CHAPTER –2
REVIEW OF LITERATURE
## CHAPTER 2

### CHAPTER-2: REVIEW OF LITERATURE

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2. REVIEW OF THE LITERATURE

2.1 Introduction

Rudolph Diesel has invented the diesel engine over a hundred years past with vegetable oil as a fuel choice. As fossil oil diesel became dominate, due to its low price and this fuel was used as the primary fuel for diesel engines. Diesel engines running with diesel fuel contribute to pollution considerably though they play a significant and indispensable role in today’s fashionable life. A better solution to avoid these dual problems, the environmental pollution and energy shortage is to shift gradually from fossil fuels to renewable sources of energy. Biodiesel is one in all various renewable fuels that can be used as diesel engine fuel.

Biodiesel could be a perishable and clean burning fuel made up of natural, renewable sources like new and used vegetable oils and animal fats. These fats and oils are chemicals reacted with an alcohol, sometimes methyl alcohol, and the biodiesel can be produced. Biodiesel contains 11% of O₂ by weight. This O₂ content makes biodiesel a cleaner combusting fuel than the regular diesel. Biodiesel emissions are basically freed from sulfur and aromatics and have less hydrocarbons, carbon monoxide and particular matter (PM). Biodiesel contains a higher cetane number and about 5% of lower energy delivery than diesel fuel. The lubricity characteristics of biodiesel are a lot of superior to diesel. Thus a lot of the analysis, research and promotion for biodiesel production are required.
2.2. Use of Bio diesels in CI engines

Biodiesel could be a promising alternative fuel to the Diesel (petroleum product) which will be used safely in a diesel engine. Biodiesels are primarily edible and non-edible oils that are used as fuel in diesel engines with or without modification. Due to the potential properties of biodiesels number of investigations has been carried out globally to develop biodiesels as an alternate fuel to the diesel fuel. These investigations reveal that the performance of an engine with pure biodiesel as fuel is far under as compared with diesel fuel, as the biodiesel has lower calorific value and high viscosity than the diesel. The dilution or mixing of biodiesel with diesel would bring the calorific value and viscosity of biodiesel near the diesel.

2.3. Use of Bio diesel blends in CI engines

Use of 100% biodiesel as a fuel for diesel engine causes so many issues, if it is subjected to prolonged usage in CI engine due to its high viscosity and low volatility. Hence the use of biodiesel blends is mostly liked for many reasons. Mixing of the biodiesel with diesel reduces the viscosity of the fuel. Biodiesels are emulsified with diesel fuel for higher combustion and to scale back the emissions. The literature associated with the employment of biodiesel blends as fuel within the diesel engines are mentioned below.

Rao. Y V H et al [46] evaluated the performance and emission of single cylinder four stroke diesel engine with Jatropha biodiesel. The engine tests are conducted with the blends of diesel fuel and Jatropha bio diesel. The diesel to biodiesel ratio as 75:25 (B25), 50:50 (B50) and
25:75 (B75) are used to measure, analyze and to compare with of diesel fuel by experimentation. The final results showed that the blend B25 has the performance nearer to diesel fuel and B100 has lower brake thermal potency primarily due to its high viscosity as compared to diesel.

Rao. T.V. et al [47] have investigated the varied properties of L 85 and compared with diesel. L 85 contains 85% of coconut oil and 15% of kerosene oil. From the experimental results it's observed that “L85” fuel may be used as an alternate fuel for diesel engine. Altinet et al. [48] tested single cylinder direct injection compression ignition engine with the employment of methyl radical esters of vegetable oils (sun flower, Cotton seed, soya, and corn oils) as fuel. The test results shows that the thermal potency of the engine with biodiesel blends did not change and fuel consumption is increased compared to diesel. The emissions like CO and HC were reduced by 15% and 16% as compared to diesel fuel results.

Ali et al. [49] studied the employment of various blends of soya bean biodiesel and ethanol with diesel as fuel in a Cummins 522 kilowatt, six-cylinder, turbo-charged, direct injection engine. The tests showed reduction in carbon monoxide emission and no variation in carbon dioxide and hydro carbon emissions. The NOx emissions were on par with diesel.

Ranganatha. B et el [50] has conducted experimental investigation on a four stroke compression ignition engine with Mahhua biodiesel blends with diesel at numerous proportions (20%, 40%, hour
and 80%) at a constant engine speed of 1500 rpm. These investigations reveals that the brake thermal potency of biodiesel blend B20 is as regards (nearer) to the diesel fuel and the thermal potency of diesel fuel is higher by 12% when compared with neat biodiesel (100%) at full load. The CO emissions are lower for biodiesel and its blends with diesel as compared with diesel whereas NOx emissions are over the diesel.

Siva Kumar. A et al [51] conducted the performance check on a diesel engine with neat diesel fuel and Cotton seed biodiesel mixtures. The engine experimental results showed that exhaust emissions like carbon monoxide (CO), particular matter (PM) and smoke emissions were reduced for all biodiesel mixtures. However, a small increase in nitrogen oxides (NOx) emission was found for biodiesel mixtures.

Sudhakar. S et al [52] has conducted investigations to search out the quality (suitability) of “Rape seed oil in compression ignition engine. Investigations are conducted with 25%, 50% and 75% of Rape seed oil in an exceedingly mix of Rape seed oil and diesel. From the experimental results it’s found that the mix with 25% of Rape seed oil is showing higher performance.

Shekar. K et al [53] has conducted a comprehensive review on biodiesel production and its application for CIE (compression ignition engine). This review covered the present standing (status) of biodiesel productions together with their cultivation, harvesting, process and their benefits with available alternative biodiesel feed stocks. Finally
it's ended that the wide verity of biodiesel are out there (available) and may be used as an alternate fuel for CIE.

Ranganathan. L et al [54] has conducted experiments to check the combustion and emission characteristics of a four-stroke, single cylinder, direct injection diesel engine with Cotton seed biodiesel and its mix with diesel. The brake thermal potency was lower for Cotton seed biodiesel attributed due to its lower heating value. The NOx and CO₂ emissions of the Cotton seed biodiesel and its blends are slightly above the diesel whereas the emissions of HC and CO concentrations are lower. This study Supported that the Cotton seed biodiesel may be used as a substitute for diesel in CIE.

Shruthi. H has conducted [55] experiments to analyze the performance of stationary single cylinder diesel engine running with Azadirachta indica (Neem) biodiesel mixed homogeneously with diesel at numerous proportions like 10% , 20% and 30% by volume and compared with fuel. From the experimental results it's found that the brake thermal potency of the engine with this biodiesel mix B20 is slightly under diesel and the carbon monoxide emission are reduced considerably whereas NOx increased slightly.

Senthil Kumar. R et al [56] has conducted an experimental investigation on a CIE with the blends of Tyre pyrolysis oil and diesel as fuel. The performance tests are conducted on single cylinder, four stroke, water cooled DI diesel engine with a compression ratio of 16.5:1 and engine speed at 1500rpm. The tyre pyrolysis oil is mixed with diesel like 5%, 15%, 25%, 50%, 75%, and 85% by volume. From
the experimental results it's ascertained that the best biodiesel mix was 50% tyre pyrologsis oil with diesel.

Shahid. E.M et al [57] have carried out experiments with the blends of diesel and Karanja biodiesel with completely different ratios, to analyze the performance characteristics of engine and exhaust emissions. The experimental results showed that the engine running with pure biodiesel i.e. B100, leading to higher brake specific fuel consumption and lower brake thermal potency as compared to the diesel. The CO and HC emissions were reduced, however higher quantity of NOx was observed when B100 was used as fuel.

Jindal. S. et al [58] has conducted a comparative study of performance, combustion and emissions of diesel Jatropha and Karanja methyl esters in an exceedingly DI Compression ignition engine. Experiments were conducted on single cylinder, water cooled four stroke CI engine normally employed in agricultural sector for minor irrigation purpose, connected to eddy current dynamometer device for loadings. From the experiential results it's ascertained that the engine with diesel fuel has shown highest brake thermal potency than the both bio diesels. It is also observed that the Karaja biodiesel has shown higher thermal potency and lower specific fuel consumption than the Jatropa bio diesel.

Pryor, et al. [59] conducted short and long-run engine tests with neat soya bean vegetable oil in a small CI engine. Short-run tests with this vegetable oil indicated that the performance is similar to that of diesel fuel and long-run testing couldn't be carried out due to power
loss and carbon build-up on the injectors. They ended that the vegetable oil may be used for short-run operation solely.

