Comparison of Performance and Emission Characteristics of DI CI Engine Using Dual Biodiesel Blends

Dissertation-II

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by

Rakesh Kumar

(11511089)

Under the guidance of

Maninder Singh

(17902)

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LOVELY PROFESSIONAL UNIVERSITY

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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled " ***Comparison of Performance and Emission Characteristics of DI CI Engine Using Dual Biodiesel Blends"*** in partial fulfilment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of ***(Maninder Singh, Assistant Professor)*** Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

(__.04.2017)

(Rakesh Kumar)

11511089

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

(__.04.2017)

(Maninder Singh)

(17902)

COD (ME)

___The external viva-voce examination of the student was held on successfully ___________

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DECLARATION

I, Rakesh Kumar (11511089), hereby declare that this thesis report entitled "***Comparison of Performance and Emission Characteristics of DI CI Engine Using Dual Biodiesel Blends***" submitted in the partial fulfilment of the requirements for the award of degree of Master of Mechanical Engineering, in the School of Mechanical Engineering, Lovely Professional University, Phagwara, is my own work. This matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

Date: Rakesh Kumar

Place:

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Rakesh Kumar

(11511089)

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ABSTRACT

In recent years, biodiesel utilization in diesel engines has got attention due to population growth and industrialization. Biodiesel has been proven to be a good alternative because of its performance comparable to diesel and capability of reducing greenhouse gas emissions. In this study, the effects of engine load and amount of biodiesel percentage on the performance and emission characteristics of single cylinder, 4 stroke diesel engine has been investigated and presented. The dual biodiesel blends of Argemone Mexicana and Mahua (Madhuca indica) were used in the present study. The results for biodiesel blend D60A20M20 (i.e 60% diesel, 20% Argemone and 20% Mahua) with diesel showed slight increase in brake power. There was average 0.06kg/kW h increase in specific fuel consumption for the biodiesel blends at full load. The carbon monoxide (CO) and hydrocarbons (HC) emissions reduced for the biodiesel blend, while Nox emission was higher as compared to diesel. The results concluding Heat Release Rate (HRR), Indicated Thermal Efficiency (ITE), Peak Pressure and volumetric efficiency have been also presented. The results for lighter blend of biodiesel D80A10M10 (i.e 80% Diesel, 10% Argemone and 10% Mahua) with diesel showed 1.31% increase in volumetric efficiency. There is slight reduction seen in indicated thermal efficiency for all the blends. The peak pressure is observed for the diesel which was 1.75 bar more than the diesel at full load. The heat release rate is maximum for the diesel.

Keywords: Dual Biodiesel, Diesel Engine, Argemone mexicana, Mahua

1 INTRODUCTION

In the recent years, worldwide petroleum consumption has increased due to increase in population and industrialization which results in the increasing petroleum prices and in the diminution of reserve fossil fuels, therefore switching the fossil fuel with renewable energy resources is a necessary approach. Alternatively, burning of fossil fuel adds most to emissions of greenhouse gases. It is founded that biodiesel is a good substitute for the fossil fuels. The various researchers test the engine with the different biodiesels, they observed that engine gives very close performance to diesel and less exhaust emissions as compared to diesel fuels. The biodiesel can be produce by several vegetables like neem, jatropha, sunflower etc. The various countries working on the various aspects of producing biodiesel. The biodiesel has many advantages over the petroleum fuels such as, non-toxic, biodegradability, lower exhaust emission, lower sulphur content, domestic feedstock and higher combustion efficiency. Although it has many advantages over the fossil fuel, its use is restricted in unmodified engine maximum upto 20% blend with diesel. However the direct use of biodiesel led to many problem due to its high viscosity. The high cost of the biodiesel is the major problem for its commercialization.

The biodiesel could be produced from edible and non-edible plant. The plant is selected on the basis of FFA content present in it. However the use of edible oil for the production of biodiesel can lead to food scarcity. Therefore, it is essential to search for non-conventional feedstock to reduce the cost of biodiesel.

1.1 Methods Of Production Of Biodiesel

Various methods have been used for the production of biodiesel from the vegetable feedstock.

- Thermal cracking (pyrolysis)
- Microemulsification
- Dilution
- Transesterification

These are the four methods used for the production of biodiesel with different techniques. Out of these four methods transtserfication is the most successful one. These four methods are explained one by one below

1.1.1 Thermalcracking

Thermal cracking is also known as Pyrolysis. It is defined as the conversion of one element into another by means of heat. This process involves heating in the lack of air and cleavage of chemical bonds to produce small particles. The understanding of pyrolysis is hard to characterize because of dissimilar rate of reaction and different products at the completion of reaction. Pyrolyzed material can be vegetable fats, animal body fat, natural fatty acids and methyl esters of fatty acids. The apparatus for thermal cracking and pyrolysis is costly. The products acquired from this process are chemically parallel to petroleum-derived gas and diesel fuels. This process reduce the viscosity, pour point and flash point of product obtained. It also reduce the cetane number. The drawback of this process is that oxygen is removed at the completion of the reaction which reduce the environmental welfares of using oxygenated fuels.

1.1.2 Microemulsification

A micro emulsion is described as a colloidal equilibrium spreading of optically isotropic fluid microstructures with magnitudes generally in the1±150 nm range formed spontaneously from generally two immiscible liquids. This process reduces the higher viscosity of vegetable fats. Micro emulsions of vegetable fats can be prepared with diluters such as methanol, ethanol and 1-butanol. Spray characteristics of fat are enhanced after this method.

