Experimental Investigations on CI engine with different Combustion Chamber Designs

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Abstract : Energy is the main source for economic growth of any nation. The fossil fuels are the main source of energy. Many of the researchers concluded that these sources are going to be depleted in near future because of rapid increase in consumption of these fuels. The cost of the fuel is also increasing day by day due to the increase in demand for petro diesel. In addition the more usage of petro diesel products increases the environmental pollution. Therefore there is a necessity to go for alternative fuel in place of petro diesel products. The properties of vegetable oils are nearer to diesel fuel but certain properties like low voltality, high viscosity creates some problems in CI engine. Hence in this work to reduce the effect biodiesel properties combustion chamber design is modified. The various combustion chamber geometries considered in this work are Toroidal, Shallow depth and Hemispherical. The performance parameters like indicated, brake thermal efficiencies, mechanical efficiency and specific fuel consumption are evaluated. The pollutants parameters like oxides of nitrogen, un burnt hydrocarbons, carbon monoxide and carbon dioxides are determined. From the investigation it is observed the brake thermal efficiency and mechanical efficiency are about 1.14% and 7.1% increased respectively. Further the oxides of nitrogen pollutants are decreased about 18.7%.

Index Terms: combustion chamber geometry, Emission ,Jute methyl ester, Neem methyl ester, Performance.

I. INTRODUCTION

The utilization of energy is increasing rapidly mainly because of industrialization and modernization of the universe. In the total production 92% of the total energy extracted from fossil fuel is used in transportation and power sectors. The pollutants emitted from burning of these fuels are the main reason for increase in global warming. Because of this majority of the nations forward a legislation to decrease the effect of global warming. Many of the developing nations are expanding their transportation, agriculture and industrial sectors. Therefore the demand for energy is also increasing. With this the fossil fuel reserve will be depleted in nr future. Hence there is a necessity to alter the fossil fuel in place of petro-diesel products. In India municipal waste, vegetable oils and agriculture are identified as the renewable resources. The alcohols and vegetable oils are suitable and available alternate fuels to use in compression ignition(CI) engines. These are derived from renewable sources. Alcohols are having low cetane number therefore these fuels are not suitable to use in CI engines. Compared to alcohols vegetable oil parameters are similar to that of base diesel. Hence these fuels can be directly used in compression ignition engines without any modification of the engine. These fuels contain more oxygen, hydrogen, carbon and large sized molecules. The chemical structure of vegetable oils are similar to that of base diesel but molecular weight and viscosity are different. Due high molecular structure and viscosity vegetable oils are difficult to break into small size droplets and spray into combustion chamber. These fuels contain more carbon residue correlated to base diesel. This leads to more smoke pollutants in engine exhaust. The stoichiometric air fuel ratio is high due to more oxygen content of the vegetable oils. The vegetable oil heating value is low correlated to base diesel fuel. Therefore certain modifications are required to enhance the performance parameters of the base engine. The modifications such as injection timing, combustion chamber geometry and injection pressure are incorporated to improve the performance and pollutant parameters of the engine. The economic feasibility is the main reason for inertia to utilize vegetable oils in compression ignition engines. In some areas vegetable oils are reasonably available at low prices compared to petro-diesel products. Therefore the cost of oils will decrease in coming future. Based on the topographical, agricultural and potential conditions the potentiality of vegetable fuels are varied. Many types of vegetable oils are tested across the globe to ascertain performance of compression ignition engine. The different kinds of vegetable fuels such as pongamia, rice bran oil, palm oil, coconut oil, soybean oil and jatropha are identified as suitable fuels [1]. The major problems with vegetable oils to use in compression ignition engines are low volatility and high viscosity. Different methods are adopted to overcome these problems. The different techniques like preheating, transesterification, microemulsification, pyrolysis, themal barrier coatings to the engine components, mixing of fuels with additives and variation combustion chamber geometry are used [2]. The investigations are being conducted to develop certain lubricants to utilize in vegetable fuels in compression ignition engines.