A single cylinder four stroke CI engine was accustomed to evaluate the performance and emission characteristics of Mahua biodiesel and its blends with diesel by shivakuamr, B et al [60]. The test fuels used for this experiment are neat (100%) Mahua Biodiesel, a neat (100%) diesel and its blends of 20, 40, 60 and 80 percent of biodiesel by volume within the diesel fuel. The experimental results indicates that the rise in biodiesel concentration within the blends reduces the CO and HC emission considerably whereas fuel consumption and NOx emission will increase as compared with pure diesel. The brake thermal potency and brake specific fuel consumption for B20 is nears to the diesel fuel.

Sahoo, P.K. et al.[61] have conducted performance tests to examine the non-edible biodiesels like Jatropha, Karanja and polanga. These biodiesels were mixed with standard diesel in 3 completely different fuel blends (B20, B50 and B100) and tested for the usage this biodiesels as a substitute fuel for water cooled, three cylinder tractor engine. Brake specific fuel consumptions for all the biodiesel blends with diesel will increase with increase in biodiesel within the blends. There’s a reduction in CO and HC for all the biodiesel blends when compared with diesel fuel. Finally it had been ended that the Karanja biodiesel is showing higher performance than alternative biodiesels employed in this work.
Jameel Basha. S.M. et al [62] has Investigated the performance of a four stroke ICE with C85 (Coconut oil (85%) and kerosen oil (15%)) as a fuel. Single cylinder four stroke IC engine with rope brake dynamometer device is employed as check engine for this investigation. From the experimental results it’s ascertained that the performance of the engine with C85 fuel is nearer to the fuel.

An experimental investigation [63] was carried out by Diplip kumar et al on single cylinder four stroke IC engine with biodiesel blends of Cotton seed methyl radical Esters and Azadirachta indica Oil methyl Esters. From the experimental results it’s ascertained that Cotton seed biodiesel offers higher performance compared to Neem biodiesel, the smoke, HC and CO emissions for these diesel blends are less as compare to the pure diesel.

An experimental investigation has been conducted by Hemanth Kumar et al [64] on a single cylinder IC engine burning with blends of Mahua biodiesel and diesel. Five concentrations (B20, B40, B60, B80 and B 100) are taken for this investigation and the engine performance characteristics are studied with completely different load conditions. The investigation indicated that the brake thermal potency of the engine with diesel fuel is higher than the Mahua biodiesel and its blends. Finally it’s ended that the Mahua biodiesel may be adopted as an alternate fuel for application in agricultural engine as a renewable fuel replacement for diesel.

Ramu. S. et al. [65] investigated the Performance and emission characteristics like brake thermal potency, exhaust gas temperature;
monoxide (CO), un-burned hydrocarbon (HC) and oxides of nitrogen (NOx) of single cylinder four stroke IC engine with Mahua biodiesel mix B20. The results showed that the engine performance with Mahua biodiesel mix B20 is similar to that of neat fuel with nearly an equivalent brake thermal potency, and slightly higher fuel consumption. The CO and HC emissions are reduced considerably compared to neat fuel whereas the NOx is increased.

Pandey. A.K. et al [66] has investigated the impact of Karanja biodiesel blends on engine performance and emissions. A W06DT, six cylinders four stroke variable speed and turbocharged with bury cooled DI CI engine connected on 1125 kW hydraulic dynamo meter was accustomed to conduct the performance tests. The result indicates that the brake thermal potency, CO and HC emissions of the engine decreases with Karanja methyl ester as compared with diesel fuel whereas NOx emission and specific fuel consumption will increase.

Ragit. S. S et al [67] has conducted performance tests on a four-stroke single cylinder, water cooled CI engine with Azadirachta indica (Neem) biodiesel blends. Brake thermal potency of Azadirachta indica biodiesel has been found lower than that of diesel fuel at rated load of the engine. With the Azadirachta indica biodiesel blends the HC is reduced at any load conditions. The smoke density, NOx and EGT showed increasing trend with increase in load and increase in biodiesel quantity in the blends. The emissions (CO, CO₂ and O₂) don't
contribute unhealthy impact on engine. Thus, Azadirachta indica biodiesel may be a substitute for diesel fuel in CI engine.

Manieniyan. V. et al [68] has conducted experimental investigations on a twin cylinder diesel engine to evaluate the performance and emissions with diesel and blends of Mahua biodiesel and diesel in numerous ratios of 20:80, 40:60, 60:40, 80:20 and a hundred percent biodiesel. From this investigation it had been concluded that the brake thermal potency of the Mahua biodiesel mix B20 is slightly nearer to the diesel.

Kamlesh. A et al [69] has conducted experimental investigation on a four stroke CI engine with Jatropha biodiesel mixed with diesel as an alternate fuel for compression ignition engines. From the experimental results it’s ascertained that the performance of the engine with diesel fuel is high as compared with Jatropha biodiesel blends. The brake specific fuel consumption of the engine with biodiesel blends is higher than the diesel fuel. The CO and HC emissions are under the diesel as compared with Jatropha biodiesel blends. Finally it is concluded that the performance of the engine with Jatropha biodiesel blend B25 is nearer to the diesel fuel.

Mahesh. R et al [70] have investigated the performance and emission characteristics of Mahua biodiesel and its blends with diesel on a single-cylinder CI engine to search out its quality as an alternate fuel. The biodiesel is mixed with diesel in B0, B25, B50, B75 and B100 on the quantity basis. The performance and emission characteristics of biodiesel blends are evaluated at completely different
engine loads at a rated speed of 1500 rpm and results are compared with diesel. It’s ascertained that the Mahua biodiesel mix B25 showing higher performance as compared with other blends.

Reddy, R.P. et al [71] has evaluated the performance and emission characteristics of DI compression ignition engine operated on Marine fish oil bio diesel. The investigations were carried out on single cylinder four stroke direct injection CI engine with the volumetric mixing ratios of bio diesel with standard diesel (B0, B10, B20, B40, B60, B80 and B100). From the experimental results it’s ascertained that the bio diesel mix B20 is best for CI engine in terms of performance and emissions.

Savariraj. S et al [72] has investigated the performance and emission characteristics of single cylinder diesel engine with Mahua biodiesel blends. The brake thermal potency, brake specific fuel consumption, exhaust gas temperatures, CO, HC, NOx and smoke emissions were analyzed and compared with the performance of diesel fuel. From the tests results it’s ascertained that the decrease within the brake thermal efficiency of the engine with the quantity of Mahua biodiesel within the mix is increased. The utmost share of reduction in brake thermal potency was ascertained for B-100 at rated load. The smoke and NOx emissions of the engine were increases with increase in biodiesel in the blends. But CO and HC emissions of Mahua biodiesels were less than that of diesel.

Mofijur. M et al [73] studied the feasibility of Jatropha as a possible biodiesel as an alternate fuel for CI engine. They found that
the viscosity, performance and emissions characteristics of B10 and B20 biodiesel blends are nearer to diesel and concluded that the B10 and B20 Jatropha biodiesel blends may be employed in a CI engine with none of engine modifications.

Hadiya et al [74] has conducted experimental investigation on a four stroke CI engine with Cotton seed biodiesel and its mix with diesel. Four blends of Cotton seed biodiesel like B20, B40, B60 and B80 are employed in this experiment. From the experimental results it had been ended that the combustion characteristics of the Cotton seed biodiesel blends B20 and B40 are followed closely with that of the diesel fuel.

Laxminarayana Rao et al. [75] have investigated the performance of CI engine with rice bran oil methyl ester (RBME) and its diesel blends. It’s been observed that the brake thermal potency of the engine with diesel fuel is over the bio diesel. It’s also ascertained that the CO and HC were shriveled and therefore the NOx and soot emissions were slightly increases with increase in biodiesel in the blends as compared to diesel fuel operation. Finally it is concluded that the performance of the engine with biodiesel blend B25 is nearer to the diesel fuel.

Shruthi H et al [76] has conducted experiments to analyze the performance of stationary single cylinder CI engine running on jatroph and Azadirachta indica (Neem) biodiesels mixed with diesel singly in numerous proportions like 10% , 20% and 30% by volume and compared with diesel fuel. From the experimental results it’s found
that the brake thermal potency of the engine with Azadirachta indica biodiesel mix B20 is slightly under the diesel fuel and the carbon monoxide emissions are reduced considerably whereas nitrogen oxide emission (NOx) increased slight.