1.1.3 Dilution

Direct use of plant fats or the mixtures of the oils has been considered to be not suitable and unfeasible for both indirect and direct diesel engines. The high viscosity, content, high FFA content, as well asgum creation due to oxidation and polymerization for the period of storage and combustion, lubricating oil thickening and carbon deposits are some problems which are come across by the direct use of vegetable fats or the use of mixtures in the Diesel engines.

1.1.4 Transesterification

Transesterification is the process in which oil or fat with an alcohol is reacted to form esters and glycerol in the presence of a catalyst. The catalyst is used to improve the reaction rate and yield. The alcohols used in this process are methanol, ethanol, propanol, butanol and amyl alcohol. Methanol and ethanol are commonly used, especially methanol because of its physical and chemical advantages and its low cost. Methanol can rapidly react with the triglycerides. The catalyst like Na and NaOH are easily dissolved in it. Generally to complete a transesterification stoichiometrically, 3:1 molar fraction of alcohol to triglycerides is used. In practice, the ratio needs to be higher to initiative the equilibrium to increase the ester yield. The reaction can be catalyzed by alkalis, acids, alkalis or enzymes. The alkalis include NaOH, KOH, carbonates and corresponding sodium and potassium alkoxides such as sodium methoxide, sodium ethoxide,sodium propoxide and sodium butoxide. Sulfuric acid, sulfonic acids and hydrochloric acid are usually used as acid catalysts. Lipases also can be used as biocatalyst. Alkali-catalyzed transesterification is much quicker than acid-catalyzed transesterification and is most frequently used commercially. This process raised the cloud point and pour point. This process is use with fats having less fatty acid content. This method is generally chosen over all other process for the biodiesel assembly.

1.2 Production source of biodiesel

- Vegetable oils
- Animal fats
- Non-edible oils
- Waste cooking oil

1.3 Advantages of biodiesel

The biodiesel has many advantages over the diesel fuel, which are discussed below:

- Biodiesel is a renewable source of energy.
- Biodiesel can be used in existing engine without any modification.
- Environmental compatibility compared to fossil fuels.
- Biodiesel is having excellent lubricity as compared to diesel due to its higher viscosity.
- Biodiesel can be domestically produced.
- Biodiesel is having higher oxygen content, which helps in reduction in emissions like carbon monoxide and unburnt hydrocarbons.
- Biodiesel is east to store and safer to handle.

2 TERMINOLOGY

FAMEs	Fatty acid methyl esters	B20	20% Biodiesel and 80 Diesel
CN	Cetane number	B30	30% Biodiesel and 70% diesel
FFA	Free fatty acid	B40	40% Biodiesel and 60 Diesel
AMME	Argemone mexicana methyl ester	A5M5D10	B10
MME	Mahua methyl ester	A10M10D80	B20
TAGs	Triacylglycerides	A15M15D70	B30
Di	Direct injection	A20M20D60	B40
Ci	Compression ignition	Kg	Kilogram
Na	Sodium	kW	kilowatt
NaOH	Sodium hydroxide	RPM	Revolutions per minute
ml	millilitre	BP	Brake power
gm	gram	IP	Indicated power
˚C	Degree Celsius	FP	Friction power
B100	100% Biodiesel	BTE	Brake thermal efficiency
B10	10% Biodiesel and 90% diesel	SFC	Specific fuel consumption
BMEP	Brake mean effective pressure	IMEP	Indicated mean effective pressure
FMEP	Friction mean effective pressure	NHR	Net heat release rate
CO	Carbon monoxide	CO_2	Carbon dioxide
NO_x	Oxides of nitrogen	HC	Unburnt hydrocarbons

3 REVIEW OF LITERATURE

Azam et al.[1] 75 Indian plants, which contain 30% more oil in their kernels, fruits or nut had been investigated. The sponification number (SN), iodine value (IV) and cetane number of fatty acid methyl esters (FAMEs) emperically calculated and were used according to their suitability for use as biodiesel which could met the specificaton of biodiesel standard of USA, Germany & Europian standard organization. Out of 75 plants, 42 had met the standard value of cetane number (CN) which was more than 51. All the 42 spieces which qualified the specification of cetane number (CN), also met the specification of iodine value (IV), which was less than 115 .Generally higher value of cetane number was preffered, but with increase in the cetane number the iodine value decreased which meant degree of unsaturation decreased which resulted in solidification of the fatty acid methyl esters at high temperature. To avoid this situation the upper limit of the cetane number (CN) had been specified as 65 in US biodiesel standard. Out of the 42 plants which met the standard specification of both cetane number & iodine value. The 15 had higher melting points therefore these might not be used in cold weather conditions.

Ilic et al. [2] had investigated the important non edible oils plants like jatropha, karnaja, tobacco, mahua, neem, rubber, sea mango, castor, cotton etc. Out of these plants jatropha, karnaja, castor and mahua were most often used in biodiesel synthesis .It had been observed that jatropha plant was the most accomplished for biodiesel production. Karnaja was nitrogen fixing tree had a significant oil content and native to India, United States, Indonesia, Australia, Philippines and Malaysia. Mahua and neem trees founded mostly in India and Burma. Annual production of mahua and neem in India were 100,000 ton and 180,000 ton correspondingly. It had been practiced that the most appropriate method for production of biofuel, was the transesterification reaction of these plants with the alcohol in the presence of catalyst. The catalyst might be acid or base accordingly the content of FFA present in plant. If the FFA content was higher than acid catalyst was used and if the FFA content was lower than base catalyst was used. The catalyst might be Homogenous or heterogenous. Solid catalyst was prefferd over the liquid catalyst for many reasons simple product separation and purification. Both homogenous and heterogenous catalyzed process involved two processes, one step process and two-step process.