Revised Manuscript Received on March 20, 2019.

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Consequently it is the right time to look for alternative fuels in position of petro diesel. These fuels are more easily available in rural based areas. Since the parameters of vegetable fuels are comparable,

these can be used in compression ignition engines. Many of the investigators performed investigation on CI engine using different biodiesel with little modification of the engine. From the investigation the problems with vegetable oil are identified as filter clogging, injector chocking and fuel pump failure [3].

Compared to diesel fuel the vegetable oils in compression ignition(CI) engines exhaust less pollutants. In rural based areas the vegetable fuels are available in decentralized method. Due to less quantity of engines and available in rural areas the pollutants are also less compared to urban areas. Alternative fuels like natural gas, biodiesel, biogas, hydrogen and biodiesel are used in compression ignition engines to test the suitability. From the experiments vegetable oils are identified as suitable alternative todiesel fuel among the available alternative fuels [4]. In the present work investigations are carried out on compression ignition(CI) engine by varying combustion chamber geometry. The various combustion chamber designs used in this work are Toroidal, Shallow depth and Hemispherical combustion chambers. Further in this work two types of biodiesels like Neeem methyl ester(NME) and Jute Methyl Ester(JME) are used to investigate the pollutant and performance parameters.

II. MATERIALS AND METHODOLOGY

In this work experiments are carried out on a water cooled single cylinder 4 stroke compression ignition engine. The engine is Kirloskar made. The loading is applied by using eddy current dynamometer. Experiments are conducted on the base engine without any modification of the engine. The main difficulties associated with biodiesel are injector pump failure, filter clogging, ring sticking and unwanted exhaust emissions. The experimental setup is designed and instrumented by taking necessary precautions. Different thermocouples and pressure sensors are attached inside the engine cylinder to measure temperatures and pressures at various locations.

2.1 The Engine Setup

A single cylinder 4 stroke naturally aspirated water cooled compression ignition engine is used for conducting the experiments.

S.No.	Parameter	Specification
1	Engine Power	5.2 kW
2	Rated speed	1500 rpm
3	Compression ratio	17.5:1
4	Stroke length	110 mm
5	Cylinder bore	87.5 mm
6	Connecting rod length	235 mm
7	No. of cylinders	1
8	Loading device	Eddy current dynamometer
9	Stroke type	4

Table:2.1 Specifications of the engine

Fig. 2.1. Engine setup

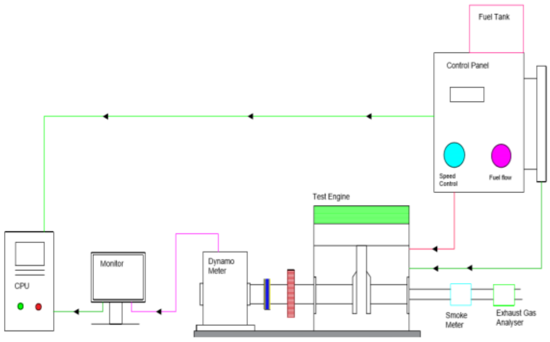

Fig. 2.2. Test Engine Schematic layout

Fig.2.3. HCC

Fig.2.4.TCC

Fig.2.5.SDCC

Properties	Diesel fuel	Neem methyl ester	Jute methyl ester	Method
Specific	0.83	0.88	0.85	ASTM D
Density	830	948	978	ASTM D
Kinematic Viscosity@	3.01	13.05	3.8	ASTM D 445
Heating value	42.5	34	38	ASTM D
Flash point	50	175	166	ASTM D
Fire point (°C)	60	191	179	ASTM D

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Cetane number	47	45-47	44-48	ASTM D 613

Table-2.2 Physical and chemical properties of biodiesel compared to diesel as per ASTM Standards