Narasimham et al [77] injected vegetable oils rather than diesel fuel in dual-fuel operation and studied the consequences various engine parameters on performance. With the employment of groundnut and coconut oils the maximum amount as 90% of alcohol is burned. They concluded that with the open combustion chamber a lot of quantity of alcohol is burned than swirl kind.

An experimental investigation has been conducted by Kiran C H et al [78] on a single cylinder CI engine burning with blends of Honge oil biodiesel, Fishoil biodiesel and diesel separately. 5 concentrations (B20, B40, B60, B80 and B100) are taken for this investigation and therefore the engine performance characteristics are studied completely at different engine load conditions. The investigation indicated that the biodiesel mix B20 had shown higher thermal potency than the other blends. Finally they conclude that the above biodiesel and its blends may be adopted as an alternate fuel for application in agriculture engine as renewable fuel replacement for diesel.

Sagar .P. et al [79] has been conducted a technical review of using the biodiesel of non-edible plant oil like Jatropha oil, Karanja oil, Cotton seed oil, Castor seed oil, Mahua oil and Azadirachta indica oil in CI engines, and compared with normal diesel fuel. They observed
that the numerous variety of researchers have carried out large number of studies on usage of biodiesel. The causes of technical issues arising by the employment of different biodiesels, the modifications to oils and engine which are employed to beat these issues are focused in this review. The review shows that variety of biodiesels may be used satisfactorily in CI engines. The literature results recommend that biodiesel may be used as a substitute for diesel fuel with none important modification in engine. Finally it’s ended that much more research analysis is required to beat the sensible issues within the usage of biodiesels in diesel engines.

Sharanappa. G et al [80] has conducted an experiential study to gauge and compare the performance and emission characteristics of CI engine with the blends of Karanja, Mahua and fish oil methyl esters. The experiments were conducted on a Kirlosker, 3 cylinders, four stroke DI engine with bio diesel at mix magnitude relation of 10/90, 20/80 and 60/40 with normal diesel at 1500 rate. The brake thermal potency of the engine with bio diesel mix B 20 is slightly under the diesel fuel. Among all the bio diesel blends the fish oil methyl ester has shown higher performance.

Pramanik. K et al [81] has evaluated the performance of the CI engine with the blends of Jatropha biodiesel and diesel. Acceptable thermal efficiencies of the engine were obtained with blends containing up to 50% by volume of Jatropha biodiesel. From the engine test results it’s been established that 40–50% of Jatropha biodiesel may be substituted for diesel with none engine modification.
Baradwaj. V et al [82] has conducted engine test to check the Performance Characteristics of Compression Ignition Engine Fuelled with Blends of Biodiesel from Cottonseed biodiesel. Three combinations of the mixtures of Cotton seed oil biodiesel together with diesel (10%, 15 % and 20% blends) are taken for the experimental analysis. Experiments are conducted by employing a single cylinder direct-injection CI engine (3.5 kilowatt capacity) at 3 completely different load conditions i.e. no load (0 kg), half load (3 kg) and full load (6 kg). The performance characteristics of the engine with Cotton seed biodiesel blends are evaluated and compared diesel fuel. B10 mix of biodiesel has the very best performance characteristics as compared with other blends. The brake power, brake thermal potency is lowest value whereas the brake specific fuel consumption and exhaust gas temperature are higher than diesel fuel.

Ekrem et al [83] has conducted experiments on a CI engine to gauge the performance, emissions and combustion characteristics with neat rapeseed oil and its blends of 5%, 20% and 70% with diesel fuel separately. From the combustion analysis, it had been found that ignition delay was shorter for neat rapeseed oil and its blends as compared to that of the pure diesel. The combustion characteristics of oil and its diesel blends are closely followed those of standard diesel engine.

Wittison. K et al [84] has conducted performance and emission tests on a single cylinder CI engine with Jatropha biodiesel blends B10 and B20. The properties of bio diesel blends were with in normal
limits. From this experimental study it’s ascertained that the performance of engine with Jatropha bio diesel mix B10 is nearly same as that of the diesel.

Sukumar Puhan et al. [85] have studied the performance and emissions of a four-stroke, direct injection CI engine with Mahua oil and Mahua biodiesel. The engine test results showed high thermal potency just in case of Mahua biodiesel as compared to Mahua oil. Completely different emissions like monoxide (CO), nitrogen oxides of gas (NOx) and hydrocarbons (HC) are measured and compared. Supported this study, it’s ascertained that the Mahua biodiesel performs well as compared Mahua oil on the basis of performance and emissions.

Miyamoto et al [86] have measured the engine performance by measuring the soot output within the exhaust with a smoke-meter and ascertained substantial reductions in PM (particular matter) within the emissions. It’s ended that the development in exhaust emissions by oxygenated fuels depends on the oxygen content of the fuels and the local oxygen concentration within the fuel plume despite of the method of oxygen improvement.

Martin. L.J [87] et al has studied the impact of diesel addition on the performance of Cottonseed biodiesel fuelled DI engine. From the engine test results it's been established that 20–40% of Cottonseed biodiesel may be substituted for diesel with none engine modification.
Ilker sugozu et al [88] has conducted the experiments on a CI engine to check the performance with canola oil methyl ester at rated speed. They found that the brake thermal potency of the engine was less with biodiesel as compared to diesel operation. The brake specific fuel consumption was found higher due to low heat value of canola oil methyl ester as compared with diesel. The CO emissions were decreases and the NOx emissions were increase at all loads as compared to diesel fuel.

Baiju. B et al [89] has evaluated the performance and emission of CI engine with the blends of Rubber seed bio diesel and diesel by employing the exhaust gas recirculation. From this experiential result it's found that the mix B20 has higher brake thermal potency as compared with B100 with out exhaust gas recirculation and with the 15 % exhaust gas recirculation the brake thermal potency of B100 is improved.

Bhojraj .N et al [90] has conducted experiments on CI engine with Cottonseed and Jatropha biodiesels. They investigated the performance of engine in terms of brake thermal potency and indicated thermal potency. The results of investigations showed that the brake thermal potency and indicated thermal potency of Cottonseed biodiesel was slightly over that of Jatropha biodiesel.

Ghosh .B.B et al has studied [91] performance and emission of CI engine by employing the fuel as Karanja, Jatropha and putranjiva biodiesels mixed with diesel singly in numerous proportion like B0, B10, B30 B50 and B70. From this experimental work it's ascertained
that Karanja, Jatropha and putranjiva biodiesel blends have shown terribly satisfactory results as an alternate fuel for diesel engine and out of three biodiesels Jatropha biodiesel has better performance and low emissions at every load in all respects.

Sreenatha Reddy. S. et al. [92] tested the properties like viscosity, density, flash point temperature, and cetane value of Karanja and Jatropha biodiesels as fuel in diesel engines. The blends of variable proportions of the Jatropha and Karanja with diesel were prepared to gauge performance of the engine and compared with diesel fuel. The engine performance and emission characteristics were evaluated in a single cylinder CI engine and a comparison was created to recommend the better choice among the biodiesel under study.

Schumacher et. al [93] has investigated the performance of engine by fuelling with Soya been biodiesel and diesel fuel blends effectively. It is found that a reduced particular matter, emissions of hydrocarbons and carbon monoxide, whereas increasing oxides of gas emissions with the biodiesel blends. The optimum mix of biodiesel and diesel was blend B-20 fuel mix. It is concluded that the increase in NOx emissions may be reduced by retarding engine timing.

Ashish. K et al [94] has evaluated the performance of a medium capability CI engine with thumba biodiesel and diesel blends. The performance tests were conducted on a single cylinder four stroke engine connected to eddy current dynamometer with thumba biodiesel and its blends with diesel (B10, B20, B40, B60, B80 and B100) at completely different engine loads to gauge the brake thermal potency,
specific fuel consumption and exhaust emission. From the experimental results it's found that the mix of thumba biodiesel (B10) with diesel gave most brake thermal potency under all load conditions.

Ghai. S et al [95] have conducted experiments on a four stroke, single cylinder, CI engine with sunflower biodiesel and its blends (B25 and B30) to investigate the performance and emission characteristics. It's reported that there's a decrease in brake thermal potency with biodiesel blends. With biodiesel blends a significant reduction in emissions of hydrocarbons as well as CO was detected. The NOx emissions with biodiesel blends were ascertained to be higher as compared to diesel. Finally it's ended that the each blend (B25 and B30) may be employed with success in the CI engine.