Bing et al.[3] ten major trees were taken which could be used as potential raw material for biodiesel .The relation between the fatty acid composition of vegetable oils and fuel properties of biodiesel were analyzed. Only fully matured seeds were used because immature seeds had not reached the final fatty acid composition. The fresh seeds of Xanthoceros Sorbifola and Armeniaca Sibiricas were stored at room temperature for one week to dry before they were transferred to the laboratory in polypropylene bags under cool conditions. The parameters of biodiesel fuel such as, density, kinematic viscosity, cetane number, iodine value, oxidation stability and cold filter plugging point, were depended on oil nature. The sapium Sebifrum, Vernicia Fordii, Idesia Polycarpa and Elacis guineensis biodiesel should be used after they were mixed with petroleum diesel or a high cetane number of biodiesel.

Wang et al.[4] siberian apricot seed were used for production of biodiesel. The fully matured siberian apricot fruit were used. The siberian apricot had excellent value of cold filter plugging point. The cetane number observed was 48.8 which satisfied the standard value, but it had poor oxidation stability. The flash observed was also high which was173˚C. It had low acid value and water content. The cold flow properties of the fuel were excellent. On the other hand cetane number and oxidative stability can be improved using additives and antioxidants.

Varandal et al.[5] the performance of diesel and jatropha biodiesel were compared. It had been described that engine parameters such as compression ratio and load were found to had major effect on performance and emission of biodiesel engine when ran with biodiesel and its blend with biodiesel. It was possible to used jatropha biodiesel in the diesel engine as a fuel if cleaned and properly converted to combustible diesel oil. The jatropha biodiesel was purchased from commercial supplier from pune. The pure diesel was purchased from local petrol pump. After the comparison, it could be concluded that the break specific fuel consumption (BSFC), brake thermal efficiency (BTE) and exhaust gas temperature (EGT) of the engine are function of the biodiesel blend and load. It was observed that performance of the engine reduced with increase in biodiesel percentage in blend, for the same operating conditions. But with increase in the load the engine performance was similar to that of diesel. B20 shows comparable performance to the diesel. Biodiesel blends had shown reduced emission of CO and HC than that of diesel. While NO_x emission is more for biodiesel blends than the diesel fuel.

Liaquat et al.[6] the performance of the engine and emission characteristics was tested with the coconut biodiesel blended fuels and diesel fuel without any modification in engine. The engine was tested with three fuel samples. The samples were 100% diesel fuel, 5% coconut biodiesel and 95% diesel fuel, and 15% coconut biodiesel and 85% diesel fuel respectively were used. It had been observed that engine performance was tested at 100% load, kept throttle 100% wide open with variable speeds of 1500 to 2400 r.p.m and the emission characteristics were tested at 2200 r.p.m at 100% and 80% throttle position. After the comparison following results were observed the engine torque and brake power decreased for the coconut biodiesel blends fuel as compared to the diesel fuel due to the lower heating value and the brake specific fuel consumption for biodiesel blend increases as compared to diesel fuel because of low density and higher heating value in emission characteristics the HC and CO emissions were reduced due to presence of oxygenated compounds in the biodiesel blends and the CO_2 and NO_x were increased for the biodiesel blends..

Nalgundwar et al.[7] used single cylinder, four stroke DI CI engine to test the performance and emission characteristics. The biodiesel blends of palm and jatropha curcas were used for testing. The change in properties was observed when mixed in different ratio with blends of palm and jatropha. The calorific value of the biodiesel blends was lower than the diesel due to higher oxygen content. On the other hand density and viscosity of the biodiesel blends was higher than that of diesel due to large molecular weight and complex chemical structure. The cetane number was lower for the biodiesel blends. The brake specific fuel consumption increases for the biodiesel blends due to higher viscosity. There was increase in brake thermal efficiency as increase the ratio of biodiesel blends to the mixture. The exhaust gas temperature for the biodiesel blend was less than diesel fuel due to lower heating value and higher content of oxygen. The combustion reaction was not complete in diesel fuel due to which formation of carbon monoxide occur while in case of biodiesel the complete reaction takes place due to presence of oxygen content in their structure.

Ketologestwe et al.[8] the comparison between the blending cooking oil biodiesel and the petroleum diesel had been made on the performance of variable IC engine. The biodiesel was derived by the alkali catalyst transesterification process. In the study the different parameters were measured at different loads, for biodiesel and petroleum diesel and different combinations of the both. The process used for production of biodiesel for transesterification of triacylglycerols with the alkali or acid as catalyst. The engine used for testing was four stroke diesel engine which was directly coupled to dynamometer. All the results were observed at maximum speed of 2500 r.p.m. the different samples of fuel were prepared B0D100, B100D0, B50D50 and B30D70.The engine was tested at two different compression ratio 12 and 17. It was observed that engine torque improved for all the fuel samples at compression ratio 17. The carbon monoxide, polycyclic aromatic hydrocarbons and particulate matter were reduced by using biodiesel blends.

Zhiaho et al.[9] the emission characteristics of diesel engine fuelled with Pistacia chinesis bunge seed biodiesel and diesel were discussed. The experiment was carried out on the three cylinder, four stroke and water cooling diesel engine. The acid present in the fatty acid of pistacia chinesis bunge seed were palmitic, olein and linoleic and the content of these acid were 45.45%, 28.91% and 21.37%. The test was conducted at different speed of 1500r.p.m and 2400r.p.m with the different loaded conditions of 25%, 50%, 75%, 90% and 100%. It had been observed the HC emission decreased as biodiesel proportion increased in the biodiesel blends. As the biodiesel ratio increased the content of sulphur and aromatic hydrocarbons reduced. The fatty acid methyl ester had higher oxygen content, which result in the complete burning and reduced hydrocarbons. The CO emission had the same trend for the both biodiesel-diesel blend and diesel at medium and light loads. But at high load the former CO emission was more that of later blend due to existence of oxygen. The NO_x emission for lower blends like B10 and B20 was less than that of diesel. But almost same for B30 and diesel. It had been observed that exhaust smoke decreased as we increased the biodiesel in the diesel blends due to presence of oxygen.

