CHAPTER 2

REVIEW OF PREVIOUS WORK

2.1 INTRODUCTION

Diesel combustion is compression induced and depends to a major extent on successful vapourisation and mixing over an extremely short time, which is more complex and difficult than that of the spark ignition engine. The thermodynamic diesel cycle differs from the constant volume cycle of spark ignition engine as conceived by Otto. In reality, it tends to be close to the constant volume cycle but it is actually a combination of constant volume and constant pressure cycle.

In idealised diesel engine cycle, all the heat is assumed to be supplied while piston is passing over Top Dead Center (TDC), because upward motion of the piston has almost ceased, the gases are burnt at virtually constant volume. In practice, however this burning continues over part of the downward motion of the piston, during which the rate of expansion is such that the conditions approximate to constant pressure.

The diesel engine is a compression ignition engine, in which the fuel is ignited solely by the high temperature created by compression of air-fuel mixture. The engine operates on the diesel cycle. The diesel engine is more efficient than petrol engine, since the spark-ignition engine consumes more fuel than the compression-ignition engine. The use of diesel engines has been extended in transportation due to their high efficiency and economic fuel
cost. In present day diesel engines, the fuel injection systems are designed to obtain higher injection pressures.

Hence, it is aimed to decrease the exhaust emissions by increasing the efficiency of diesel engines. When fuel injection pressure is low, fuel particle diameter increases and delay period will increase. This situation leads to increase in combustion pressure which will result in higher emissions of NOx. High injection pressure reduces the fuel particle diameter, which leads to better mixing of fuel with air. If injection pressure is too high, ignition delay period becomes shorter and affects air fuel mixing and leads to reduction in combustion efficiency of the fuel.

Fuel injection is a system for mixing fuel with air in an internal combustion engine. It has become the primary fuel delivery system used in automotive petrol engines, having almost completely replaced carburettors in the late 1980s. A fuel injection system is designed and calibrated specifically for the type(s) of fuel it will handle. Most fuel injection systems are for gasoline or diesel applications. With the advent of electronic fuel injection (EFI) system, the diesel and gasoline hardware has become similar.

2.2 EFFECT OF FUEL PROPERTIES ON PERFORMANCE OF BIODIESEL AS FUEL

The physical and chemical properties of biodiesel influence the performance of biodiesel as a fuel in compression ignition engines. The properties such as density, viscosity, bulk modulus, cetane number, fuel bound oxygen, degree of saturation, surface tension and heat capacity, all have impact on the combustion and emissions of C.I. engines.

Schmidt et al (1996) reported that high oxygen content improves combustion efficiency and reduces hydrocarbon, carbon mono oxide and smoke emissions. The availability of oxygen is attributed to the formation of
NO. It was also observed that the presence of oxygen exhibits low compressibility. The oxygen content of biodiesel increases the boiling point of biodiesel.

Tat et al (2000) reported that bulk modulus is a measure of resistance to compressibility. Bulk modulus decreases with increase in temperature and increases with increase in pressure. The vegetable oil esters are less compressible than diesel. This less compressibility leads to increased mass delivery of the fuel. The high value of bulk modulus causes an advance in injection timing which leads to more fuel accumulation in the combustion chamber. It was reported that the bulk modulus is higher for unsaturated methyl esters and increases with the chain length of the acid.

Tat et al (2000) reported that unsaturated fatty acid molecules have high bulk modulus or low compressibility which leads to earlier injection of fuel. The presence of double bond reduces the chain length of the fatty acid, thus leaving less space for molecules to squeeze closer together and hence reduces compressibility. The cetane number of biodiesel can vary with differences in fatty acid composition, chain length and the saturation level. It was observed that cetane values for saturated fatty acids were higher and it increased with increase in chain length.

Tottel et al (2003) observed that fuels with high cetane number increase the power output, better cold start properties and reduce smoke emissions. Higher cetane number reduces delay period and lowers the combustion temperature. This leads to better combustion of fuel and thermal efficiency using biodiesel. The cetane number of biodiesel is linearly correlated with the saturated fatty acid composition and the chain length of the acid.
A study by Knoth et al (2003) showed that the cetane number of the fuel increases with saturated fatty acid content. The chain length of the saturated fatty acid is longer when compared to unsaturated fatty acid which is mainly due to the presence of double bond in unsaturated acids. The cetane number increases with increase in the length of the fatty acid chain.