An experimental investigation [96] has been conducted by Gowtham Kumar et al on a CI engine burning with the blends of Mahua biodiesel. Five concentrations (B20, B40, B60, B80 and B100) are taken for this investigation and therefore the engine performance characteristics are studied under completely different load conditions. The investigation indicated that the biodiesel mix B20 had shown higher potency than the other blends. Finally they ended that the Mahaua biodiesel and its blends may be adopted as an alternate fuel for application in agriculture CI engine.

Ragit. S et al [97] have carried out investigations on a stationary single cylinder, four-stroke direct injection CI engine to gauge the performance and emission characteristics with the blends of Neem
and hemp biodiesels and compared with diesel fuel. The engine performances like brake thermal potency, brake specific fuel consumption, exhaust gas temperature and exhaust emissions (CO, HC, NOx emissions) are evaluated. Significant enhancements are ascertained within the performance parameters as well as the engine exhaust emissions. The results showed that a reduction in HC, CO and thermal potency for each Neem and hemp biodiesel in any respect loads. The experimental study indicates that biodiesel blends may be used as a fuel in compression ignition engine with none engine modification.

Mohand. T et al [98] has evaluated the performance and emissions of CI engine with methyl esters of palm oil and waste cooking oil mixture as fuel. During this work refined palm oil was used as main fuel for preparing the methyl ester. Waste oil was used as an inner esterification agent to scale back overall viscosity and cloud point of the mix and blend. A single cylinder direct injection CI engine was tested with diesel, neat palm oil and methyl esters of mixture (palm oil and waste cooking oil) as fuel under variable load operational conditions. The Results showed increase in specific fuel consumption and decrease in brake thermal potency with neat palm and methyl esters of mixture as compared with neat diesel.

Sudhir. C.V et al [99] have tested the impact of waste cooking oil methyl ester in a diesel engine. It’s been reported that the thermal potency was decreased by 2% at higher loads. It’s also reported that the HC emissions were down as compared to diesel fuel. The NOx
emission was same as diesel for waste cooking oil methyl ester attributable to O\textsubscript{2} content in oil structure. It’s been additional reported that the peak pressure and the ignition delay were increased for waste oil methyl ester as compared to diesel fuel.

The studies of Radha et al on four stroke diesel engine [100] with Azadirachta indica (Neem) biodiesel that in renewable in nature indicates that a rise in engine speed up to 1050 rpm the brake thermal potency is increased and on the far side 1050 rpm there was a small decrease within the brake thermal potency. The reduction in CO emission and increase in NOx emission was recorded in these studies.

Sharanappa. G et al [101] has conducted experiments on a CI engine to gauge the performance and exhaust emissions with the blends of Mahua biodiesel and diesel fuel (10%, 20%, 40%, 60% and 80% by volume). From the experimental results it’s ascertained that the performance and emissions of biodiesel mix B10 is closure to the diesel fuel.

The performance and emission characteristics of an unmodified CI engine are studied by Sylvester. G et al [102] with Azadirachta indica (Neem) methyl ester (NME) and its blends with diesel. The check results reveal that the blends of NME with diesel up to 40% by volume are giving higher engine performance and improved emission characteristics.

Ansari et al [103] has studied the performance and emission characteristics of 4 stroke ICE with diesel and soybean been blends.
From the experiential results it had been ascertained that the performance and emissions for B50 and B20 were under the pure diesel.

Sukumar .P et al. [104] prepared Mahua biodiesel blends and tested in a 4-stroke direct injection engine. Tests were carried out at constant speed of 1500 rpm at completely different engine loads. Results showed that brake thermal potency of diesel fuel is over the biodiesel blends. Emissions of carbon monoxide, hydrocarbons, were reduced with biodiesel. Supported this study, it’s ascertained that Mahua biodiesel may be used a substitute for diesel in diesel engine.

Ramesh DK et al [105] has studied the impact of injection pressure and performance of engine with Azadirachta indica biodiesel mixed with diesel (B20) engine tests are conducted at constant speed 1500 rpm at 3 completely different injection pressure (180, 200 and 220 bar) for learning the impact of injection pressure on engine performance. This study reveals that the injection pressure 200bar is optimum pressure for higher results with Azadirachta indica biodiesel mix B20.

Yuzhang et al [106] investigated the employment of blends of methyl radical esters soybean vegetable oil and diesel in a turbo-charged, four- cylinder, direct injection engine changed with bowl in piston and medium swirl kind. They found that the blends gave a shorter ignition delay and similar combustion characteristics as diesel. The results of emission concentration in flame show that total
hydro carbon (THC) emissions of biodiesel blends are considerably lower that of standard diesel.

Nagarhalli. M. V et al [107] has carried out experiments to gauge the performance and emission characteristics of a single cylinder, CI engine fuelled with mineral diesel and Karanja biodiesel blends. The results of experimental investigation with biodiesel blends were compared with the diesel. The results indicate that the CO and HC emissions are reduced for B20 and B40. The thermal potency reduced slightly for blends compared with diesel. The BSFC was slightly high for B20 and B40. From the investigation, it may be ended that biodiesel may be used as an alternate to diesel in a CI engine with none engine modifications.

Nithyananda B.S et al [108] has investigated investigation mechanical properties and performance characteristics biodiesel extracted from Azadirachta indica and Jatropha, coconut oils and its blends with diesel (B10, B20, B40 and B50). The performance characteristics of those biodiesel blends are evaluated at 1500 rpm and therefore the results are compared with diesel. It’s ascertained that the brake thermal potency of Azadirachta indica biodiesel mix (B20) is slightly lower than the diesel fuel and better than the mixed pongania and coconut bio diesel blends B20 at full load. Finally it’s ended that these Azadirachta indica biodiesel bland (B20) and mixed pongania and coconut biodiesel (B20) may be used on substitutable to the fuel.
Chattopadhyay. S et al [109] has evaluated the performance characteristics of the CI engine with the Jatropha biodiesel blends (B10 and B20) to check the performance of the engine in terms of brake thermal potency (BTE), brake specific fuel consumption (BSFC) and exhaust gas temperature (EGT). The performance of the blends B10 and B20 are nearer to the diesel. Thus, the blends B10 and B20 showed comparable engine performance with better green house gas emission characteristics and hence the standing of an economical surroundings friendly biodiesel for diesel engines.

Shruthi.H et al [110] has conducted experiments on a single cylinder four stroke DI engine with Mahua biodiesel and its blends with diesel of 20%, 40% and 60% by volume at a constant speed of 1500 rpm to investigate and compare the suitability of these biodiesel blends. This analysis reveals that the biodiesel from Mahua oil is a quite suitable as an alternate fuel to the diesel fuel.

Jane. P et al [111] have studied the impact of usage of waste plastic oil in a CI engine with none engine modification. The engine employed in this study is four cylinders naturally aspirated 4-stroke CI engine (Compress Ignition) “Hino W06d”. In this work, the engine burning with blends of diesel fuel with plastic oil within the ratio of diesel to waste plastic oil 75:25 (B25), 50:50 (B50) and 25:75 (B75) are by experimentally measured, analyzed and compared therewith the diesel fuel. The results showed the brake specific fuel consumption of waste plastic oil blends were above the diesel fuel. Quantities of
emissions of carbon dioxide, carbon monoxide, hydrocarbon and NOx from waste plastic oil were over diesel operation.

Lakshmi kanth G et al [112] has conducted performance tests on a single cylinder vertical four stroke water cooled kirloskar build DI engine with diesel, Mahua biodiesel and its 50% blend. The performance characteristics of mix are evaluated and compared with diesel. From the experimental results it’s ascertained that fuel consumption, exhaust gas temperature are high for Mahua biodiesel and its mix in any respect loads. The brake thermal potency is lesser than the diesel however in overall view the engine runs well with none modifications.

Dilip Kumar. K et al [113] has conducted experimental investigation on a four stroke CI engine with Cotton Seed and Azadirachta indica (Neem) biodiesels and its blends (B5, B10, B15 and B20) with diesel to gauge the performance and emission characteristics. From the experimental results, it's ascertained that the performance of blend B10 have nearer to the diesel. However, its other blends showed affordable efficiencies. From the experimental results, it's ascertained that Cotton seed biodiesel offers higher performance compared to Azadirachta indica biodiesel.