S.Jindal [10] the effect of engine parameters on the NO_x emission had been investigated using jatropha biodiesel fuel in the diesel engine. It had been observed in many researches that biodiesel upto 20% might be used without any modification in engine. It was concluded that using biodiesel as fuel in the diesel engine without any modification reduced the power, thermal efficiency and increased the specific fuel consumption and comparatively higher emission of NO_x. In this study firstly the engine was tested using diesel fuel at standard parameters and then with 100% biodiesel under different value of compression, injection pressure, engine speed, injection time and emission were recorded. The experiment was carried out at an advanced fully computerised experimental engine test rig consist of a single cylinder, water cooled, four stroke, variable compression ratio diesel engine connected to dynamometer. For 100% diesel the test was carried at compression ratio 17.5:1 and injection pressure of 210kg/cm^2 at speed of 1500r.p.m and for 100% biodiesel the test was carried out at different compression ratio (16, 17 and 18) , three injection pressure 150, 200, 250 kg/cm^3 and different engine speed (1400, 1425, 1450, 1475, 1500 and 1525r.p.m). During the experiment the results observed were that with the increased compression ratio, the ignition delay reduced and peak pressure increased resulted in high temperature which cause larger amount of NO_x formation.

Chavan et al.[11] the emission and performance of variable compression ratio engine were discussed using different blends of jatropha biodiesel. The experiment had been performed on a single cylinder VCR engine at different loads with various compression ratio. The blends prepared were JB100, JB10, JB20, JB30 at 40˚C.The experiment was performed at compression ratio of 14-18 for each blend at different load of 0, 3, 6, 9, 12kg. It had been observed that density, flash point, fire point were increased as the biodiesel blends increased. The results obtained were that with increase in load and compression ratio, the hydrocarbon emission were reduced. But at higher loads the diesel fuel showed less HC emission at compression ratio of 14-16. The NO_x emission increased with increase in load and compression ratio. The carbon monoxide emission were reduced which might be due to rich oxygen content in biodiesel. The blend JB100 had showed least CO emission at CR of 14, 15, 16.The better results were found with blend JB30 which reduced HC and CO emission upto 43% and 50% respectively. The NO_x emission were increased by 20% at lowest load (0) but decreased upto 50% at load of 6kg.

Rahaman et al.[12] the performance of direct injection variable compression ratio compression ignition engine had been investigated with the karnaja biodiesel. The experiment was performed with D100/B0 and three pongamia oil blends which were blended with diesel (D95/P5, D90/P10 and D85/P15). The experiment was carried out on a single cylinder 4 stroke variable compression diesel engine. It was coupled to a 3 phase loaded rheostat. The results obtained were the brake specific fuel consumption of engine decreased with increased load. The brake thermal efficiency increased with increase in load and indicate thermal efficiency decreased with increase in engine load. The indicated thermal efficiency was lower for the biodiesel and its blends as compared to diesel fuel. The volumetric efficiency was maximum at no load conditions and it was observed that volumetric efficiency was higher for biodiesel and its blends as compared to diesel fuel.

Naveen et al.[13] the experimental investigation had been made on the performance of a variable compression ratio diesel engine using ziziphus jujube oil as biodiesel. The different blends used B20, B40, and B60 were compared with diesel. The method used for the preparation of biodiesel was esterification process and catalyst used was potassium methoxide. The test was conducted on a particularly designed tilting cylinder block arrangement for varying the compression ratio. The results obtained were B20 had the lesser fuel consumption at higher load for all the compression ratios apart from the compression ratio of 17.1 and B60 had higher fuel consumption for all the compression ratios which might be due to higher density and lower calorific value. The brake thermal efficiency increased at higher loads, but decreases as the percentage of biodiesel increased. B20 had the higher brake thermal efficiency which was similar to diesel. The exhaust gas temperature decreased with increase in blends of biodiesel and compression ratio. B60 had the lower EGT as compared to B20 and B40.

Sithta et al.[14] the engine performance and emission characteristics of diesel compression ignition engine were tested using blends of argemone oil and diesel. The transesterification had been done in single step due to low FFA value. The blends prepared were B0D10, B20D80, B40D60, B60D40, B80D20 and B100D0. It had been observed that brake thermal efficiency improved as the load increased. The maximum BTE founded for B20 was 28.56%, which was slight higher as compared to diesel. The BTE was lower for B40, B60, B80, B100 which was might be due to decrease in the calorific value. The brake specific fuel consumption decreased with increase in the load. The BSFC for B20 and B40 was close to diesel at higher loads. But for B60 and B100 the BSFC was higher than the diesel. The brake specific energy consumption obtained was closer to the diesel for the B20. But the BSEC for B40, B60, B80, and B100 was higher than that of diesel due to the lower calorific value as we increase the fraction of biodiesel blends. The carbon monoxide emission was lower for all biodiesel blends as compared to the diesel due to complete oxidation. The reduction in the hydro carbon emission for all the biodiesel blends as compared to diesel. The smoke density for the B40 was 28% which was 50% for the diesel.