Usta et al (2005) observed that biodiesels have higher viscosity than conventional diesel. The fuel viscosity affects the fuel injection characteristics and fuel atomisation. The increase in viscosity leads to increase in biodiesel fuel injection by mass. The higher viscosity of biodiesel also leads to poor atomisation, smaller spray cone angles, high spray jet penetration and larger droplet sizes. Smaller spray cone angles and advanced start of injection are the main reasons for lesser thermal efficiency and increased NOx emissions of biodiesel.

Ahmed et al (2006) reported that coconut oil methyl ester has got the smallest mean drop size when compared to peanut and canola methyl esters due to its lower surface tension. This reduction in fuel drop size improves the combustion efficiency of the fuel. The fuel atomisation is affected by surface tension. The biodiesel with higher surface tension offers resistance to fuel atomisation.

Bamgboye et al (2008) studied the dependence of cetane number on fatty acid methyl ester composition of biodiesels. It was observed that the fatty acid methyl esters from vegetable oils were mostly unsaturated, while the animal fat and palm oil are saturated fatty acids. It was reported that the cetane number for saturated fatty acids were above 60, while those of unsaturated fatty acids were below 60.

Alptekin et al (2008) observed that density, viscosity, cetane number and heat of combustion are interrelated for all fuels used in engines.
The high density fuels usually have higher viscosity which affects the fuel injection characteristics. Modern diesel engine fuel injection systems measure fuel by volume. Hence the changes in the fuel density will influence the mass of fuel injected and performance characteristics.

Knothe (2009) reported that the most common fatty esters contained in biodiesel are mainly C12 to C16 fatty acids including lauric acid (C12:0), myristic acid (C14:0), palmitic acid (C16:0), stearic acid (C18:0), oleic acid (C18:1), linoleic acid (C18:2), and linolenic acid (C18:3). Emission tests were conducted in a CI engine and observed that there was a decrease in NOx emissions with saturated fatty acids like lauric acid and palmitic acid and increase in emissions with unsaturated fatty acids like linoleic acid.

Smith et al (2010) found that the high degree of saturation and increase in chain length of the fatty acid tends to increase the cloud point which may cause clogging of fuel lines. It was proposed that the cloud point can be reduced by blending with diesel and by the use of additives. The double bonded molecules of biodiesel tend to have a higher flame temperature which increases the combustion temperature and the formation of oxides of nitrogen.

2.3 PERFORMANCE OF BIODIESEL AS FUEL IN CI ENGINES

Ramadhas et al (2004) reported that it is necessary to look for alternative fuels, which can be produced from materials available within the country. Biodiesel, which can be used as an alternative diesel fuel, is made from renewable biological sources such as vegetable oil and animal fats. It is biodegradable, non-toxic and possesses low emission profiles. Relatively low CO emissions were obtained with esters in comparison with raw vegetable oils. Maximum CO₂ emissions were about 10.5% with diesel fuel and marginally lower with vegetable oil. It was due to better spraying qualities
and more uniform mixture preparation of these esters. NOx emissions with vegetable oil fuels were lower than those with diesel fuel and NOx values of methyl esters were higher than those of raw fuels. Smoke opacity during each of the vegetable oil operations was higher than that of diesel fuel. The opacity values of methyl esters were between those of diesel fuel and raw vegetable oil fuels. The greater smoke opacity of vegetable oil fuels are mainly due to heavier molecules of hydrocarbons. It was concluded that the use of vegetable oils as I.C. engine fuels can play a vital role in helping the developed world to reduce the environmental impact of fossil fuels.

Ramadhas et al (2005) had done a two-step esterification to produce biodiesel from high FFA vegetable oils. Biodiesel production method consists of acid-catalysed pretreatment followed by an alkaline-catalysed transesterification. Pure rubber seed oil, diesel and biodiesel were used as fuels in compression ignition engine and the performance and emission characteristics of the engine were analysed. B10 biodiesel blend gave a good improvement in brake thermal efficiency of diesel engine by about 3% at the rated load conditions. It was found out that emission and brake specific fuel consumption reduced while using B10. Higher the concentration of biodiesel blend, higher is the reduction of smoke density in exhaust gas. The NOx emission formation is a highly temperature dependent phenomenon, with increase in biodiesel blends NOx emission was also expected to increase.

