EXPERIMENTAL INVESTIGATION ON PERFORMANCE OF P- HCCI ENGINE USING BIODIESEL MIXTURE

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Abstract

This paper presents the performance of single cylinder HCCI Engine using Biodiesel Mixture. The Homogeneous charge compression ignition (HCCI) combustion is a new trend alternative technology to current engine combustion systems. Many inventions in HCCI is being worked out to use it as a method to reduce exhaust emissions and also fuel economy. The quality of homogeneous mixture of air and fuel is the key feature of HCCI combustion. HCCI has the characteristic nearly eliminate NOx emissions while increasing efficiency as in diesel engine. HCCI adapts a pre mixture of gas-phase fuel and air being burned spontaneously and entirely by an auto ignition process. Homogeneous Charge Compression Ignition (HCCI) engines promises a high thermal efficiency combined with low levels of NOx and PM emissions. The purpose of this study is to analyze the effect of alternative fuel when used in the HCCI engine combustion process. The experiments were conducted in a modified single cylinder water-cooled diesel engine. In this experiment we use diesel and bio-diesel Mixture as the fuel at different millisecond injection.

Keywords: Homogeneous Charge Compression Ignition (HCCI), Diesel, Diesel Engine, Performance and Exhaust Emission, Biodiesel Mixture

1. INTRODUCTION

Because of the reduction of petroleum of reserves and air pollution emerged from exhaust emissions, there have been great efforts to use alternative fuels in diesel engines for substitution diesel fuel. Known petroleum reserves are limited and will eventually destroyed. Biomass energy technologies are use waste or plant matter to produce energy with a lower level of greenhouse gas emissions than fossil fuel sources. The biofuel economy will grow rapidly during the 21st century. The biofuel economy, and its related bio refineries, will be shaped by many of the same forces that shaped the development of the hydrocarbon economy and its refineries over the past century.

Biodiesel is step by step gaining acceptance in the recent market as an ecofriendly fuel and the demand is expected to increase all at once as an alternative renewable energy source in the near future. The biggest difference between biofuels and petroleum feed stocks is oxygen content. Biofuels have oxygen levels of 10 to 45% while petroleum has essentially none, making the chemical properties of biofuels very different from those of petroleum. All have very low sulfur levels and many have low nitrogen levels. Biodiesel which has combustion characteristics similar to diesel and biodiesel blends has shorter ignition delay, higher ignition temperature and pressure as well as peak heat release compare to diesel fuel. Moreover, the engine power output and brake power efficiency was found to be equivalent to diesel fuel. Biodiesel and diesel blends can reduce smoke opacity, particulate matters, un-burnt hydrocarbons, carbon dioxide and carbon monoxide emissions but nitrous monoxide emissions have slightly increased.

Biodiesel HCCI is new technology to use of both biofuels and HCCI combustion. The main aim is to use HCCI combustion mode is simultaneous reduction of NOx and soot, as well as reduction of fossil CO_2 emissions. In this mode, biodiesel combustion burns lower in-cylinder temperature, therefore it reduces NO_X emissions. Biodiesel HCCI mode also enhances the fuel efficiency because of combustion of ultra-lean mixtures.

1.1 Biodiesel Mixture as an Alternative Fuel for IC Engine

Biodiesel is an oily liquid synthesized from fatty material. It has a light yellow color and mild odor and a bitter taste, it has many advantages such as: Renewable, it can be extracted from vegetable oil, Potential for Carbon Neutral lifecycle, simple to make, Non-toxic, Biodiesel is free from sulphur (< 0,001 %), the only alternative fuel that does not require engine modification or retuning, safer for storage and handling than petroleum diesel, Can be used neat or blended in any ratio with petroleum diesel and dramatically reduced emissions. Because of high viscosity of vegetable oils and low volatility causes the atomization and spry patterns problems, leading to incomplete combustion and severe carbon deposits, injector choking and piston ring sticking.

The methods used to reduce the viscosity are:

- Emulsification,
- Pyrolysis,
- Dilution and
- Transesterification process.