Ravichandran N et al.[15] variable compression ratio diesel was used to evaluate cotton seed methyl ester and its diesel blends. The engine used for the experiment was four stroke, VCR, direct injection diesel engine with three compression ratios (16:1, 17:1, 18:1). The fuel used was cotton seed oil blend B20. The fatty acid composition of oil was linoleic acid (55.2-55.5%), palmitic acid (11.67-20.1%) and oleic acid (19.2-23.26%). The results obtained were BSFC for the blend is higher than that of diesel at all loads which was due to lower calorific value. The BSFC was lower for compression ratio 18 as compared to 16 and 17 for the cotton seed oil. The brake thermal efficiency was higher for the diesel because of its calorific value and viscosity. The brake thermal efficiency for the blend was increased with increase in compression ratio. It had been observed that CO emission reduced as the percentage of biodiesel increase in the blend due to inherent oxygen which helped in complete oxidation. The smoke emission was less for the blend with compression ratio 18. The unburnt HC emission decreased with increase in amount of biodiesel in the blend. The NO_x emission for the blend was higher which was due to high peak temperature.

Kumar et al.[16] carried out experimental study using had single cylinder, four stroke diesel engine with palm biodiesel and its diesel blends at different injection pressure. The experiment was performed at different injection pressure of 220bar, 240bar, 260bar, 280bar and 300bar, at constant speed with varying load. It was observed that the brake thermal efficiency increased with increase in load and pressure from 220bar to 300 bar. The higher brake thermal efficiency was observed at an injection pressure of 260bar at full load. The BSFC reduced with increase in load. It was concluded that when the injection pressure increased the diameter of fuel particle became small as a result improved mixing of fuel and air. The maximum BTE efficiency observed was 30.33% at injection pressure 260bar. The emission results were obtained that reduction in CO and CO_2 and nitric oxide (NO) but increase in level of HC at 260 bar.

Venkateswara Rao P [17] the performance and emission characteristics of variable compression four stroke engine had been investigated with B20D80 blends using jatropha biodiesel. The method used for preparation of biodiesel was transesterification. The results observed were that for the blended fuel brake thermal efficiency was always less as compared to diesel which was due to lower calorific value of biodiesel. The brake thermal efficiency increased as the compression ratio increased. The brake specific fuel consumption for blend was 2.4% higher as compared to diesel, for compression ratio of 20:1.The volumetric efficiency reduced with increase in compression ratio and load. The CO emission reduced with increase in both compression ratio and brake power. The HC emission for biodiesel blends decreased with increase in compression ratio which was due to presence of oxygen molecules. The NO_x emission was higher at higher compression ratio for all loads. The smoke density decreased as the compression ratio increased from 14:1 to 20:1, which may be due to improved oxidation of fuel.

F.M et al.[18] the study had been directed on go through the works that were carried out using biodiesel derived from oil of; mahua, cotton seed, canola, rice-bran, shea butter, biodiesel from waste frying oil, jatropha, waste palm oil, blend of ethanol and biodiesel, and diesel-biodiesel-ethanol fuel blends. The common method used for the preparation of biodiesel was transesterification using catalyst. The H_2SO_4 used as catalyst for esterification process and KOH for transesterification with methanol. It was concluded that biodiesel and its blends reduced brake power by 4-5% and increase B.S.F.C by 5-10%. CO_2 emission were reduced by 5-8% and NO_x emission increased by 11-22% which was due to presence of unsaturated fatty acid. It was observed that B20 fuel gave the better performance as compared to other blends.

Bawane et al.[19] the performance of engine was tested using blends of undi biodiesel with diesel. The blends prepared were U00, U25, U50, and U75. The injection time was varied from 27˚ BTDC to 31˚ BTDC with the increment of 2 degree an engine load from 0.75kW to 3kW with the increment of 0.75kW. The compression ratio 16.5 was kept constant. It was concluded that best suited blend was U25 which could be used without any modification in engine. The best suitable compression ratio to used blend U25 was 16.5:1. The engine gives better performance at an injection pressure of 200bar. The best suitable value of injection timing for the blend U25 was 29˚ BTDC. The BSFC for blend U25 was higher as compared to diesel which was due to lower heating value of biodiesel and the brake thermal efficient was lower for the biodiesel blend U25 as compared to diesel. It was observed that CO_2 emission for U25 was higher at 29˚ BTDC among the all injection timings, but for diesel highest CO_2 emission was observed at 27˚ BTDC. The lowest CO emission was at 29˚ BTDC which was due to complete combustion and thus CO_2 formation was higher and for diesel lowest CO_2 emission was observed at 27˚ BTDC. The HC emission was lower for U25 at all the injection timings and for all the loads. The NO_x was higher for diesel as compared to blend U25. For U25 the NO_x emission was higher at 29˚ BTDC and lower at 31˚ BTDC.

Ravindranath et al.[20] review had been made on the performance and emission characteristics of VCR diesel using biofuel. It was observed that higher compression ratio was required because it permitted an engine to extract more mechanical energy from a given mass of air-fuel blend. The author detected by reviewing that as the compression ratio increased the BSFC decreased by 7.75%, brake thermal efficiency increased by 8.49% and brake power also increased by 1.34% using biodiesel blends. The emission like CO and HC were also reduced using biodiesel blends.