Deepak agarwal and Avinash kumar agarwal (2007) conducted experiments with jatropha biodiesel in a single cylinder water cooled diesel engine by varying injection pressures from 180 bar to 240 bar with an increment of 20 bar pressure. Increase in brake thermal efficiency and decrease in smoke emission were observed for 200 bar pressure. However further increase in injection pressure from 200 to 240 bar resulted in decrease in brake thermal efficiency and increase in smoke emissions. Based on brake
thermal efficiency and smoke emission, fuel injection pressure of 200 bar was found optimum for jatropha biodiesel.

Pradeep et al (2007) reported the effects of hot exhaust gas recirculation (EGR) in a single cylinder diesel engine. The results showed that the reduction in brake thermal efficiency over an EGR range of 0-25% was 4.9% for jatropha biodiesel whereas it was 6.6% for diesel. A marginal decrease in smoke and carbon monoxide emissions was observed for jatropha biodiesel when compared to diesel. Hot EGR of 15% effectively reduced NOx emission without adverse effects on the performance, smoke and other emissions.

Can Hasimoglu et al (2008) studied the effect of biodiesel (produced from sunflower oil) usage in LHR engine on the performance characteristics. When biodiesel was used as fuel, increments in engine power and torque were mainly caused by the higher mixture heating value of biodiesel. The deterioration of engine power and torque for biodiesel fuel was caused by higher viscosity of biodiesel. Lower heating value of biodiesel caused an increase in specific fuel consumption. By the application of thermal barrier coating, there was an improvement in the specific fuel consumption which causes an increase in brake thermal efficiency for biodiesel in LHR engine. The combined effect of increased intake air temperature and lower exhaust gas temperature before the turbine inlet decreases the volumetric efficiency for biodiesel fuel in LHR engine. Filter plugging and starting problems were observed during the operation.

Anand et al (2009) reported that a maximum of 2.3 degree CA (crank angle) advance in dynamic fuel injection timing was observed with biodiesel compared with the diesel fuel. The ignition delay is lower for biodiesel compared with diesel fuel at all engine speeds. The maximum thermal efficiency occurring at the maximum torque speed of 1400 r/min is
observed to be 40.7 percent and 40.5 percent for diesel and neat biodiesel respectively. A significant reduction in unburnt hydrocarbon and smoke emissions, comparable carbon monoxide emissions, and higher nitric oxide emissions were observed with biodiesel compared with diesel fuel operation. In general, an improvement in combustion characteristics and reduced exhaust emissions, except nitric oxide, were observed for biodiesel compared with diesel fuel, with a marginal penalty in brake thermal efficiency.

Bajpai et al (2009) experimented on Diesel and karanja oil fuel blends (5%, 10%, 15%, and 20%) at varying loads. The brake specific energy consumption (BSEC), brake thermal efficiency (BTE), and exhaust emissions were evaluated to determine the optimum fuel blend. The viscosity of preheated neat karanja oil at 90°C was found to be very close to that of petroleum diesel oil. The flash point of karanja vegetable oil (KVO) and its blends was higher than that of diesel oil, which signifies a safe range for the storage of KVO. KVO10 was found to be the best, and it improved the thermal efficiency of the engine. Similarly, the BSEC and exhaust emissions were also reduced appreciably. A decrease in the exhaust gas temperature and NOx emissions were observed for KVO10. The performance of the KVO-fuelled engine was marginally better than the diesel-fuelled engine in terms of thermal efficiency, BSEC, smoke opacity and exhaust emissions, including NOx emission, for the entire range of operations. It was concluded that the self-lubricity and oxygen content of KVO played a key role in engine performance.