Investigations are carried out by M C Navindgi et al [114] on performance of biodiesel obtained from Mahua biodiesel and its blends of 20%, 40%, and 60% by volume on a four stroke DI engine connected with an eddy current dynamometer device. The brake thermal potency, specific fuel consumption, smoke density and CO
emission were measured and compared with diesel. These investigations reveals that the power output reduced with increase within the concentration of Mahua biodiesel blend and B20 may be used as higher substitute fuel for DI engine with none modification.

Elango. T et al [115] have investigated the performance and emission characteristics of a CI engine with completely different blends of Jatropha biodiesel and diesel. Engine performance (brake specific fuel consumption, brake thermal potency and exhaust gas temperature) and emissions (HC, CO, CO2, NOx and Smoke Opacity) were measured to search out the behavior of the engine. The results showed that the brake thermal potency of diesel is higher at all the engine loads. Among all the blends, the utmost brake thermal potency and minimum brake specific fuel consumption were found for blends up to 20% Jatropha biodiesel. The optimum mix is found to be B20 as the carbon dioxide gas emissions were lesser than the diesel whereas decrease in brake thermal potency is marginal.

Harinath Reddy. M et al [116] has investigated the performance characteristics like brake thermal potency, brake specific fuel consumption exhaust gas temperature and emission characteristics like monoxide, hydro carbon, nitrogen oxide of a single cylinder vertical Direct injection kirloskar engine with Mahua biodiesel and its blends with diesel as fuels and compared with diesel fuel. From the results it's ascertained that the brake thermal potency of the blends B20, B40, B60, B80 and B100 are less than the diesel and B20 was
selected as optional mix. The CO and HC emission decreases with the increase of Mahua biodiesel within the mix.

Ashish. J et al. [117] has evaluated the performance and emission characteristics of single cylinder four stroke CI engine by exploitation Mahua and linseed biodiesel and its blends with diesel. The blends of variable proportions of biodiesel with diesel (M25, M50, M75 and M100) are employed to conduct tests and to compare the performance and exhaust emission with diesel. The brake thermal potency of the biodiesel mix B25 is nearer to the diesel and CO and HC were found to be lower.

An experimental investigations were carried out by S Savari raj et al [118] on a 5 kW, single cylinder vertical four stroke water cooled, direct injection constant speed kirlosker engine with eddy current dynamometer device to gauge the performance and emission characteristics with Mahua biodiesel blends in variable proportion like B25, B50, B75 and B100 and compared with the performance of pure fuel. The results showed that the decrease in brake thermal potency of the engine as the quantity of Mahua biodiesel within the mix increased. The smoke density, brake specific fuel consumption and nitrogen gas oxides will increases with increase in concentration of the Mahua Biodiesel within the mix.

Scholl and Sorenson et al [119] found that the carbon monoxide, oxides of gas (NOX) and smoke emissions were slightly lower for soybean methyl ester than diesel, whereas HC emission showed 50% reduction as compared with the diesel fuel.
Raheman .H et al [120] has conducted engine performance (brake specific fuel consumption, brake thermal potency and exhaust gas temperature) and emissions (CO, smoke density and NOx) tests to check the behavior of the CI engine running on Mahua biodiesel and its blends with diesel. From the experimental results it's ascertained that the mix of Mahua biodiesel B20 could be an appropriate fuel for diesel and so may facilitate in controlling air pollution.

S Ramu et al [121] has investigated the impact of biodiesel specifically 20MOME (80% diesel +20% Mahua oil methyl radical ester) on a Kirlosker single cylinder DI engine. The results showed that the engine performance below biodiesel mix (B20) were kind of like that of neat fuel with nearly same brake thermal potency and slightly higher fuel consumption. The carbon monoxide and hydrocarbon emissions decreases considerably compared to neat fuel whereas the NOx emission will increase.

Dharmadhikari et al [122] has conducted experiments on a CI engine to gauge the performance parameters like brake thermal potency, brake specific fuel consumption and the emissions like carbon monoxide (CO), carbon dioxide gas (CO2), organic compound (HC) and oxides of gas (NOx). The results of experimental investigation with biodiesel blends with diesel are compared therewith of diesel. The results indicated that the CO and HC emissions were ascertained to be less for B10 and B20. The brake thermal potency of the engine decreases for all blends compared with diesel, and the brake specific fuel consumption was slightly a lot of for B10 and B20.
Experimental investigation were conducted by Santhosh B et al [123] on performance of biodiesel obtained from Mahua oil and its blends with diesel from 15%, 25%, 35% and 45% by volume to gauge the behavior of the engine at injection pressure 200bar and compression ratio as 17.5:1. From the results it's ascertained that the injection pressure and compression ratio were found to own important effects on engine performance parameters and therefore the performance of biodiesel blends B15 and B25 were nearer to the performance of diesel fuel. Mahua biodiesel blends B15 and B25 is found appropriate fuel blends for diesel as alternate fuel and will facilitate to control air pollution.

Kawade. G.H. et al [124] examined the reports concerning biodiesel engine performances and emissions printed by extremely rated journals in scientific indexes. From these reports, the impact of biodiesel on engine power, economy, and emissions of a four-stroke compression ignition engine is surveyed and analyzed in detailed. It describes several researchers worked in improvement of CI engine performance and operational parameters for biodiesel fuel with computer software system methods. Lastly, the scope and challenges being faced by the researchers in this field are analyzed and clearly represented.

Lenin. AH et al [125] has conducted experiments to assess the performance, emission and combustion characteristics of CI engine with Mahua methyl ester fuel blends of B25 and B50 and compared with pure diesel fuel. The results indicates that the performance of
engine with biodiesel blends B25 is nearer to the diesel and B25 may be employed in diesel engines with none engine modification.

Suryawanshi. J et al [126] has studied the performance and emissions of a CI engine with neat Palm oil biodiesel and its blends with diesel. It’s been found that the brake thermal potency of diesel is higher at half and full load and therefore the brake specific energy consumption was lower as compared to the biodiesel at different engine speeds. Exhaust gas temperature was higher with blends of biodiesel as fuel. It’s been additional found that there was a major reduction in CO emission and un-burned hydrocarbon emission for all blends of biodiesel at half and full loads. Smoke and HC emission was additional reduced with a rise in biodiesel in the mix. Biodiesel ends up in higher NOx levels as compared to diesel.

Several researchers have ascertained that the crude vegetable oils, once used for long hours, choke the filter due to the high viscosness and insoluble in petroleum. Viscosities of vegetable oils exert a powerful influence on the fuel spray pattern [127]. High viscosity of oil causes poor atomization, massive droplets and high spray jet penetration. As a result, the blending of fuel and air mixture is also improper and affects burning. This might additional cause poor combustion, significant smoke, in the course of loss of power and economy. In tiny engines, the fuel spray could impinge upon the cylinder walls, washing away the lubricating oil and inflicting dilution, of the crank case oil.
2.4 Use of biodiesel blends with minor engine modifications.

Reddy. S. S. K. et al [128] has conducted theoretical and experimental investigation on the performance of a four stroke adiabatic D.I diesel engine. Adiabatic engine is developed with air gap insulation over piston and cylinder liners, partially stabilized zirconium (PSZ) coated cylinder head. A software package has been developed in C Language for an insulated engine with the theoretical results obtained and therefore the same factors were compared with experimental results. It's ended that the entire insulation of the engine has improved the brake thermal potency by 2.35%.

Murali Krishna. M.V.S. et al [129] has conducted performance tests on a low heat rejection diesel engine with waste cooked (fried vegetable oil) oil. The low heat rejection engine has designed with ceramic coating on cylinder head, cylinder walls and piston with air gap insulation. From the experimental results it’s found that the brake thermal potency of low heat rejection engine is improved by 3.5% as compared with traditional engine. It had been ended that the low heat rejection engines are suitable for vegetable oil operations.

Murthy. V.S.S. et al [130] have reviewed the low heat rejection diesel engines to search out the potential benefits present in this area. The employment of insulation to the engine parts to scale back in cylinder heat transfer has been investigated as a way of rising engine performance by increasing the thermal potency. The ways of reducing heat rejections studied in this review are using air as insulating medium around metal elements, coating the engine combustion
chamber surfaces with ceramic materials and using ceramic parts. They summarized that the low heat rejection engines can have improved thermal potency and emissions compared to normal engines.