Among these four methods, the transesterification is commonly used commercial process to produce clean and environment friendly Biodiesel. Methyl esters of used cooking oil, sunflower oil, rice bran oil, palm oil, soybean oil, Mahua oil, Jetropha oil,castor,karanj and coconut oil have been successfully tested on C.I. engines. In present research Biodiesel Mixture is use as an Alternative fuel. My Research I Used three vegetables Oils like Castor, Karanj and Coconut to make Biodiesel Mixture.

Table 1. Important properties of Biodiesel Mixture and diesel

Fuel Property	Biodiesel Mixture	Diesel
Density Kg/m^3	0.890	0.860
Boiling point,℃	130	188-343
Kinetic Viscosity, cst	4.204	2-4
Calorific Value,kJ/kg	37,891	42,000
Flashpoint, °C	140	55
Auto ignition Temp.°C	230	316
Cetane number	57	51

For compression ignition engines conversions to HCCI Engine are require homogeneous charge insert in to cylinder so injection system modified. We use heater to vaporize biodiesel fuel then install it in intake manifold.

1.1.1 Objectives of Research

- To modify of a single cylinder diesel engine run in to HCCI mode fuelled with Diesel and Bio-fuel.
- Tuning of fuel vaporizer with Diesel engine to run it on HCCI mode in optimized condition.
- To study effect of the bio-fuel on performance parameters like brake thermal efficiency, brake Specific fuel consumption and emission etc. with HCCI mode of working.
- To study the emission parameters mainly exhaust parameters like hydrocarbon emission, oxides of carbon (CO & CO2) and oxides of nitrogen (NOx) by running engine HCCI mode with bio-fuel.

1.1.2 Research Methodology

HCCI: Homogeneous Charge Compression Ignition

HCCI is a form of internal combustion in which the fuel and air are compressed to the point of auto ignition. HCCI engines are operated with the compression ignite on of homogeneous charge formed by premixed air and fuel mixtures through early injection on to the hot surface of a heated chamber known to be the vaporizer.

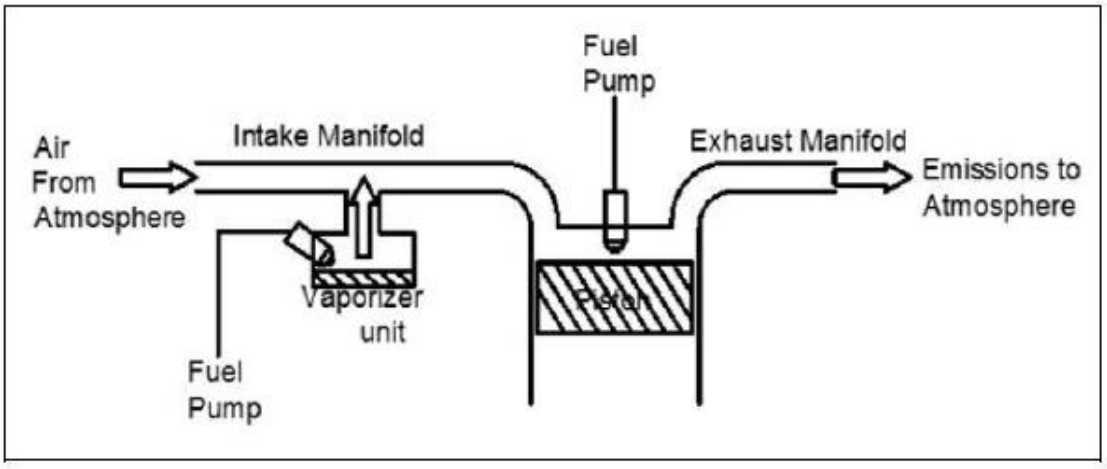
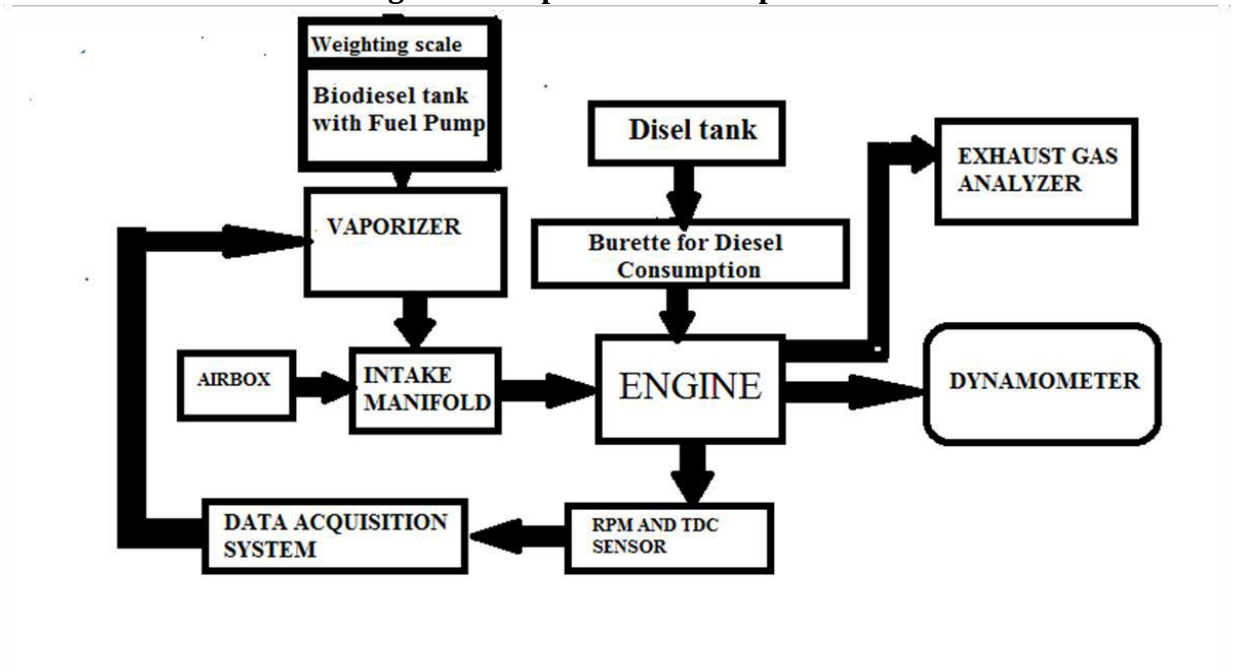