Bai-Fu Lin et al (2009) had conducted an experimental investigation of Petroleum diesel and eight kinds of vegetable oil methyl ester (VOME) fuels in an unmodified direct injection (DI) diesel engine. The VOME fuels have higher cetane number and thus can provide better ignition quality. The higher viscosity and higher oxygen content of VOME fuels also
yield better air–fuel mixing. The increased oxygen available during combustion process improves the combustion. Therefore, it was found that the use of VOME fuels in a diesel engine can reduce exhaust gas temperature (EGT) whilst reducing smoke and total hydrocarbon (THC) emissions, however with a marginal increase in nitrogen oxides (NOx) emissions. The VOME fuels such as palm kernel oil methyl ester (PKOME) and palm oil methyl ester (POME), which have shorter carbon chain lengths and more saturated bonds, have superior ignition quality. The superior ignition quality and higher oxygen content of these VOME fuels tend to allow better combustion at a lower temperature. Therefore, significant reductions in EGT, smoke and THC emissions are observed.

A lower combustion temperature also suppresses the formation of NOx emissions. The superior air–fuel mixing and higher oxygen content available for combustion results in a rapid rise of the heat release rate and the combustion pressure. The experimental results demonstrated that the physical and chemical fuel properties of VOME fuels have significant effects on the combustion timing, combustion rate, and combustion efficiency.

Murat karabektas (2009) studied the effects of a turbocharger on a diesel engine with biodiesel as fuel. It was reported that increase in BSFC was mainly due to lower calorific value and higher density of biodiesel. Noticeable increase in NOx emission and reduction in smoke emission for biodiesel were observed for turbocharged engine. However overall performance of the turbocharged engine improved when compared to naturally aspirated engine.

Nabi et al (2009) carried out tests with biodiesel produced from cottonseed oil (CSO). The engine experimental results showed that exhaust emissions including carbon monoxide (CO), particulate matter (PM) and smoke emissions were reduced for all biodiesel mixtures. However, a
A marginal increase in oxides of nitrogen (NOx) emission was experienced for biodiesel mixtures. Compared to neat diesel fuel, 10% biodiesel mixtures reduced PM and smoke emissions by 24% and 14% respectively. Biodiesel mixtures (30%) reduced CO emissions by 24%, while 10% increase in NOx emission was experienced with the same blend. The reason for the reduction in PM, smoke and CO and increasing NOx emission with biodiesel mixtures was mainly due to the presence of oxygen in their molecular structure. Thermal efficiency with biodiesel mixtures was marginally lower than that of neat diesel fuel due to lower heating value of the mixtures. However, volatility, higher viscosity, higher density may be additional reasons for efficiency reduction with biodiesel mixtures.

Ozsezen et al (2009) conducted performance and emission tests on a diesel engine with waste palm oil methyl ester and canola methyl ester as fuel. The results showed that there was reduction in brake thermal efficiency by about 1.42% for palm oil with no significant change in the case of canola oil methyl esters. This reduction was due to lower calorific value of the fuels. NOx emissions were increased for both the fuels due to shorter ignition delay, higher peak pressure and temperature inside the cylinder. It was observed that the start of combustion was earlier by 2°C for both the fuels when compared with diesel fuel. The earlier start of combustion was related to higher cetane number of biodiesel fuels.

Sahoo et al (2009) conducted tests with neat biodiesel from Jatropha, Karanja and Pongamia; and their blends (20 and 50 by vol%) at varying loads (0, 50 and 100%). The engine combustion parameters such as peak pressure, time of occurrence of peak pressure, heat release rate and ignition delay were computed. It was concluded that neat Pongamia biodiesel (PB100) which results in maximum peak cylinder pressure (6.6 bar higher than that of diesel) as the optimum fuel blend as far as the peak cylinder
pressure is concerned. The ignition delays were consistently shorter for JB100, varying between 5.9 degree and 4.2 degree crank angle lower than diesel. Similarly, ignition delays were shorter for Karanja biodiesel (KB100) (varying between 6.3 degree and 4.5 degree crank angle) and Pongamia biodiesel (PB100) (varying between 5.7 degree and 4.2 degree crank angle) lower than diesel.

Sahoo et al (2009) conducted performance and emission tests with biodiesels prepared from jatropha, pongamia and polonga oils in a water cooled three cylinder diesel engine. The results showed that B20 blends of all the three biodiesels have better thermal efficiency when compared to diesel fuel. A significant increase in NOx, carbon monoxide emissions and noticeable reduction in hydrocarbon, smoke emissions were observed for B40, B60 and B100 fuels.