Raju. K et al [131] investigated the performance characteristics of a four stroke CI engine by variable diameter of the manifold from 26 mm to 34 mm in steps of 2 mm and compared with traditional manifold diameter (30 mm). From the experimental results it's found that 34 mm diameter manifold will increase the brake thermal potency of the engine by 2.38% and reduces the brake specific fuel consumption by 7.4% as compared with traditional manifold.

Hoag et al [132] carried out experiments with constant air-fuel ratio on a Cummins V903 engine with partially stabilized zirconium (PSZ) coating as an insulation material and compared the performance with base engine. The results are recorded with a specially designed data acquisition system. From the results they ended that the performance parameters vary directly with relation to degree of insulation.

Investigations of Assanis et al [133] on a single cylinder, DI engine shows the consequences of ceramic coatings on engine performance and exhaust emissions. Tests are conducted on a standard metal piston with completely different thickness of ceramic coatings. The two pistons insulated with 0.5 mm and 1.0 mm thick was used in this investigations. The thinner ceramic coated piston provided 10% higher thermal potency and thicker coated piston
resulted in 6% higher thermal potency than standard engine. Due to improved combustion within the insulated engine the emissions are lower than the base line engine.

Bhatt. Y.C et al [134] has conducted experiments on a single cylinder four stroke diesel engine by varying its compression ratio, to check the performance and emissions characteristics with Mahua biodiesel and its blends with diesel. They found that Mahua biodiesel mix B20 may be substituted in CI engine with none modifications. From the experimental results it's ascertained that the performance of engine with Mahua biodiesel mix B20 was improved with the rise in compression ratio from 16:1 to 20:1.

Kobori et al [135] developed a Low heat rejection (LHR) engine with the piston and cylinder head coated with 0.1 millimeter thick and the liner is coated with 0.5 millimeter thick thermal barrier coating materials and all other engine parameters are kept constant. Experiments are conducted on this LHR insulated engine and compared with traditional engine. They ended that the LHR engine can maintain 5 to 6% fuel economy and therefore the thermal potency is improved in any respect load and speed. This is due to higher premix combustion, lower diffused combustion, reduced heat loss, high rate of warmth within the main portion of the combustion chamber.

Senthil Kumar. R et al [136] has conducted experiments on a four stroke CI engine with Mahua biodiesel to search out impact of compression ratio, Injection timing and injection pressure on the
performance of the engine. Tests were conducted at completely different compression ratios varying from 16:1 to 21:1. Injection gap pressure from 170bar to 270bar and injection timing 19º before TDC to 29º before TDC. From the experimental results it’s ascertained that the utmost brake thermal potency is found for Mahua biodiesel mix B40 at 23º before TDC of injection timing, Injection pressure as 210 bar and compression ratio of 18:1.

The study of Kawamura et al [137, 138 & 139] indicates that a pre-combustion chamber has sensible potential for LHR engine. In this study it is observed that high combustion wall temperature of pre-combustion chamber improves fuel consumption and exhaust emissions. Their investigations on LHR engine show a reduced heat rejection however no improvement in fuel economy and exhaust emissions. It’s attributable to insufficient air-fuel combining and degradation of combustion.

Pugazhvadivu. M et al [140] has conducted experiments to check the performance and emissions of a single cylinder, stationary CI engine with preheated Mahua biodiesel. Mahua biodiesel was preheated to 130ºC and therefore the impact of preheating on the engine performance and emissions were determined. From the experimental results it had been ended that Mahua oil preheated to 130ºC may be used as fuel in CI engine.

Woshni et al [141] and Furuhama et al [142] conducted experiments on a single cylinder DI engine with solely piston insulation which ends poor performance in LHR engines as compared
with a completely insulated engine. This is often attributable to low temperatures within the combustion chamber and results in poor combustion.

Jameel Basha. S M et al [143] has conducted experiments on four stroke CI engine to search out the impact of ceramic coating on the piston and cylinder parts. From the experimental results it’s ascertained that the brake thermal potency of engine with ceramic coated piston and cylinder is increased by 3.5% as compared with traditional CI engine.

Ganapathi et al [144] has evaluated the performance of a ceramic coated and air insulated four stroke CI engine. The modifications are carried out by using partially stabilized zirconium (PSZ) coating to cylinder head, Values and air gap liner to the engine. From the results of experimentation it had been conducted that the ceramic coated with air gap insulation four stroke diesel engines performed higher when compared to base engine.

The investigation of Havstad et al [145] has clearly shown enhancements starting from 5 to 9% in BSFC of an insulated engine over a normal engine. Their measurements indicate that the in-cylinder heat transfer (heat loss) decreases by 30% within the insulated engine. In their experiments, a constant air-fuel (A/F) ratio is maintained for the insulated and non-insulated engines to make sure similar combustion in each case.

Jindal et al [146] has investigated the consequences of the engine operational parameters viz. compression ratio, injection
pressure, injection timing and engine speed on emissions of the engine running with pure biodiesel as fuel. From the experimental results it's ascertained that the combined increase of compression ratio, injection pressure and retarding injection timing ends up in lower emissions as compared to the diesel fuel.

Sun et al [147] concluded from their experiments that with decrease in premixed combustion by 75% in an insulated engine increase the brake specific fuel consumption by 9%. So as to decrease in ignition delay in LHR engine, 25% gasoline fuel is mixed with diesel which ends a decrease in BSFC. This will be done by increasing the injection pressure. In each of these cases the fuel composition and injection pressure was altered to change the heat release and to improve the BSFC of an insulated engine. So as to own the complete advantages of LHR engine, the combustion system is to be changed to keep up a fascinating heat release profile.

Appa rao. K et al [148] has conducted experiments on a four stroke CI engine to search out the impact of injection timings on performance of the engine. The engine tests are conducted by variable the injection timing of the engine from 18º before TDC to 26º before TDC. From the experimental results it’s ascertained that the utmost brake thermal potency is found for at 22º before TDC of injection timing.

Comparative performance of various versions of low heat rejection engine with mohar oil based bio diesel conducted by T R Reddy et al [149] to gauge the performance of low heat rejection
engine. The LHR engine is developed with ceramic coated engine parts and air gap insulated piston. From the experimental results it's ascertained that the brake thermal potency is improved by 7%, Brake specific fuel consumption decreased by 11% and NOx level increased by 58% with low heat rejection engine at an injection pressure 190bar as compared with standard engine.

Raheman. H et al [150] has investigated the performance of a variable compression ratio CI engine with Mahua biodiesel and its blends. The compression ratio of the engine is varied from 16:1 to 20:1. From the experimental results it’s ascertained that with a rise in share of biodiesel in the blend the performance of the engine is decreased, whereas the performance is improved with increase in compression ratio.

Phaneendra V et al [151] has investigated the performance of a four stroke CI engine with different helical threaded intake manifolds to achieved the swirl motion of inlet air and to boost the performance of the engine. Helical threaded manifold with variable pitch from 10mm to 25mm insteps five mm were employed in this work and it’s ascertained that the 10mm pitch helical threaded manifold engine has showed higher performance with increase in brake thermal potency by 5.13% and brake specific fuel consumption reduced by 5.5%.

Siva Kumar et al [152] has conducted experimental investigation on low heat rejection engine with different operational parameters. The blow down loses may be overcome by employing a idea of extended expansion cycle LHR(EEE) within which the
expansion ratio is larger than that of compression ratio. This higher expansion ratio may be achieved by late closing of inlet valve. From the experimental results it’s found that the thermal potency is improved for LHR and LHR(EEE) engines.

The investigations of Alkidas [153] concluded that the poor fuel economy of LHR engines ascertained by several previous investigators is that the results of insufficient air-fuel combining and deteriorated combustion. However, the performance parameters are improved for LHR engine than the standard engine. In case of un cooled engines there's a reduction in ignition delay, combustion duration, premixed combustion and a rise in diffusion combustion as compared to a conventionally cooled engine. So as to comprehend the potential gains of fuel economy in an LHR engine, conversion of a cooled engine to LHR engine by a lot of insulation is not enough, however appropriate modification to optimize the injection system is additionally required.