Sharma et al.[21] analysis had been made on the performance and emission characteristics of VCR diesel engine using B40 and B80 jatropha biodiesel and preheated jatropha biodiesel. Jatropha was designated as biodiesel because it may well harvest in any kind of land either it is low rainfall zone or the heavy rain fall zone. In the experimental arrangement two fuel filter were provided so that when one filter was stopped, supply of fuel could be switched over additional filter. The results observed were that brake power showed all most analogous trend for all the fuel but a slight higher for the diesel which was due to higher calorific value of diesel. The brake specific fuel consumption for the biodiesel blend was higher which was due to the higher density of biodiesel blends. The brake thermal efficiency was higher for the preheated jatropha biodiesel as compared to the biodiesel blends, but it was less than that of diesel. The Exhaust Gas Temperature for the blends and preheated jatropha biodiesel founded to be higher as correlated to diesel. The CO, CO_2 and HC emission for the biodiesel blends and preheated jatropha was lower as compared to diesel fuel which was due to biodiesel holds less carbon atoms. The O_2 emission for the blends of biodiesel was higher than that of diesel because biodiesel was oxygen rich fuel, it contains oxygen 11% by weight.

Sivalakshami et al.[22] performed to find out the optimum compression ratio for a VCR engine using Methyl Ester of Pongamia Pinnata. The performance and emission characteristics had been analyzed and compared with diesel. The experiment had been carried out in a VCR, fully automated single cylinder, four stroke, and direct injection diesel engine. The engine was operated at speed of 1500 r.p.m. with variable C.R 14.1 to 20.6 and at different loads. The method used for the preparation of oil was transesterification. The oil was chemically reacted with alcohol in the presence of catalyst. The results observed were that brake thermal efficiency increased with increase in C.R from 14.1:1 to 18.1:1 at maximum load. The brake specific fuel consumption for MEPPSO was decreased from 0.53 to 0.46kg/kWh with increase in C.R from 14.5 to 18.1. The CO, HC and smoke emission were founded to be decreased for MEPPSO. The NO_x for MEPPSO founded to be higher as compared diesel.

Mohod et al.[23] waste cooking oil ethyl ester was used as fuel in the four stroke, single cylinder VCR type diesel engine. The engine performance was analyzed with different blends of biodiesel and was compared with diesel. The blends prepared were B0, B5, B10 and B20. The results observed were that the brake power increases as the load increases for all the blends of biodiesel. The fuel consumption was higher for all the biodiesel blends which was due to higher density of biodiesel. The BSFC for the lower blend i.e B10 was lower than that of diesel, but BSFC for the higher blend i.e in case of B20 was higher than that of diesel. The brake thermal efficiency founded to be higher for B10 which might be due to additional lubricity provided by the biodiesel. The EGT increased as percentage of biodiesel blends increased in the mixture which was due to better combustion. The trend for the NO_x emission was similar for the lesser loads and it was higher at full load. The NO_x emission increased as the biodiesel blends increased in the mixture.

Kumar et al.[24] the performance of the diesel engine had been investigated with diesel, ethanol and vegetable oil blends. The engine was ran with different compression ratio of 17, 17.5 and 18. The different blends prepared were D100E0V0, D90E5V5, D85E10V5, and D80E10V10. It was observed during the experimentation that the performance was enhanced at compression ratio of 17 and 18. The engine gave better performance withD90E5V5. The mechanical efficiency and brake thermal efficiency were increased. The specific fuel consumption was reduced to 0.08kg/kWh at a torque of 0.38N-m.

Shavi et al.[25] the performance of VCR engine ran with diesel and different blends of honge oil was investigated. The objective of the research was to investigate the properties of biodiesel as well as blends of biodiesel with pure diesel. The testing had been performed with different compression ratio. The different blends prepared were D100, B20D80 and B40D60. The engine was ran at 1500 r.p.m with varying loading conditions. The brake specific fuel consumption for the diesel was less which was due to higher calorific value of diesel than the biodiesel. It was concluded that increasing compression ratio upto definite limits increase brake thermal efficiency, decreases smoke-CO emissions and BSFC. Thus it was concluded that VCR show comparable trend for the diesel, blend of diesel and biodiesel.

Chaudhri et al.[26] the performance and emission characteristics of C.I engine using neem biodiesel had been investigated. The test had been performed with the different blends. The BSEC for diesel and B50 fuels are 10.12 MJ/kWh and 10.33 MJ/kWh respectively. The CO emission with $B50X_{1,}$ $B50X_2$ and $B50X_3$ fuels with different additives are lower by 7%, 6% and 6.6% respectively compared to diesel fuel. The HC emission were decreased by 17%, 17% and 17.3% for $B50X_{1,}$ $B50X_2$ $B50X_3$ fuels respectively compared to diesel fuel at no load. The brake thermal efficiency with B50 fuel was also higher.

prabhu et al.[27] combustion, performance and emission characteristics of diesel engine with neem oil methyl ester and its diesel blends were analyzed in a four stroke diesel engine. It was concluded that BTE and BSFC for 20, 40 and 100% NOME are lower than that of diesel fuel at full load. In the emission characteristics, it was observed that there was 20% increase in NO_x emission for 20, 40 and 100% NOME at full load as compared to diesel fuel. The CO emission were lowered by 23, 30 and 40% for 20, 40 and 100% NOME at full load as compared to diesel fuel. The HC emission were increased using 20, 40 and 100% NOME as compared to diesel. The smoke emissions were decreased by 25 and 33%. Thus it can be concluded that 20% NOME blend was better compared to 100% NOME.