Figure 1.1-Basic HCCI concept

HCCI technology uses homogeneous charge inside the combustion chamber and this is obtained by premixing the air and vaporized fuel outside the combustion chamber.

Schematic Diagram of Experimental Setup.



- Experimental Procedure to Test Engine with Modification for HCCI
- Fuel Vaporizer system is installed in the intake manifold.
- Ensure cooling water circulation for eddy current dynamometer and engine.
- Start the set up and run the engine at no load for 4-5 minutes.
- Switch on the computer and run engine software. Reading taken with help of sensors whose sensed output is connected to the Data acquisition system.
- The engine is started by first connecting the Data acquisition system with the Computer and then followed by software initialization.
- An electronically controlled port injection system is employed to inject bio- fuel in to the inlet manifold with vaporizer system.

- Gradually increase load on the engine. And also readings are observed for various injections timings decided at each load condition.
- Wait for steady state and log the data in the engine software.
- The exhaust gas composition CO, UHC, CO2, O2 and NOx emissions were measured by gas analyzer.
- View the results and performance.

1.2 Biodiesel production

- Sodium hydroxide was added to methanol in a mixer and stirred for 10 to 15 minutes until it is completely dissolved.
- It was then mixed with the three mix vegetables oil in a reactor equipped with a heater, magnetic stirred at 60℃. Stirring was continued and the product was placed in a separating funnel and left over night for glycerin to settle to the bottom of the funnel and then removed in a measuring cylinder.
- The impure methyl ester (biofuel) has contain moisture so biodiesel should be moisture free then I add hexane into biodiesel**.**

Fig1.2 Actual experimental set-ups for Making Biodiesel Mixture

2. LITERATURE REVIEW

[1] Gajendra Singh, Akhilendra Pratap Singh, Avinash Kumar Agarwal present on "Experimental investigations of combustion, performance and emission characterization of biodiesel fuelled HCCI engine using external mixture formation technique." From Elsevier

In this paper study of in a modified two cylinder engine, in which, one cylinder was operated in HCCI mode while other was operated in conventional CI mode. HCCI engine can be operated with a wide variety of fuels starting from mineral diesel to various blends of biodiesel (B20 and B40). The basic requirement of the HCCI engines is homogeneous mixing of fuel and air, which is done by using port fuel injection strategy in this study. An external device was used for fuel vaporization and mixture formation. For controlling HCCI combustion, different EGR conditions (0%, 15% and 30%) were also applied.

