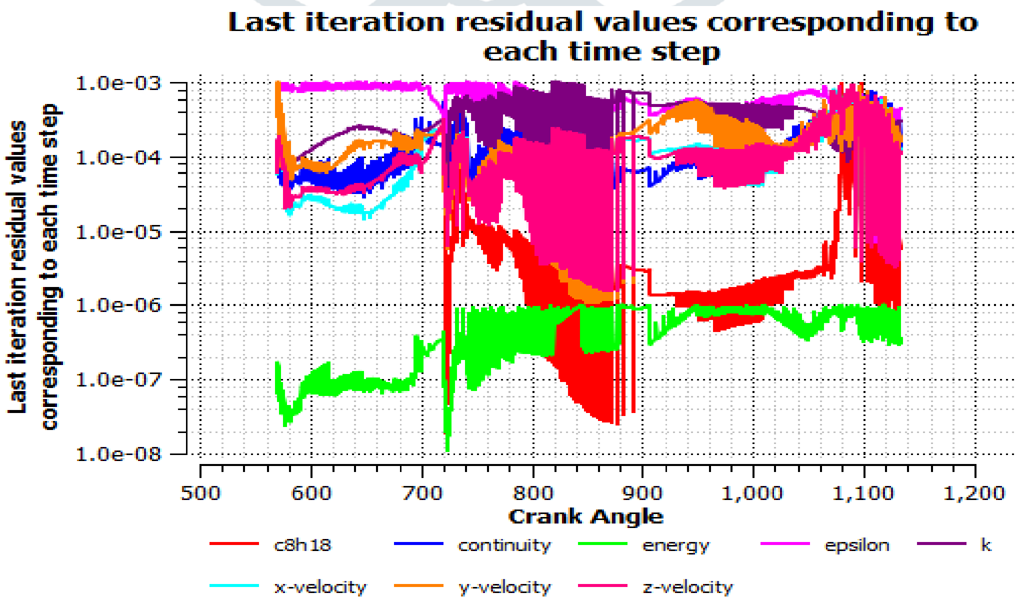

Figure C.2.2

VI. CONCLUSION

Based on the experimental results, the conclusions can be summarized as follows:

1. Bio-diesel (KOME) with diesel fuel can be conveniently used in CI engines as blends with diesel without any engine modifications.'
2. HC, CO and CO2 emissions were reduced for biodiesel-diesel blends. Higher compression ratios have the advantage of reduced emissions.
3. At load 6.1 and CR16, Blend B15+D85 more Effective. Gas emission rate in this blend B15+D85 are HC (20 Ppm), CO (0.109 %), CO2 (2.79 %), O2 (14.84 %), NOX (318 Ppm) at load 6.1 and CR16.
4. At load 6.1 and CR18, Blend B20+D80 more Effective. Gas emission rate in this blend B20+D80 are HC (15 Ppm), CO (0.073 %), CO2 (3.05 %), O2 (13.84 %), NOX (651 Ppm) at load 6.1 and CR18.
5. At load 12.1 and CR18, Blend B10+D90 more Effective. Gas emission rate in this blend B10+D90 are HC (35 Ppm), CO (0.194 %), CO2 (5.04 %), O2 (10.71 %), NOX (1768 Ppm) at load 12.1 and CR18.
6. At CR 16, Blend BD15+D85 Mechanical Efficiency (5.87) is more as compare to other blends.
7. At CR 18, Blend BD10+D90 Mechanical Efficiency (5.49) is more as compare to other blends.
8. Biodiesel blends with diesel gives a good improvement in thermal efficiency due to the additional lubricity and oxygen content is the possible reason for it. The change of compression ratio from 16 to 18 resulted in increase in brake thermal efficiency in case of BD5+D95, B10+D90, B15+D85 and B20+D80 blends.
9. In general, increasing the compression ratio improved the performance and cylinder pressure of the engine and had more benefits with biodiesel than with high pure diesel.
10. CFD simulation result more accurate as compared to actual result. Main advantage of simulation are minimizing time and cost.
11. We can easily change compression ratio, Fuel properties, boundary condition, temperature, pressure in CFD simulation.