Sukumar puhan et al (2009) conducted performance and emission tests in an air cooled diesel engine with linseed oil methyl esters at varying injection pressures. The fuel injection pressure was varied from 200 to 240 bar with an increment of 20 bar. The results show that at 240 bar pressure, the brake thermal efficiency was comparable to that of diesel. A marginal reduction in smoke, HC and carbon monoxide emissions and a significant increase in NOx emission were observed. It was reported that the presence of oxygen in biodiesel was the reason for higher NOx emission.

Tiegang fang et al (2009) performed combustion and emission tests on a high speed direct injection diesel engine with blends of soya bean biodiesel. It was observed that under normal injection timing the NOx emissions were found to be increased. By adopting dual injection mode and retarding the injection timing the NOx emissions were lowered by 34%. It was stated that simultaneous reduction of NOx and smoke wase possible with dual injection mode.
Jindal et al (2010) conducted experiments by varying nozzle opening pressures (150, 200 and 250 bar) and compression ratio (16, 17 and 18) as against the standard values set by manufacturer for diesel as fuel (210 bar nozzle opening pressure and 17.5 Compression ratio). The highest performance is delivered by the engine at 250 bar injection pressure and compression ratio of 18 at which BSFC improves by 10% and brake thermal efficiency improves by 8.9%. With regard to emission aspects, increase in compression ratio leads to increase in emission of HC and exhaust temperature whereas, smoke and CO emission reduces. NOx emissions are found to remain unaffected at higher injection pressure. For all combinations of compression ratio and injection pressure, the emissions of HC, NOx, smoke opacity and exhaust temperature are lower with pure bio-diesel against that of diesel fuel. It was found that for fuelling the engine with bio-diesel, higher compression ratio associated with higher injection pressure gives better efficiency.

Enweremadu et al (2010) carried out experiments with used cooking oil (UCO) biodiesel and its blends in a diesel engine. The blends of biodiesel reduced the engine performance marginally compared to diesel. BSFC increases with increase in percentage of UCO biodiesel in the blend and is due to the lower heating value of UCO biodiesel and its blends. NOx emissions were slightly higher while un-burnt hydrocarbon (UBHC) emissions were lower for UCO biodiesel when compared to diesel fuel due to the presence of oxygen. The ignition delay of UCO biodiesel decreases with increase in percentage of UCO in the blend and is less when compared to that of petroleum diesel. The peak pressure of UCO biodiesel and its blends is higher than that of diesel fuel. The rate of pressure rise and heat release for UCO biodiesel and diesel are similar. The exhaust gas temperature increase with increase in percentage of UCO in the blend. Increased oxygen content
which improves combustion is a reason given for higher exhaust gas temperature.

Aydin et al (2010) conducted the performance and emission tests of a diesel engine with cottonseed oil methyl ester. For the study, cottonseed oil methyl ester (CSOME) was added to diesel fuel by volume of 5% (B5), 20% (B20), 50% (B50) and 75% (B75) as well as pure CSOME (B100). The effects of CSOME diesel blends on engine performance and exhaust emissions were examined at various engine speed and load condition. Results showed that with the increase of CSOME in the blends, the torque was decreased due to higher viscosity and lower heating value of CSOME. At rated power output, brake specific fuel consumption of B20 was lower than those of other fuels including diesel fuel. It may be due to the fuel based oxygen and higher cetane number, leading to more complete combustion at low speeds. The CO emissions decreased with biodiesel usage due to the presence of oxygen in CSOME. In these experiments, NOx emissions were decreased for all blends and B100 except for B5. The experimental results proved that lower and medium percentages of CSOME can partially be substituted to the diesel fuel without any modifications in diesel engine.