Conclusion: Two-stage heat release was observed for HCCI combustion mode. First stage combustion was due to low temperature combustion chemistry, while the second stage combustion was dominated by high temperature combustion chemistry. Chemical kinetics of diesel HCCI was found to be faster compared to

biodiesel HCCI. Effect of EGR was investigated and it was found to be a very effective tool to control HCCI combustion. Reduction in power output and increase in ISFC were observed upon increasing biodiesel content in the test fuel, possibly because of biodiesel's lower calorific value compared to mineral diesel.

[2] Salvador M. Aceves, Daniel Flowers, Joel Martinez-Frias, Francisco Espinosa-Loza, William J. Pitz and Robert Dibble Present on, "Fuel and Additive Characterization for HCCI Combustion", SAE International, Paper - 2003- 01-1814.

In this paper study of HCCI combustion using diesel and its blends with biodiesel as test fuels in a constant speed engine. Since diesel like fuels are difficult to mix homogeneously with intake air, external mixing using a biodiesel vaporizer was done to achieve HCCI combustion. Mineral diesel has lower boiling range as compared to biodiesel therefore external mixture formation was easier for mineral diesel compared to biodiesel/blends. Two-stage heat release was observed for HCCI combustion mode. First stage combustion was due to low temperature combustion and second is high temperature combustion. This is - paper experiments were performed in a modified two cylinder diesel engine, in which, one cylinder is operated in HCCI mode while other is operated in conventional CI mode. In this experiment perform with a wide variety of fuels starting from diesel to various blends with biodiesel (B20 and B40). For varying EGR rate (0%, 15%, and 30%).

Conclusion: This study concludes t h a t N O x emissions reducing different biodiesel blends. A power output reduces and an increase in ISFC was observed upon increasing the biodiesel blend. CO, HC and smoke emissions was small increase observed with increasing biodiesel content and EGR rate.

[3] HarisankarBendu, S. Morgan (2014) present on "Mixture preparation and control strategies in HCCI engines."

In this paper study of the different strategies of controlled auto-ignition by HCCI combustion and mixture preparation method for external and in-cylinder.

Conclusion: The HCCI combustion engines have the potential to improve the thermal efficiency, while reducing the trade-off emissions in conventional diesel engines. The port fuel injection has a high degree of mixture homogeneity compared to the injection methods, but lacks start of combustion control. The emissions of NOx and smoke are low in all advanced combustion modes in comparison with conventional diesel engine, while the UHC/CO emissions are increasing in all temperature combustion concepts except in MK combustion.

[4] Francisco J. Jiménez-Espadafor, Miguel Torres, José A. Velez, Elisa Carvajal, JoséA.Becerra (2011) present on "Low temperature combustion mode in HCCI engine fuelled with diesel and biodiesel fuels."

In this paper study of HCCI combustion fuelled with diesel and biodiesel based on a high swirl ratio and EGR rate. In the experiment measure the HRR, NOx, CO, HC and soot emissions. Also evaluate the performance of early injection strategy use in the fuel wall impingement. Bowl shape piston geometry has been designed with a dedicated swirling flow model.

Conclusion: High injection delay in HCCI combustion with colza biodiesel, high swirl level and EGR rate. This condition reduces maximum engine power compared with diesel combustion mode, but significantly reduces NOx and soot emissions. Also EGR rate increase NOx emissions reduce and smoke level increase, like conventional diesel combustion. Biodiesel percentage increase small increase in NOx and soot emissions.

[5] Hyung Jun Kim , Kwan Soo Lee , Chang Sik Lee (2011) present on "Effect of narrow spray angle and advanced injection timing in HCCI combustion engine fuelled in DME."

In this paper study of the performance and emission characteristics of HCCI combustion according to the narrow spray angle and advanced injection timing fuelled with dimethyl ether (DME) in the diesel engine. The shape of the piston head are modified to bowl type to apply the narrow spray angle and advanced injection timing. The spray, combustion and emission characteristics are calculated by using numerical method of the KIVA-3 V release 2 codes coupled with chemical kinetic model of DME oxidation. Model validation was conducted by a comparison of experimental results data and accurate prediction. To evaluate combustion, performance and emission in the engine for the injection timing range BTDC 80° to BTDC 10°.