III. RESULTS & DISCUSSIONS

3.1 Performance Parameters:

Jute methyl ester(JME) and Neem methyl ester(NME) are used as fuels in the engine to determine the performance parameters. The performance parameters like specific fuel consumption(SFC), brake thermal efficiency(BTE), mechanical efficiency(ME) and indicated thermal efficiency are determined. The properties evaluated for JME and NME are similar to diesel fuel. Further three different kinds of combustion chamber geometry are varied with diesel and biodiesels are Hemispherical Diesel(HD), Toroidal Diesel(TD), Shallow Depth Diesel(SD), Toroidal Jute Methyl Ester(TJME), Toroidal Neem Methyl ester(TJME), Shallow Depth Jute methyl ester(SJME) and Shallow Depth Neem methyl ester(SNME). Fig.3.1.1 shows the variation of brake thermal efficiency with brake output power. From the figure it is identified that with increase of brake power the brake thermal efficiency is also increased. The BTE of Toroidal JME is about 27% at full load condition. This value is almost nearer to base engine. The minimum brake thermal efficiency is observed for Toroidal NME and is about 18.5%. This value is minimum correlated to other piston configurations. This is mainly due to lower calorific value of neem methyl ester compared to jute methyl ester. The BTE observed for Toroidal JME is almost nearer to base engine due to swirl in motion is high for Toroidal combustion chamber correlated to other combustion chamber geometries. Certain fuel properties of Jute methyl ester are superior that the Neem methyl ester.

Fig.3.1.2 indicates the difference between output power vs mechanical efficiency. The trend of the graph is similar to that of BTE. There is a proportional increament in mechanical efficiency at partial load condition. At maximum load operation the mechanical efficiency is almost constant for entire operations. The ME obtained for Toroidal JME is about 83% where as for standard engine is about 77.5%. The Toroidal JME mechanical efficiency at maximum load condition is high compared to conventional engine and is about 7.13%. The reason is flame travelling speed is in line with fuel air mixture moment in the cylinder. Further the ME for Toroidal NME is low correlated to Toroidal JME. This is mainly due to higher viscosity of neem methyl ester compared to jute methyl ester. Fig 3.1.3 shows the variation of indicated thermal efficiency with brake power. The indicated thermal efficiency(ITE) is slowly increased from zero load condition to full load condition. The Toroidal JME indicated thermal efficiency is about 43.9% at maximum load condition where as for diesel is about 42.3%. The higher ITE for Toroidal JME is due to high rate of combustion in Toroidal combustion chamber geometry. The Toroidal NME indicated thermal efficiency is less correlated to Toroidal JME. The calorifica value of NME is lower compared to JME.

Fig.3.1.4 shows the differences between specific fuel consumption and brake power. There is a significant reduction in specific fuel consumption upto 42% of full load operation. For remaining load operation no much variation in SFC is observed. The Toroidal JME specific fuel consumption is about 0.287 kg/kWh for full load condition where as for base engine it is about 0.29 kg/kWh at maximum load operation. The Toroidal JME specific fuel consumption is almost equal to base engine at full load operation. The energy generation rate is more because of proper mixing of fuel air mixture. The another reason is toroidal configuration wall thickness is low correlated to other piston geometry. The low SFC is observed for Toroidal NME and is about 0.45 kg/kWh at maximum load condition.