REFERENCES

1. www.wikipedia.com/wiki/petroleum.
2. www.wikipedia.com/wiki/biofuel.
3. Dan Moldovanu and Nicolae Burnete "Computational fluid dynamics simulation of a single cylinder research engine working with biodiesel" Moldovanu, D., Burnete, N.: Computational Fluid Dynamics Simulation of thermal science: Year 2013, Vol. 17, No. 1, pp. 195-203.
4. Avinash Kumar Agarwal, Atul Dhar, 'Experimental investigations of performance, emission and combustion characteristics of Karanja oil blends fuelled DICI engine', Renew Energy 52 (2013) 283-291.
5. Shikha Gangil, Ranjana Singh, Priyanka Bhavate, Divya Bhagat, Bharat Modhera, 'Evaluation of engine performance and emission with methyl ester of Karanja oil', Perspectives in Science (2016).
6. Bhuiya, M. K., Rasul, M.G., Khan, M.M.K., Ashwath, N., Azad, A.K., Hazrat, M.A., 2015, "Prospects of 2nd generation biodiesel as a sustainable fuel – Part 2: Properties, performance and emission characteristics," Renewable and Sustainable Energy Reviews, 09, pp. 86-102.
7. Takase, M., Zhao, T., Zhang, M., Chen, Y., Liu, H., Yang, L., Wu, X., 2015, "An expatiate review of neem, jatropha, rubber and karanja as multipurpose non-edible biodiesel resources and comparison of their fuel, engine and emission properties," Renewable and Sustainable Energy Reviews, 43, pp. 495–520.
8. Hassan, M.H., Kalam, M. A., 2013, "An overview of biofuel as a renewable energy source: development and challenges," Proceedings of 5th BSME International Conference on Thermal Engineering, Procedia Engineering 56, pp. 39 – 53.
9. Darshana S. Gaikwad , Ajay V. Kolhe "Study of Combustion Modeling In CI Engine with Biodiesel as an Alternative Fuel" The International Journal Of Engineering And Science (IJES) Volume||3 ||Issue|| 1||Pages|| 25-29||2014||ISSN(e): 2319 – 1813 ISSN(p): 2319 – 1805.
10. Avinash Kumar Agarwal, Atul Dhar, 'Experimental investigations of performance, emission and combustion characteristics of Karanja oil blends fuelled DICI engine', Renew Energy 52 (2013) 283-291.
11. Shikha Gangil, Ranjana Singh, Priyanka Bhavate, Divya Bhagat, Bharat Modhera, 'Evaluation of engine performance and emission with methyl ester of Karanja oil', Perspectives in Science (2016).
12. Gayatri Adia;Carrie Halla;David Snydera;Michael Buncea;Christopher Satkoskia "AN Experimental and simulation study of increases in fuel consumption and NOx emissions in a bio fuelled diesel engine" Proceedings of ASME Internal Combustion Engine Division 2009 Spring Technical Conf.ICES2009 May 3-6, 2009, Milwaukee, Wisconsin, USA.
13. Syed Saleem Pasha and Mohammed Imran "Compitational Fluid Flow Dynamic Analysis on I.C Engine using ANSYS" International Journal of Engineering Research & Technology (IJERT)ISSN: 2278-0181 IJERTV4IS051259 www.ijert.org (This work is licensed under a Creative Commons Attribution 4.0 International License.) Vol. 4 Issue 05, May-2015.
14. Rohith.S, Dr. G .V. Naveen Prakash "Cold Flow Simulation in an IC Engine" International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 Volume: 02 Issue: 07 |Oct-2015.
15. Shaik Magbul Hussain, 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 (IJEST.
16. Andrew Hockett "A computational and experimental study on combustion processes in natural gas/diesel dual fuel engines"
17. S. M. Ameer Uddin, A. K. Azad, M. M. Alam and J. U Ahamed "Performance of a Diesel Engine run with Mustard-Kerosene blends" 6th BSME International Conference on Thermal Engineering (ICTE 2014)
18. Venkatesh T. Lamani, Ajay Kumar Yadav and G.N. Kumar "CFD Simulation of a Common Rail Diesel Engine with Biobutanol-Diesel Blends for Various Injection Timings"

19. Hoon Kiat Ng , Suyin Gan , Jo-Han Ng , Kar Mun Pang “Simulation of biodiesel combustion in a light-duty diesel engine using integrated compact biodiesel–diesel reaction mechanism”.
20. F. Payri *, J. Benajes, X. Margot *, A. Gil “CFD modeling of the in-cylinder flow in direct-injection Diesel engines”.