Conclusion: In the injection timing BTDC 30° the Nitrogen oxide (NOx) emission is decreased, while injection timing of BTDC 70° the hydrocarbon (HC) and carbon monoxide (CO) emissions at high levels. Also, the IMEP and ISFC have decreasing and increasing patterns respectively as the injection timing was advanced. Regarding engine performance, increasing of the injected fuel mass yield an increase of IMEP but these results in increased the fuel consumption.

Summary and Conclusion:

- As seen from above literature survey, use of bio-fuel as fuel in engine gives best performance and lower emission. So it is economical and environment Friendly, that is the reason of select bio-fuel as a fuel.
- The IMEP increases with the increase of premixed ratio at low to medium loads.
- The emissions of NOx and smoke are low in all advanced combustion modes in comparison with conventional diesel engine.
- The lower soot generation for biodiesel is hypothesized due to a lower soot formation rate and a higher soot oxidation rate.
- The HCCI combustion engines have the potential to improve the thermal efficiency, while reducing the trade-off emissions in conventional diesel engines.
- Low volatility and high viscosity of biodiesel with convectional diesel engine choke the fuel injector upon long-term usage.

2.1 Reasons To Modify Diesel Engines Conversion In To HCCI Engine

- The problem of air pollution around the globe is real and serious, diesel exhaust emissions are a major source of pollution in most urban centers around the world and a major contributor to climate change. Trucks, buses, generators and ships burn millions of gallon of diesel fuel daily. Many countries are to alternative fuels to reduce diesel exhaust emissions, especially in urban centers.
- Furthermore, as the price of crude oil continues to increase, the use of alternative fuel becomes increasingly economical and reduces the import burden of oil country like India.
- Price of diesel is low compare to petrol and has higher efficiency than petrol so people of the urban area are switched over to the diesel engine which make a serious problem in urban are to solve this problem higher efficient and economical operated Biodiesel fuelled diesel engine is required.
- Biodiesel is an alternative source if petroleum source is out of stocks
- HCCI Engine is give high power output compared to C I Engine also it used alternate fuel.

2.1.1 Modification Done To Convert Diesel Engine In To Hcci Engine.

- Cutoff System
- Data Heater Installed On Copper Pipe
- Install Heater In Intake Manifold
- Injector Acquisition Unit.
- Temperature Sensor Installation

2.1.2 Analysis Part as Experimental Set-up

A. Experimental engine test rig.

Fig 2.1 Actual experimental set-ups for modified engine (HCCI engine)

A vertical, single cylinder, water-cooled, four stroke, and high speed diesel engine has been used for the experiment. The technical specification of engine is as under:

Engine	Kirloskar AV1
Dynamometer	eddy current, water cooled
Bore (mm)	87.5
Stroke (mm)	110
Displacement (cm^3)	661
Compression ratio	17.5
RPM	1500
H.P.	5.2

3. FINDING RESULTS AND DISCUSSION

- **Engine performance parameters for conventional Diesel and Diesel-Biodiesel HCCI:**