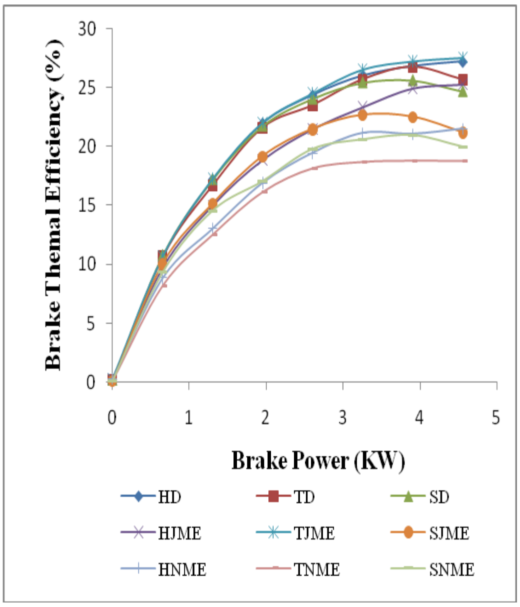

Fig.3.1.1 BP vs BTE

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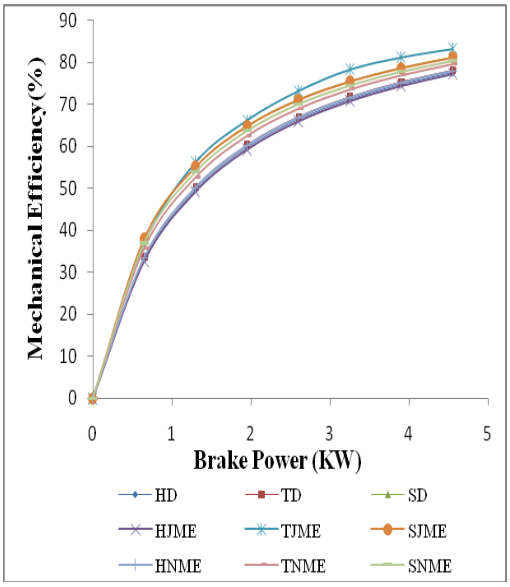

Fig.3.1.2 BP vs ME

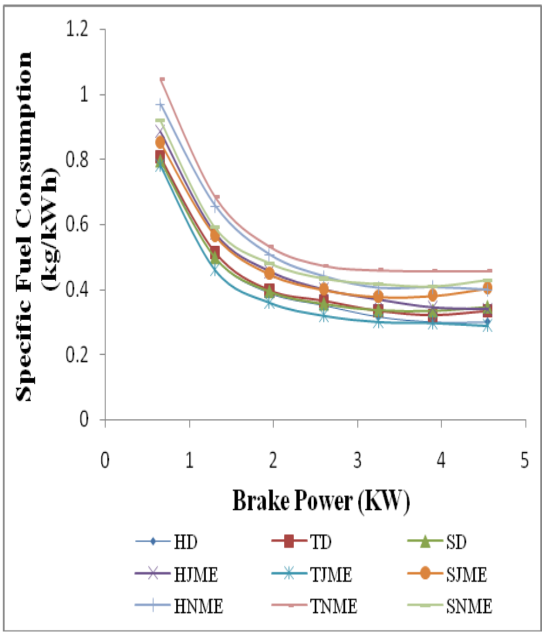

Fig.3.1.4 BP vs SFC

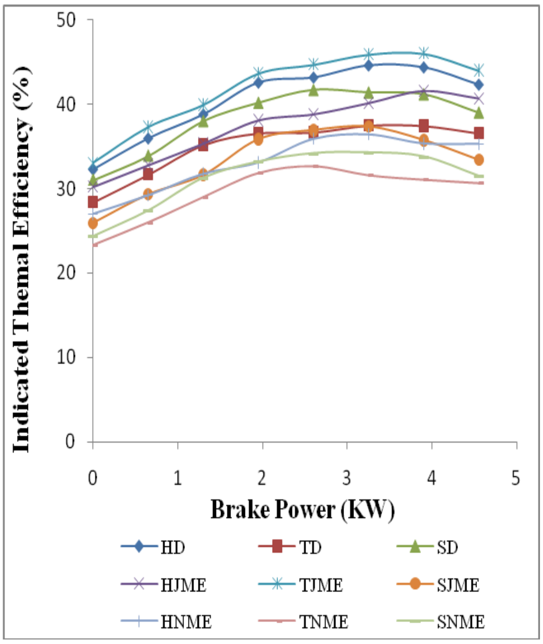

Fig.3.1.3 BP vs ITE

3.2 Emission Characteristics

The pollutant parameters are evaluated with different piston configurations by using Neem methyl ester and Jute methyl ester. The pollutant parameters like unburned hydrocarbon, NOx, carbon monoxide and carbon dioxide are determined.