Qi et al (2010) reported that biodiesel from soybean crude oil was prepared by a method of alkaline-catalysed transesterification. Results show that diesel engine can perform satisfactorily on biodiesel and its blends with diesel fuel without any engine hardware modifications. The BSFC increases with increase in percentage of biodiesel in the blends due to the lower heating value of biodiesel. The brake thermal efficiency of biodiesel and its blends are marginally lesser than that of diesel at low engine loads, and almost the same at high engine loads. The oxygen content in the biodiesel results in better combustion and increases the combustion chamber temperature, which leads to higher NOx emissions, especially at high engine loads. HC emissions of
biodiesel and its blends have marginal difference from diesel fuel. It was observed that there was a significant reduction in CO and smoke emissions at high engine loads. The combustion starts earlier for biodiesel and its blends than for diesel. The peak pressure rise rate and peak heat release rate of biodiesel are higher than those of diesel fuel at low engine loads, but inversely at high engine loads. The study suggests that excess oxygen content of biodiesel play a key role in engine performance and biodiesel is proved to be a potential fuel for complete or partial replacement of diesel fuel.

Flavio Caresana et al (2010) investigated the impact of the bulk modulus of biodiesel on the injection characteristics of a diesel engine. The bulk modulus differences were the reason most frequently invoked to justify the marginal increase in NOx emissions observed with biodiesel-based fuels compared with petroleum diesel. It was reported that biodiesel use in mechanically controlled injection systems instead of blends with conventional diesel fuel involves comparable maximum injection pressure values, and advancement in injection timing.

Hwanam kim et al (2010) conducted experiments on CRDI diesel engine to study the effect of biodiesel and bioethanol blended diesel fuel on the emissions. It was observed that the fuel consumption for the blend increased due to lower calorific value of the blend. Smoke emissions were reduced by 50% while marginal reduction in HC and carbon monoxide was observed. NOx emission increased for the blends when compared to diesel.

Saravanan et al (2010) conducted tests on a stationary diesel engine fuelled with biodiesel prepared from rice bran oil and diesel. It was observed that the delay period and rate of pressure rise were lower for rice bran oil biodiesel when compared to diesel. NOx emission increased by 18% and smoke emission reduced by 35% for rice bran oil biodiesel. It was reported
that the presence of oxygen in biodiesel was the reason for increase in NOx emission.

Dattatray bapu halwan et al (2011) investigated the effects of blends of biodiesel and ethanol with diesel in a multi cylinder diesel engine. It was reported that injection timing has to be changed to 18° CA instead of the actual injection timing of 13° CA before top dead centre. This was due to the displacement of 50% diesel by the blends. NOx emissions were doubled, while smoke emissions were reduced by 60-70% for all the blends. The carbon monoxide emission reduced significantly at lower loads.

Rao (2011) studied the effects of 100% biodiesel in normal mode and preheated mode in a single cylinder diesel engine. A reduction in brake thermal efficiency and increase in NOx emission were observed for normal operation mode. In preheated mode of operation the efficiency and NOx emission were comparable with that of diesel. It was reported that high NOx emissions were due to the presence of unsaturated fatty acids and the advanced injection caused by higher density of jatropha biodiesel.

Boubhari chokri et al (2012) conducted performance and emission test on a compression ignition engine with blends of waste vegetable oil esters. The results showed that there is a decrease in power output by about 5% with every 10% increase in biodiesel by volume. The NOx emission decreased by 2.5% whereas the particulate emission decreased by 10% for increase in biodiesel blends.

Ameya vilas Malvade et al (2013) investigated the effects of using palm oil biodiesel in a stationary single cylinder compression ignition engine. The properties of palm oil biodiesel were comparable with that of diesel. The results of the performance tests showed that the brake thermal efficiency and specific fuel consumption were comparable with diesel for blends up to B30.
Increase in fuel consumption and decrease in efficiency were reported for B50.

Bhupendra singh chauhan et al (2013) performed tests using blends of Karanja oil esters in a diesel engine. The blends were 10%, 20%, 30%, 100% of karanja biodiesel with remaining being diesel fuel. It was observed that the brake thermal efficiency was lowered by 3-5% from that of the diesel’s value when the blends were used as fuels. There was a reduction in carbon monoxide, unburnt hydrocarbons and smoke when blends were used. NOx emissions increased with the usage of biodiesel blends when compared to diesel fuel. It was also observed that the peak cylinder pressure and heat release rate for the biodiesel usage was lower when compared to diesel fuel usage.