A. Effect of Load on Specific Fuel Consumption:

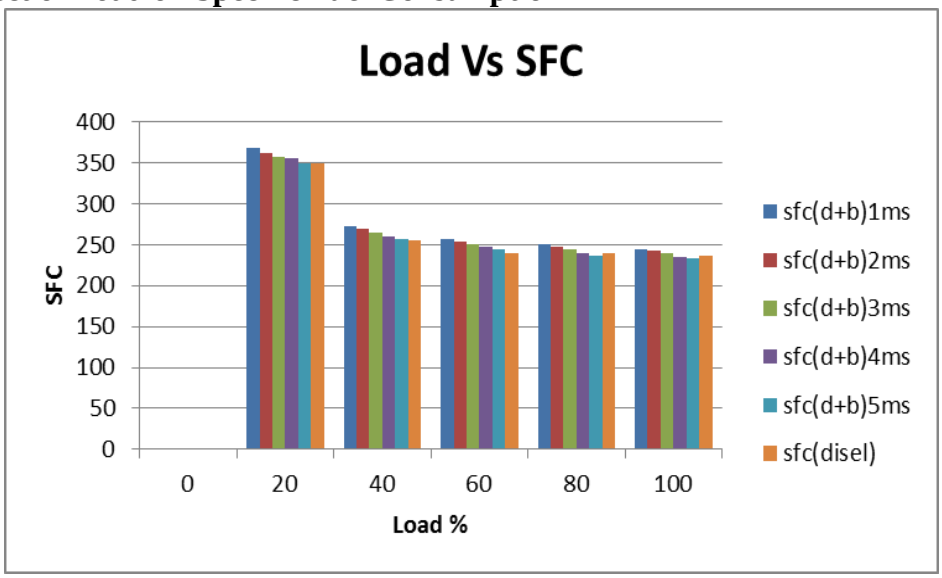


Fig 3.1 Load vs. Specific Fuel Consumption both diesel and Biodiesel.

Fig.1 shows the correlation between the load (%) and SFC consume by the engine while operating on diesel and Biodiesel. SFC consume by the engine was found decrease with increase load for the both the fuel. But compare to diesel the SFC of Biodiesel slightly increase.

B. Effect of Load on Volumetric Efficiency

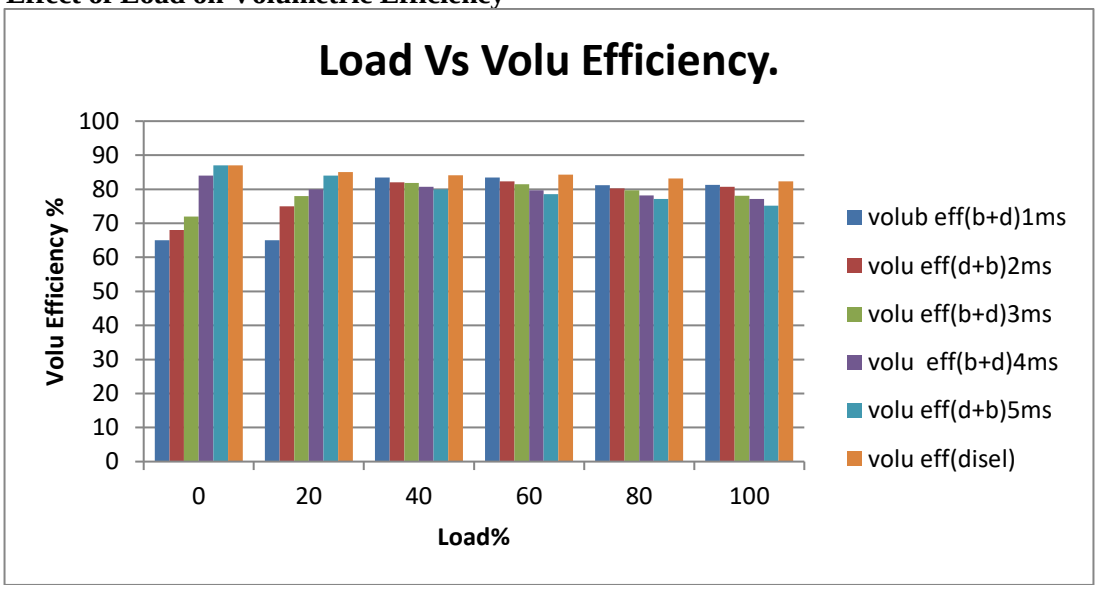


Fig 3.2 Load Vs. Volumetric Efficiency for both diesel and Biodiesel.