Sivalakshmi et al.[28] experimental study had been made on the performance and emission characteristics of a diesel engine fuelled by neem oil blended with alcohol. During experiment it was observed that alcohol upto 20% were blended with neem oil by manual mixing at room temperature. The B.T.E was improved with the use of neem oil-alcohol blend as compared to those of neat neem oil. The smoke intensity was reduced with the use of neem oil-alcohol blends with respect to that of neat neem oil. The No_x emission was also slightly reduced. The CO & HC were also lower with neem oil–alcohol blends as compared to neat neem oil.

sivalakshmi et al.[29] experimental investigation had been made on a diesel engine fuelled with neem oil and its methyl ester. The result obtained were, the peak cylinder pressure for NOME is higher as compared to diesel and neat neem oil. The BTE and BSFC for neat neem oil & NOME was lower than that of diesel at all loads. There was 37% reduction in No_x emission for neat neem oil & 19% reduction for NOME at full load. There was an increase in CO emission for neat neem oil & NOME by 40% & 20% at full loads. The HC emission were increased by 54% in case neat neem oil and 24% in case of NOME. The smoke emission for neat neem oil and NOME were higher than that of diesel by 46.8% & 16% at full load. Thus it was concluded that performance combustion and emission characteristics of NOME are better as compared to neat neem oil.

D.S et al.[30] experiment was performed to study the use of neem methyl ester in CI engine. The result obtained were the fuel consumption of the engine was the higher using NOME. The BTE of neem blends were lower as compare to diesel and it was observed that combustion characteristics of methyl ester was also poor which might be due to high viscosity and poor volatility. The HC and CO emission were reduced for all the blends, as injection pressure was increased. The emission decreased due to complete combustion of fuels. Knocking was not observed for biodiesel blends.

Sharma et al.[31] various aspects of engine performance using neem-diesel blend B20 as fuel were studied through extensive experimentation at different injection pressure on a single cylinder direct injection diesel engine. It was observed that BTE at higher load was slightly low as compared to that with pure diesel. The BSFC was also higher as compared to pure diesel. The minimum NO_x concentration was emitted at injection pressure of 1.57kN/cm^2 for both the fuels. The CO emission for neem-diesel blend were lower as compared to pure diesel for all injection pressure and HC emission were also reduced for neem-diesel blends.

kumar et al.[32] experimental investigation was carried out on Di Ci engine with biodiesel blends of cotton seed methyl ester and neem oil methyl ester. The engine used for the experiment was single cylinder, four stroke water cooled, and constant speed diesel engine. The different blends were prepared with different ratio. It was observed that the cotton seed methyl ester gives better performance as compared to neem methyl ester. The BTE of cotton seed methyl ester- C20 increased than pure diesel. The smoke and emissions for the blends of cotton seed oil methyl ester and neem oil methyl ester were less as compared to pure diesel. The results was better for the C20 blend.

Radha et al.[33] the experimental investigation had been made on a single cylinder, direct injection, and water cooled diesel engine using straight thumba oil, neem oil and 20% biodiesel blend of thumba oil. It was observed that 20% biodiesel has same performance as that of pure diesel. The CO emission was reduced by 2% in case of 20% biodiesel. The NO_x emission was reduced by 6% and the smoke density was reduced by 3% in case of 20% biodiesel. The BSFC increased by 1% for the 20% biodiesel blend, 3% in case of straight thumba oil.

Shrigiri et al.[34] the performance, emission and combustion characteristics of a diesel engine were investigated using cotton seed and neem kernel oil methyl ester in a single cylinder, four stroke, and direct injection LHR engine. The results founded were that the BTE was lowered by 5.9% and 7.07% at peak load and BSFC was higher by 28.57% and 10.71% for cotton seed oil methyl ester and neem kernel oil methyl ester as compared with conventional diesel fuel. The HC emission for CSOME and NKOME were increased by 3.52% and 2.41% as compared diesel fuel. The oxides of nitrogen for CSOME and NKOME were 21.67% and 11.69% which was higher than that of diesel fuel. The smoke level for CSOME and NKOME was increased by 2.24% and 4.32% higher than the diesel fuel.

Manikanta et al.[35] the experimental investigation had been made on the performance analysis of VCR engine using diesel at different loads. It was observed that with respect to brake power the optimum compression ratio was 17. But with respect to brake thermal efficiency and specific fuel consumption the compression ratio was founded 18. Therefore the optimum compression ratio for the diesel engine was 17.5.

Amit pal[36] the engine performance and exhaust emission of 39kW multicylinder engine were investigated using jatropha oil as biodiesel. The blends prepared were B10 and B30 and the results was compared with petroleum diesel fuel. The engine consist of four cylinder and it was four stroke diesel engine connected to eddy current type dynamometer for loading. It was observed that at low speed more torque is obtained for biodiesel. The torque was 30% more than the diesel oil for B30 blend at 1500r.p.m. The maximum brake power observed was 35kW at 1500r.p.m for the B10 blend. The brake thermal efficiency was better for higher blends. The smoke opacity was reduced upto 35% for biodiesel.

Ragit et al.[37] single cylinder-4 stroke CI engine was operated on the esters of hemp oil and neem oil. The results obtained were compared with baseline data of mineral diesel. There was 45.07% reduction in NO_x , 84.42% reduction in HC, 28.35% in smoke and BTE increased by 0.19% at full load for hemp biodiesel and 6.06% reduction in NO_x, 2.59% reduction in HC, 18.39% reduction in smoke at full load for neem biodiesel. The HEMP methyl ester shows excellent kinematic viscosity as compared to NEEM methyl ester and diesel fuel. It was concluded that methyl ester of hemp oil could be used as alternative fuel without any engine modification.