Fig.3.2.1 shows the variation between brake output power vs CO pollutants. It is found that from 0% to 72% rated load condition no much variation in the emission levels. But after 72% of load condition CO pollutants are increased drastically. The carbon monoxide emissions for Hemispherical JME is 0.45% at 100% load operation. The carbon monoxide pollutants for TD is 0.54% at 100% load condition. The H JME emissions are less compared to base diesel engine and is about 20%. This is due to maximum fuel air mixture burning rate. Engine brake output vs HC pollutants are plotted in the fig.3.2.2. It is observed that from 0% load condition to 100% load condition HC pollutants are increased for all piston geometries. The unburnt hydrocarbon pollutants for Toroidal JME is 53ppm at 100% load condition. The HC pollutants for base diesel is 64 ppm at 100% load condition. The unburnt hydrocarbon emissions are low with Toroidal JME correlated to standard diesel and is 16.8%. The hydrocarbon pollutants obtained is less for Toroidal JME correlated to standard diesel and is 15.8%. The Toroidal NME emissions are high and is 205ppm at 100% load condition. The high viscosity and uneven combustion spray is the main reason for high emissions. Fig.3.2.3 shows the variation between brake power and CO_2 emissions. It is concluded that the carbon dioxide pollutants are increased linearly from 0% load condition to full load condition.

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The CO2 pollutants for Toroidal NME is 10.01% at 100% load condition. The carbon dioxide pollutants for base diesel is 11.04% at 100% load operation. The Toroidal NME pollutants are less compared base diesel and is 8% at 100% load condition. The reason is effective combustion inside the engine cylinder.

Fig.3.2.4. shows the graph between brake power and NOx with various combustion chamber geometry. It is revealed that the oxides of nitrogen pollutants are increased from 0% load to 100% load condition. The oxides of nitrogen pollutants for hemispherical NME is 1840ppm at 100% load operation. The NOx emissions for JME is high correlated to NME and is about 7.4%. The main cause is improved inside cylinder temperature and rate of pressure rise is high. The Toroidal JME NOx pollutants are less correlated to remaining piston geometry and is 905ppm at 100% load condition.