C. Effect of Load on Exhaust gas Temperature

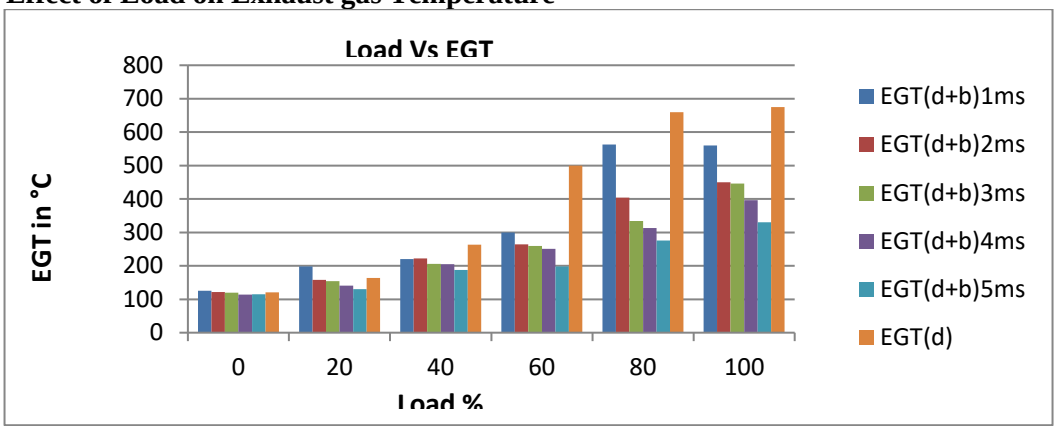


Fig 3.3 Load Vs. Exhaust Gas Temperature both diesel and Biodiesel.

As shown from Fig.3 that at high load temperature increase but compare to diesel it is lower temperature of exhaust.

D. Effect of Load on CO2 emissions

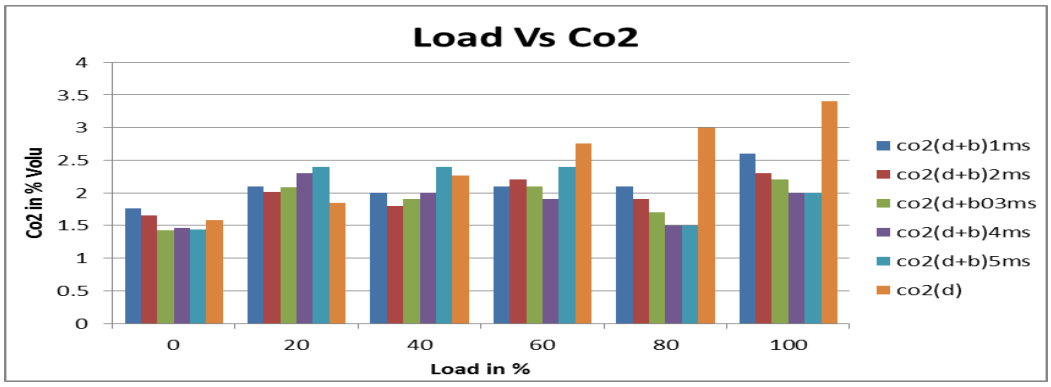


Fig 3.4 Load Vs. CO2 emission both diesel and Biodiesel.

CO_2 emission was increased as the load increased and it is decreases for the higher load for biodiesel.

E. Effect of Load on CO emissions

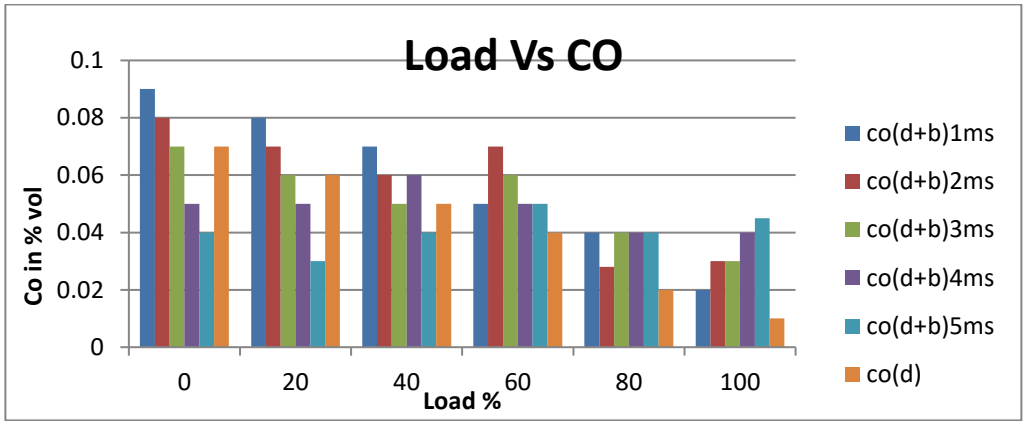


Fig 3.5 Load Vs. CO emission for both diesel and Biodiesel.