Liaquat et al (2013) carried out an endurance test on a single cylinder diesel engine for 250 hours with diesel and then with palm oil biodiesel blended with diesel (B20). Scanning electron microscopy analysis showed that at the end of 250 hours endurance test, the injector deposits were less for the engine with diesel fuel when compared with B20 fuel. After 250 hours endurance test the increase in BSFC was found to be 1.49% for diesel and 2.22% for B20 fuel. It was reported that the HC and carbon monoxide emission reduced while NOx emission increased significantly for B20 fuel.

Lu-yen-chen et al (2013) studied the performance and emissions of a single cylinder diesel engine fuelled with jatropha biodiesel and its blends. Tests were conducted with B5, B20, B40 and B100 and blending ratio upto 40% by volume recommended for jatropha biodiesel. The NOx emission increased marginally while the smoke, HC and carbon monoxide reduced significantly for the blends.
Mohamed Saied Shehata (2013) carried out performance and emission tests with biodiesel produced from palm oil and found that biodiesel fuels produced a lower brake power and brake thermal efficiency due to its lower heating value while they possessed higher brake specific fuel consumption due to high mass of fuel burnt per cycle. The emission of carbon monoxide was lesser due to high oxidation rate since biofuels contain high concentration of oxygen in the fuel molecules. The NOx emissions were higher for biofuels. The peak pressure was higher for biodiesel usage due to the higher oxygen content, higher cetane number and shorter ignition delay. It was concluded that biodiesel produced from palm oil is a suitable alternative to diesel fuel with no major engine modifications.

Mofijur et al (2013) conducted performance tests using blends of jatropha methyl ester in a C.I.engine. The results showed that the viscosity of all the three fuels differed marginally. The increase in biodiesel percentage resulted in a decrease in the calorific value and increase in density of the blended fuel. The brake power decreased by 4.6% and 8.9 % for B10 and B20 fuels when compared to diesel fuel. The brake specific fuel consumption gradually increases in the order of usage of diesel, B10, B20 as fuels. The HC emission decreased by 3.8% and 10.3% with the usage of B10 and B20 when compared to diesel fuel usage. The CO decreased by 16 % and 25 % with the usage of B10 and B20 when compared to diesel fuel usage. The NOx emission increased by 3 % and 6 % with the usage of B10 and B20 when compared to diesel fuel usage. It was concluded that the blends B10 and B20 are suitable to be used in a diesel engine with no major engine modifications.

Jaichander et al (2013) conducted performance and emission tests using POME20 (Pongamia oil methyl ester 20% with diesel fuel 80%) in a direct injection diesel engine with a jerk type injection system. Two types of chamber geometries were used- One with a HCC (hemispherical combustion
chamber) type piston and the other with a TRCC (Torroidal re entrant combustion chamber) type piston. The results showed that the brake thermal efficiency was higher for TRCC type at 220 bar injection pressure than for HCC type at 200 bar injection pressure due to better air mixing and hence better combustion with TRCC type. The CO, UBHC, Smoke emissions were considerably decreased at higher injection pressures with the modified chamber types when compared to the standard chamber type. NOx emission was found to be higher with modified chambers due to a more supportive condition for combustion. The higher oxygen content in POME also served as a cause for the NOx emission increase. At high injection pressures the modified chambers reduced the ignition delay period due to better air movement and mixing. TRCC type chamber with POME showed maximum peak pressure and heat release rate.

Liaquat et al (2013) conducted tests on a compression ignition engine with blends of coconut oil methyl esters. Coconut oil biodiesel was used, 5% (CB5) and 15% (CB15) blends with diesel to study the emission and performance characteristics of a diesel engine and the results were compared with 100% diesel fuel operation. The performance test was carried out at full load with variable speeds of 1500-2400 rpm with speed increment of 100 rpm. The emission test was carried out at 100% and 80% throttle positions. The results showed that biodiesel blends usage resulted in decrease in torque and brake power while increasing the brake specific fuel consumption. The CB5 and CB15 blends decreased the HC, CO emissions when compared to diesel but led to increased emission of NOx when compared with diesel fuel usage. The sound level decreased with CB5 and CB15 usage when compared to diesel fuel usage.