Raheman. H [154] has conducted performance tests on a CI engine by varying compression ratio and injection timing of the engine with Karanja biodiesel and its blends with diesel. The compression ratio of the engine is varied from 16:1 to 20:1. From the experimental results it’s been found that the performance of the engine with biodiesel blends was increased with increase in compression ratio and advanced injection timing. It’s been ended that the Karanja biodiesel mix B20 may be used as an alternate to diesel fuel at higher compression ratio.
Murali Krishna M.V.S.K. et al [155] has conducted Investigations on a low heat rejection engine with crude rice bran oil as substitute fuel to diesel. Experiments were conducted to gauge the brake thermal potency and exhaust gas temperature with completely different versions of engine like standard engine, engine with superni inserts for piston and cylinder lines (SPSL) at completely different operational conditions of rice bran oil at room temperature and preheated temperature (65°C). From the experimental results it’s ended that the thermal potency of the engine with superni inserts for piston and cylinder liner (SPSL) at preheated condition of rice bran oil approaches to that of traditional engine with diesel fuel. Marginal increase within the thermal potency is ascertained with increase in injection pressure.

Reddy. S.S.K. et al [156] has studied the impact of injection pressure on the performance of Alcohol burning insulated engine. An insulated engine is meant with partially stabilized zirconium (PSZ) coating on engine parts and performance tests were conducted with five different injection pressures (180, 175, 170,165 and 160 bar). From the experimental results it’s ascertained that the performance of the engine at 165 bar injection system pressure is best.

Experimental investigations of Miyairi et al [157] on a single cylinder DI engine indicates improved engine performance, reduced HC emissions, increased NOx emissions and reduced volumetric potency. The engine used for this investigation is insulated with monolithic ceramics like PSZ and sintered silicon nitride (SSN). In the
experiments, the fuel injection system and the quantity fuel injected was kept same as normal engine. Temperatures of the cooling water and lubrication oil are maintained at 80°C throughout the experiments. The cylinder liner is water cooled to stop the lubrication problems and to stop the deterioration of volumetric potency.

Muralidharan. K et al [158] has conducted performance check on a variable compression ratio engine with the waste cooking oil biodiesel and its blends with diesel. The compression ratio of the engine is varied from 18:1 to 22:1. From the experimental results it’s ascertained that the performance of the engine will increase with increase in compression ratio.

Durga. B et al [159] has conducted an experimental investigation to search out the impact of catalyst to Alcohol fuel engines. The experiments are carried out on a ceramic hot surface ignition engine (CHSI) with numerous coatings like copper coatings, Aluminum coating, Chromium oxide coating, magnesia coating and Nickel coating separately. From the experimental results it's found that out of 5 coatings to combustion chamber copper coating engine has shown best results.

Experimental investigation is conducted by Wade et al [160] on a single cylinder DI engine with ceramic coated cylinder head, valves, steel piston and compared with the performance of normal water cooled engine. A constant air-fuel ratio is maintained for both insulated and non-insulated engines to make sure similar combustion. They obtained a 4 to 7% improvement in fuel
consumption in any respect operational conditions relative to the baseline water cooled engine.

Navindgi. M. C et al [161] has conducted experimental investigations on a variable compression ratio engine fuelled with diesel and castor oil biodiesel and its blends. From the experimental results it's ascertained that the optimum compression ratio is 18:1 with injection pressure as 240 bar for this biodiesel.

Parikh et al [162] worked on the management of NOx in adiabatic engine with completely different techniques and their combinations. This minimizes the engine performance impairment. Impact on exhaust NOx levels with controlled temperature of EGR is by experimentation studied with retarding injection timing, for various mixtures of EGR quantities and injection timings at completely different operational conditions. It's ended that the NOx levels are reduced significantly with minimum loss of power, potency and minimum smoke emissions.

Chandra Mouli M et al [163] has investigated the performance characteristics of a four stroke CI engine by arranging a convergent – Divergent nozzle within the inlet manifold so as to extend the air velocity within the manifold of the engine. The throat diameter of the nozzle in varied from 15mm to 21mm in steps of 2mm. From the experimental results it's ascertained that the 19mm throat diameter nozzle showed higher performance. The brake thermal potency is increased by 16 % and brake specific fuel consumption is reduced by 14% is ascertained at 19mm throat diameter.
Ravi Kumar et al [164] has studied the consequences of compression ratio and exhaust gas recirculation on the performance of direct injection engine. The experiments were conducted on a variable compression ratio engine by varying compression ration from 15:1 to 19:1 and completely different EGR rates like 3%, 5% and 10%. From the experimental results it's found that a rise in compression ratio will increase the brake thermal potency of the engine. It’s also ascertained that the 5% EGR decreases the combustion duration by 2-3 degrees of crank angle rotation.

Baluswamy et al [165] studied the performance of the IC engine by insulating the combustion chamber attaining an adiabatic condition. It’s ended that the cycle average temperatures and metal surface temperatures are higher in adiabatic engine due the low ignition delays. The emissions are reduced plenty compared to traditional engine. Further power and improved potency are derived from this idea by adopting appropriate means that of recovery of heat from the exhaust gases and also by reducing the losses to the cooling system.

Experimental investigation is carried out by Lohith. N et al [166] to check the performance and emission characteristics of a CI engine with Karanja biodiesel and its blends. The engine is run at high compression ratio (22:1) and by variable Injection pressures from 200 bar to 225 bar. From the experimental results it’s ascertained that the performance of the engine is improved with a rise in injection pressure.
The effects of combustion chamber insulation are studied by Zapf [167] and Griffits [168] on a single cylinder DI engine. The experimental results it is found that a marginal improvement in the performance and emission of the insulated engine. Finally they concluded that the only combustion chamber insulation cannot show a major impact on engine performance.

Prasad S.L.V., et al [169] have investigated a way to improve the air swirl to attain higher engine performance and reduction of emissions. During this work the experiments were conducted by creating straight grooves within the cylinder head in the order of variety of grooves like 1, 3 and 6. These grooves facilitate to intensity the swirl for higher combining of fuel and air and to improve the engine performance. It’s ended that the brake thermal potency of the engine with six grooves is increased by 6.9% and therefore the emissions are reduced considerably.

Lokamandhan. R et al [170] has conducted experiments to search out use of alternative fuel in low heat rejection engine with different insulating levels. The various Biodiesels like Thumba, Neem, cooton seed, Rape seed and Karanja were used with PSZ coating as insulation on piston and cylinder. It’s ended that the thumba bio diesel is found to be superior compared to other alternative bio diesels tested in this low heat rejection engine. Compared to thumba fueled base engine the brake thermal potency of thumba fueled low heat rejection engine is higher by 7% at rated load.
Roy Kamo et al [171 & 172] applied skinny (thin) thermal barrier ceramic coatings to a normal DI engine and operated the engine at numerous speeds. It's concluded that the fuel economy at full load is 6% higher and 3.5% higher at lower loads when compared to a normal engine. The coating in diesel engines is low price and a straightforward approach for enhancing the engine performance and to reduce the fuel consumption.

Navindgi. M.C. et al [173] has investigated the performance of a variable compression ratio engine with Mahua biodiesel and its blends with diesel by varying injection pressure from 180 to 220 bar and fuel preheating temperature from 30°C to 70°C. From the experimental results it's ascertained that the performance of the engine is improved with a rise in injection pressure and fuel temperature. Mahua biodiesel may be used as an alternate fuel to the diesel fuel.

Stang [174] designed an insulated piston with ceramic crown. The ceramic crown is supported with a conventional aluminum base and the two are separated by a layer of insulating material. These two parts are bolted with Belleville Springs to compensate the differential longitudinal” thermal growth between the bolt material ceramic crown and aluminum base. From the experimental results it's ascertained that the insulated engine has shown an improvement in the performance and emissions.

Krishna.S.S. et al [175] have conducted performance and emission tests on a low Heat rejection engine with Mahua Bio diesel mix. The piston, cylinder head and values of engine was coated with a
nano ceramic material $\text{Al}_2\text{O}_3$ through plasma spray method engine tests were conducted with and without ceramic coating and results were compared. From the experimental results it's ascertained that the Mahua biodiesel blends has shown lower brake thermal potency than the diesel when ceramic coating wasn't provided. The brake thermal potency of Mahna blends is nearer to the diesel with $\text{Al}_2\text{O}_3$ ceramic coating to the engine parts.

Performance analysis of low heat rejection engine has been carried out by Murthy P.V.K et al [176] with pure diesel as fuel. The low heat rejection engine is designed with 3mm air gap piston and PSZ coating on piston, cylinder and cylinder head. From this experimental work it's ascertained that the optimum injection timing is 33° before TDC for standard engine and it's 32° b TDC for LHR engine. The injection pressure for LHR engine is 190 bar.