It is cleared from Fig-5 that CO emissions are very low compare to diesel while High milli second injection for Biodiesel.

F. Effect of Load on NO emissions

NO emissions were found also low in HCCI engine compare to diesel engine at Low and High Load Condition.

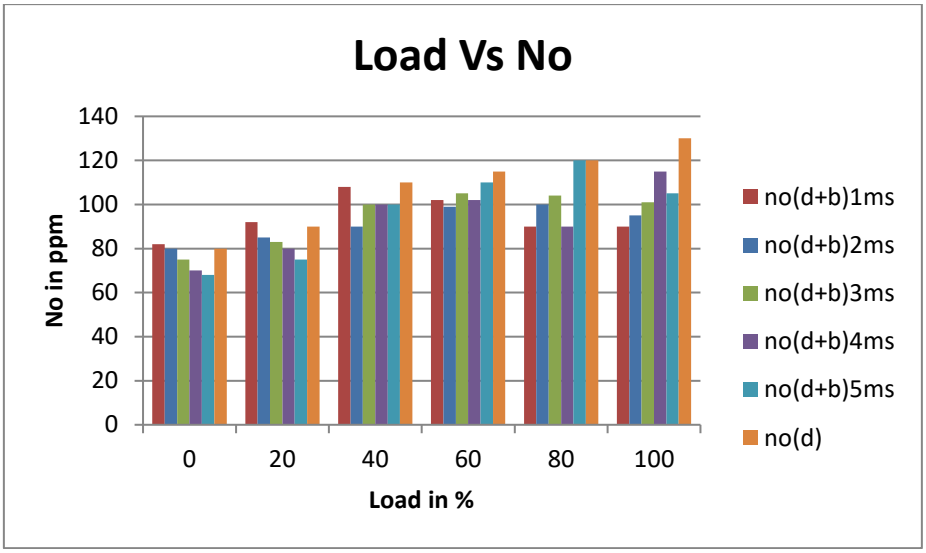


Fig 3.6 Load Vs. NO emission for both diesel and Biodiesel.

4. CONCLUDING REMARKS

- Specific fuel consumption of Biodiesel injection decrease at gradual increase load but compare to diesel engine slightly increase. With increase in milli - second injection in HCCI mode, the SFC decrease.
- Exhaust gas temperature overall decrease in all load rating.
- Volumetric efficiency decrease at 0 to 20% load but increase in high milli second.
- The volumetric efficiency decreases with increase in Load and this is due to fact that the engine cylinder temperature during suction is higher for higher load Conditions. With increase in HCCI, the volumetric efficiency decreases which is due to the displacement of the part of air by the vaporized fuel during the suction stroke.
- The brake thermal efficiency is measured at every 20% rise in load from 20% to 100% of rated load condition. The brake thermal efficiency increases with the increase in load up to 100%, then after it decreases. For HCCI, The brake thermal Efficiency of conventional diesel engine is higher than the Biodiesel HCCI at Lower loads. As the graph show at high load with high milli second injection Increase brake thermal efficiency.
- The co emissions are lower for high time in ms at 0 to 40% load and high load co maximum compare to C.I engine. The CO is observed at different load conditions. Graph represents the variation of CO emission with the increase of load from 0% to 100% at every 20% load increase. The CO emission is observed to be decreasing due to increased rate of complete conversion of C to CO2.
- The NOx emissions are lower for diesel-biodiesel HCCI compared to the conventional diesel in the low load and high load. The NOx emission is observed to be increasing with load and this is due to the rise in combustion temperature favoring the NOx formation. The NOx emission is lower for HCCI engine than the conventional engine for lower loads. At higher load conditions the Biodiesel HCCI emissions maintains its lower pace.

- The hydrocarbon emission is observed with different load conditions. Graph -represents the variation of HC emission with the increase in load from 0% to 100% at every 20% load increase but high load it is decrease. HC emission decrease with increase in load denotes a much complete combustion taking place in the engine combustion chamber.
- Biodiesel is viable alternative fuel for the diesel engine. Existing diesel engine was successfully converted into HCC engine.

These observations lead to the conclusion that up to 3ms HCCI leads to the highest performance with lower emissions and hence is most suitable when compared to the conventional diesel system.

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