Mohammed El-Kasaby (2013) studied the effect of jatropha curcas biodiesel and its blends in a variable compression diesel engine and compared
the results with diesel. Maximum peak pressure was observed for B50 blend at low and high speeds whereas an optimum peak pressure was observed with B10 blend at economic speeds. NOx emission was found to be greater with biodiesel usage when compared to diesel fuel usage. B50 blend showed higher brake torque while B10 blend gave rise to the maximum volumetric efficiency. The brake specific fuel consumption was found to be 12.5%–25% higher than that of the diesel fuel when fuelled with biodiesel blend B50. B10 blend gave the maximum brake thermal efficiency; while B30 to B50 blends gave the minimum emission of CO. B50 blend gave maximum NOx emission and exhaust temperature.

Muhammad Aminul Islam et al (2013) reported the influence of fatty acid structure on the fuel properties of biodiesel. The results reveal that increase in unsaturated fatty acid reduced the cetane number and increased the iodine value. The increase in saturated fatty acid content resulted in increase in higher heating values.

Shahabuddin et al (2013) reviewed the reports of various articles related to the biodiesel usage in diesel engines published in the last decade. It has been noticed that bio fuels reduces CO, HC, PM emissions while increases the emission of NOx. The increase in NOx was observed to be due to shorter ignition delay when biofuels are used and also due to advanced fuel injection. The shorter ignition delay and early start of combustion with biofuels were due to high cetane number, low compressibility, and fatty acid concentration in biofuels. Net heat release rate and peak cylinder pressure of biodiesel fuels was found to be lower than diesel due to lower heating value, low volatility, shorter ignition delay and high viscosity of bio fuels.

Senthil Kumar et al (2013) investigated the effects of 80% diesel blended with 5% cotton seed oil biodiesel and 15% ethanol in a single cylinder diesel engine. The intake temperature and injection timing were
varied for the performance and emission tests. The results revealed that advancing start of injection led to earlier combustion. Due to earlier combustion increase in cylinder pressure, temperature and NOx emission were observed. The smoke emission reduced with increase in air intake temperature.

Dawody and Bhatti (2014) studied the performance of soyabean oil methyl esters in a single cylinder diesel engine and compared the results with diesel. The results showed that the brake thermal efficiency reduced by 3% with that of diesel. The increase in NOx emission was 35% and reduction in smoke emission was 48%. Marginal reduction in HC and carbon monoxide was observed in the tests. It was finally concluded that the performance of B20 was comparable with that of diesel.

Gaurav paul et al (2014) carried out experimental and numerical investigation on the performance and emission tests on a diesel engine with blends of jatropha biodiesel. Experiments results showed that the thermal efficiency reduced by 8% and NOx emission increased by 24% for B100 when compared to diesel. Significant reduction in particulates and smoke emissions were observed. It was reported that the presence of oxygen in biodiesel increased the NOx emission and reduced the smoke emission.

Srithar et al (2014) conducted tests on a single cylinder, air cooled diesel engine with blends of two biodiesels and diesel. Biodiesels were prepared from pongamia and mustard oil for the experiments. The results showed the thermal efficiency of 90% diesel and 10 % biodiesel fuel was higher compared to diesel. An increase in NOx, HC and smoke was observed. Increase in biodiesel in other fuel blends lead to decrease in thermal efficiency and increase in HC, NOx and smoke levels.
Swarup Kumar Nayak et al (2014) conducted performance and emission tests in a single cylinder diesel engine with mahua oil biodiesel. Dimethyl carbonate was added as additive to mahua oil biodiesel by 5%, 10%, 15% and 20%. The increase in additives increased the brake thermal efficiency by 5% and reduced the NOx emissions by 40%. It was observed that HC and carbon monoxide reduced marginally with increase in additive to mahua oil biodiesel.

2.4 OBJECTIVE OF THE PRESENT RESEARCH WORK

From the literature survey, it was observed that when biodiesels are used as fuels in compression ignition engines they produce higher emission of NOX, and lesser emission of hydrocarbon and smoke. The brake thermal efficiency with biodiesel operation is comparable to conventional diesel. The literatures show that the properties like density, viscosity and cetane numbers of biodiesels are affected by fatty acid composition. The experimental work done to study the effect of saturated fatty present in biodiesels on the performance and emissions of a diesel engine is limited. Hence the objective of the present work is to focus on studying the effect of fuels with different saturation levels in biodiesel on fuel properties, performance, emission and combustion in a compression ignition engine.