Martin. L.J et al. [177] has conducted performance tests on a four stroke CI engine with Cotton seed biodiesel and its blends with diesel to search out the impact of preheating, the fuel is heated from 30°C to 90°C and tests are conducted. From the experimental results it's ascertained that the preheating of fuel will increase the brake thermal potency by 2.5% as compared with fuel without preheating. It had been ended that the preheating of biodiesel improves the performance of the engine and reduces the emissions.

Wacker [178] has shown that a high temperature metal crown piston will have insulation properties as good as that of ceramic crowned piston with further benefits like high strength, malleability
and may be machined simply. It’s on these grounds that Wallace [56 & 79] favored the employment of metallic piston with air as an insulating medium with a cast iron crown capable of withstanding each mechanical and thermal stresses.

Varatha vijayam M et al [179] has conducted experiments on a four stroke CI engine with Mahua bio diesel and its blends with diesel. The engine tests are conducted to search out the impact of injection pressure on the engine by variable injection pressure from 160 to 220 bar. From the experimental results it’s ascertained that the injection pressure of 200bar was to be found as optimum injection pressure for the bio diesel blends B10, B20, B30, B40 and B50.

Sunil Kumar Reddy et al [180] has investigated the performance of CI engine with ceramic coating. PSZ ceramic coated engine is developed to scale back the warmth transfer from the engine cylinder to cooling water. From the experimental results it’s ascertained that the engine performance is improved with PSZ coating on engine parts.

Venkatraman. M et al [181] has conducted experimental investigations on a variable compression ratio CI engine with Pongamia biodiesel mixed with diesel and by varying the injection pressure from 180 to 240 bar. From this experimental investigation, it’s ascertained that the combined increase of compression ratio and injection pressure will increase the brake thermal potency and reduces brake specific fuel consumption. Finally it had been ended that the optimum combination is attained with the compression ratio of 19:1 and injection pressure as 240 bar for biodiesel mix B20.
The performance of an engine by employing a cylinder liner insulated by an air gap is studied by Pradeepam [182] and ended that with solely cylinder liner insulation the performance obtained is marginal when compared to the base line engine.

Murali Krishna et al [183] has studied performance and exhaust emission in D I engine with air gap insulation piston and air gap insulated liner with waste cooked oil. The performance parameter like brake thermal potency and exhaust gas temperature, exhaust emission were determined. Compared with standard engine the low heat rejection engine has improved performance parameters and reduced particulate emission.

Varaprasad et al [184 & 185] developed low heat rejection (LHR) engine with an insulated piston and liner coated with PSZ. The pollution levels of aldehydes are measured, with alcohols as an alternate fuel in LHR engine with variable injection pressure, injection timings with completely different share of alcohol induction. It’s ended that the aldehyde emissions are increased with a rise in alcohol induction. The LHR engine attributable to high temperatures showed a decrease in aldehyde emissions when put next to standard engine. However, the variation of injection pressure and advancing the injection timing reduced the aldehyde emissions.

Sarada. S.N et al [186] conducted short term tests to analyze the optimum injection pressure for a compression ignition engine with Cotton seed oil as an alternate fuel. To boost the combustion characteristics of Cotton seed oil in an un-modified engine, impact of
increase in injection pressure was studied. The injection pressure was increased from 180 to 240 bar (in steps of fifteen bar). The investigations disclosed that the optimum pressure for oil as 210 bar and comparison of the performance of the engine was studied in terms of brake specific fuel consumption, brake thermal potency, indicated thermal potency, mechanical potency and exhaust emissions

2.5 Summary of literature survey

In this literature survey, the contributions of eminent researchers within the field relating to the use of biodiesels in CI engines are reviewed. The review of literature reveal that the Biodiesel has low calorific value, (9 to 19% under diesel) on weight basis due to the presence of considerable quantity of oxygen within the biodiesel, at same time it has high relative density (3 to 5% more than the diesel) and higher viscosity. So the impact on the engine is roughly 7% reduction in brake thermal potency. Hence the biodiesels are mixed with diesel and biodiesel blends are successfully employed in a CI engines. The presence of oxygen within the biodiesel causes lesser particulate formation and emissions. Many experimental investigations performed on 4-stroke DI diesel engines with biodiesels disclosed (reveals) that the hydrocarbon and carbon monoxide emissions are lower in the case of biodiesel compared to diesel. This is due to the oxygenated nature of biodiesel where this oxygen helps for better combustion and reducing hydrocarbon emission within the exhaust. CO could be a toxic combustion product ensuing from incomplete combustion of hydrocarbons. With the presence of
adequate oxygen, CO is reborn into CO$_2$. Hence CO emissions are less within the exhaust. The NOx forms by the chemical reaction between nitrogen and oxygen at sufficiently high temperatures. Since biodiesel is free from sulfur, less sulfate emissions and also particulate reduction within the exhaust has been reported.

Biodiesels or its blends with diesel, however causes numerous long-run issues in compression ignition engines, like poor atomization characteristics, ring sticking, injector deposits, fuel injection pump failure and lubricating oil dilution by crank case polymerization. These undesirable characteristics of biodiesels are due to their inherent properties like high viscosity, low volatility and polyunsaturated character.

-Several researchers worked on CI engines with biodiesel blends by increasing compression ratio and injection pressure, by changing inlet conditions, injection timing, preheating the fuel and compared with the performance of standard engines. The researchers are also worked on insulated diesel engines like ceramic coated engine parts, but the results don’t seem to be encouraging. The idea of the Insulated engine concept is recommended by several researchers however less work was done on this so far. Further the performance of biodiesel blends in insulated diesel engines with air as an insulating medium and the impact of various piston crown materials on combustion don't seem to be tried by any researchers. Hence a substantial attention is given in the present work for the development of an insulated piston engine.
2.6 Scope of the current work

With ever increase in energy demand, depleting fossil fuels and ozone layer depletion, bio fuels are progressively being considered as energy choice for the long run. Bio fuels are renewable and alternative fuels that play a significant role in transportation, power generation, industrial and modern agricultural sector. There are a wide range of bio fuels potentially available however the most bio fuels being considered globally are biodiesels. The biodiesels employed as an alternative fuel to diesel fuel should have high calorific value and low emission characteristics. It should be available in plenty at low cast and should mix homogeneously with diesel. Hence in the present work five different biodiesels namely Jatropha, Karanja, Mahua, Cotton seed and Neem biodiesels are employed. These biodiesels are mixed with diesel separately in numerous proportions and are used as a test fuels to evaluate the performance and emission characteristics of a four stroke diesel engine.

The thermal potency of an engine operating with biodiesel blends is usually lower than the engine that operating with diesel fuel due to the lower heat value, higher viscosity and low volatility of biodiesel. This problem may be corrected to larger extent by using low heat rejection CI engine that keeps hot surroundings within the combustion chamber by providing thermal insulation to the engine parts with low thermal conductivity phenomenon materials.

Among all the engine parts most of the heat transfer happens through the piston. Thermal insulation to the piston will cut back this
heat lost and therefore the performance of the engine may be improved. In the present work it is planned to provide air insulation within the piston by maintaining an air gap between piston crown and skirt. The experiments are conducted to search out the impact of this air gap on the performance and emission characteristics of the engine.

Though the air gap insulated piston configuration offers sensible performance and emission characteristics, plenty of warmth is lost to the exhaust gases. If these losses are reduced, the thermal potency of the engine may be improved. So as to scale back this heat loss, it is also planned to design a piston crown with the material which might be capable of holding the heat from the hot combustion gases during the peak cycle temperature conditions and should provide this absorbed heat to the incoming fresh charge during the suction and compression strokes of the next cycle. This could improve the combustion potency and an improvement in thermal potency is anticipated.

Thus a rugged and versatile thermal barrier piston is designed by using an air as insulating medium and also with various thermal conductivity phenomenon materials like cast iron, Copper and brass as piston inserts to scale back the warmth losses from the piston crown to the piston skirt. The salient feature of this design is that it may be adopted in any engine with none major modifications to the initial design.
2.7 Objectives of the current work

The present investigations have been carried out to achieve the following objectives.

i. To evaluate the performance and emission characteristics of a CI engine with five different biodiesels blended with diesel separately in various proportions to find best biodiesel and optimum blend.

ii. To study the effect of thermal insulation provided to the piston with an air gap and insulated inserts by using the biodiesel blend identified through the first objective and to convert this heat into a helpful work.