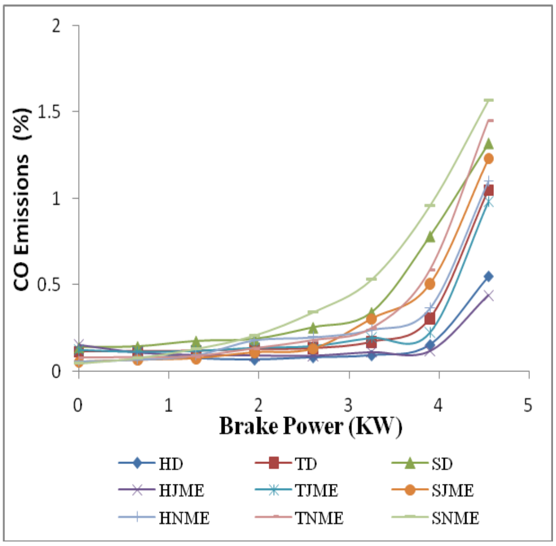

Fig.3.2.1 BP vs CO

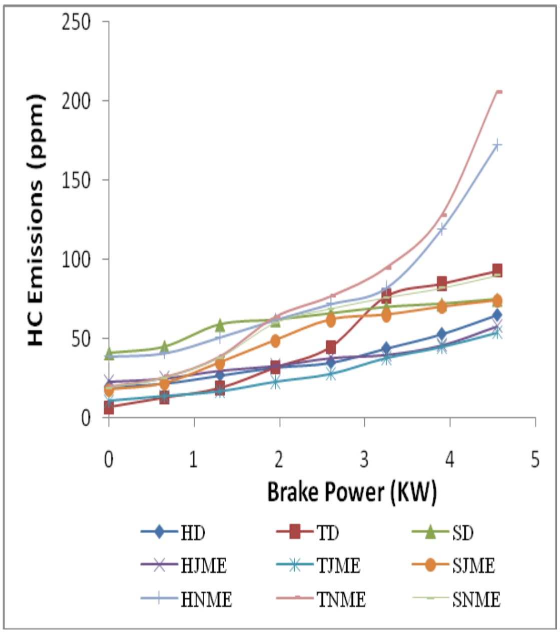

Fig.3.2.2 BP vs HC

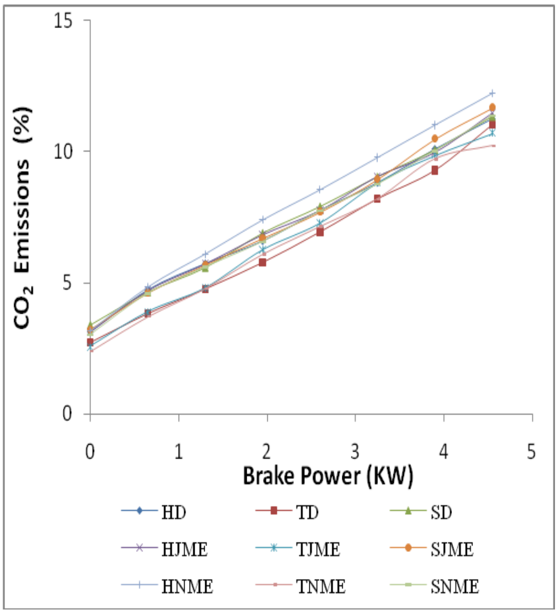

Fig.3.2.3 BP vs CO_2

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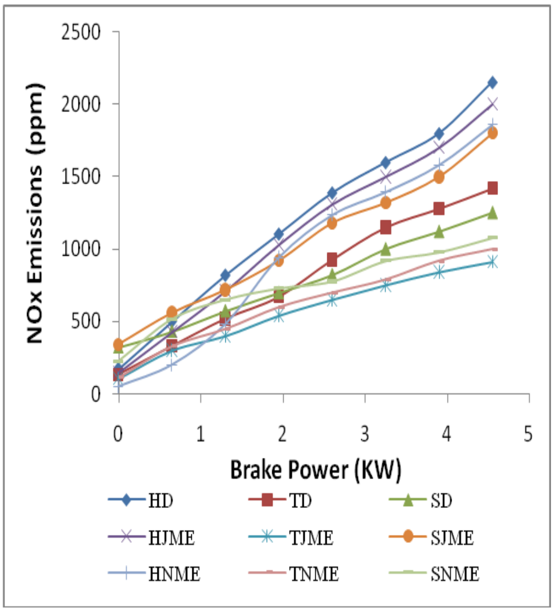

Fig.3.2.4 BP vs NO_x

IV. CONCLUSION

The experiments are carried out on single cylinder, water cooled, direct injection four stroke compression ignition engine with different piston geometry using Jute and Neem methyl esters as substitute fuels.

- The Toroidal JME mechanical efficiency is 7.13% more correlated to standard diesel engine. The main cause is increased temperature of Toroidal combustion chamber.
- The BTE recorded for Toroidal JME is almost equal to base engine diesel. This is due to high swirl motion inside the engine cylinder.
- From the experimentation the Specific fuel consumption is lower for Toroidal JME and is 3.78% correlated to standard engine. In this fuel vapour injection and air movement are the main reasons for efficient combustion.
- The Hemispherical JME pollutants are less correlated to standard engine and are 20%. This is due to maximum fuel air mixture burning rate.
- The HC pollutants are less for TJME correlated to standard diesel and is 15.8%. The complete combustion of fuel is the main cause for lower emissions.
- The NOx pollutants for JME is high correlated to NME and are about 7.4%. The main cause is improved inside cylinder temperature and rate of pressure rise is high.

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