Nabi et al.[38] the exhaust emission with neat diesel fuel & diesel-biodiesel blends had been investigated. The biodiesel was prepared from non-edible neem oil. The methyl ester of non-edible neem oil was prepared with lye catalyst and methanol. The several injection timings set for the experiment was 5˚CBTDC, 0˚CBTDC, 5˚CATDC, 10˚ATDC and 13˚CATDC. The diesel-NOME blends shows higher NO_x for all injection timings. The EGR technique was used for the reduction of NO_x emission with diesel-NOME blend. The diesel exhaust emission including smoke and CO were reduced while NO_x emission was increased with diesel-NOME blends which might be due to presence of oxygen content in the fuel.

Mathur et al.[39] the effect of different compression ratio on engine performance and emission behaviour of diesel engine fuelled with diesel fuel was studied and optimum C.R was determined. The test was conducted at 203 bar injector needle lift pressure and injection timing of 23˚C BTDC at 1500 rev/min. for entire load range. The Compression ratio was varied from 15 to 19. The result observed were the thermal efficiency increases with increase in load. The maximum BTE was obtained at a C.R of 17, due to better combustion and intermixing of fuel. The least fuel consumption was obtained at C.R of 17. The EGT was increased with increase in load and C.R. The smoke opacity at C.R of 17 was lowest, which was due to better combustion at optimum C.R. The CO emissions was also lower at C.R 17. Thus the optimum C.R founded was 17.

BM et al.[40] the experimental investigation had been carried out at different injection pressures using neem seed oil as biodiesel. The BTE was increased with increase in load for all the injection pressures. The BTE was maximum at 250 bar for the B30, which was 27.78% at higher loads. This was due to fine spray formed during injection and improved atomization. The BSFC for the neem biodiesel was higher than the diesel which might be due to calorific value of biodiesel. The BSFC was decreased with increase in I.P upto 250 bar. The CO emission was lowest at 250 bar for B20 which was 0.04%. The CO_2 emission was lowest for B20 and B30. The HC emission for neem biodiesel at full load was 25 to 30% lower than diesel. The NO_x was increased with increase in brake power. It was higher for B10 and comparable with diesel for B20.

Kumar L et al.[41] the experimental work was carried out to evaluate the effect of neem oil biodiesel/diesel blends on the performance and emission characteristics of an indirect injection, multi cylinder, 4-strokes and water cooled compression ignition engine. It was observed that as B.P increases the BTE increases for all fuels. It was because as load on engine increases the cylinder temperature increases which result into more complete combustion of fuel. The maximum BTE for the B20 fuel was 30.50% at B.P of 9.34KW. The minimum BSEC for the diesel, B10, B20 and B30 fuels were 12.04 MJ/KW-h, 12.87 MJ/KW-h, 11.80 MJ/KW-h and 12.65 MJ/KW-h respectively. The EGT was increased with increase in B.P. the maximum EGT observed was 305.68°C using diesel fuel at B.P of 9.34KW. The CO emission was lowest for the B20 fuel at B.P 4.3KW. The NO_x emission measured for B10, B20 and B30 fuels were 302PPM, 316PPM, 301PPM and 336PPM. The highest HC emission for diesel, B10, B20 and B30 fuel were 0.05%/vol, 0.04%/vol, 0.03%/vol and 0.03%/vol respectively at no load.

Dharmadhikari et al.[42] the performance and emission of C.I engine using blends of biodiesel and diesel at different at injection pressures were analyzed. It was observed the BTE of diesel and blends of biodiesel were increased with increasing load but tend to decrease with further increase in load. At full load the BTE of B20 KOME was 5% less than that of diesel. The BSFC for the blends was higher than that of diesel. The EGT was founded to be increased with increasing concentration of biodiesel in the blends. The NO_x was 5 to 10% higher for the biodiesel blends as compared to diesel. The HC emission observed were also lower for the biodiesel, which might be due to higher cetane number of biodiesel. The optimum I.P observed was 200 bar which results of air converted more heat in to the useful work resulting in higher BTE.

channapattana et al.[43] the performance and emission characteristics of compression ignition direct injection VCR engine had been investigated using hone oil methyl ester as biodiesel. The various blends prepared were B20, B40, B60, B80 and pure diesel. The test was performed with varying load. The BSFC for the B20 blend was comparable with diesel and it was maximum for B100. The BTE of B20 was almost comparable to diesel at lower load but decreases with increase in load. The average reduction of BTE for B20 was 3% and 11% for

B100. The EGT was increased by 2% for the B20 and 5% for the B100. It was observed that as the load increased for constant speed, the CO_2 emission also increase. The CO_2 was increased by 3% for B20 and 14% for B100 as compared to diesel. It was observed that CO emission decreased by 10% for B20 and 54% for B100. The HC emission also decreases. The NO_x was increased for the biodiesel. It was increased by 13% for B20.

Kumar et al.[44] the performance and emission of DI diesel engine using biodiesel B50 was analyzed at different compression ratios of 14, 16 and 18. The biodiesel prepared was jatropha biodiesel. The brake power was higher for the B50 fuel. The maximum BTE was observed at compression ratio of 18, which was due to better intermixing of fuel. It was observed that BSFC was more for the B50 as compared to diesel. The HC emission were lower at compression ratio of 18 for the B50, which was due to higher cetane number of biodiesel. The CO emission was decreased as the compression ratio increases. The O_2 emission was higher for the B50, the reason behind that was biodiesel contains nearly 10% inbuilt oxygen. Thus it was concluded the B50 could be used as fuel in the engine at higher compression ratio.

Dawody et al.[45] the experimental investigation had been made on the single cylinder, Di-diesel engine fuelled by soybean methyl ester. The experiment was performed at different compression ratios of 15, 16, 17.5 and 19. It was observed that the heat release rate increased with increase in compression ratio. There was a slight reduction in BTE for the B20 as compared to diesel. It was observed that HC emission decreased as the percentage of SME increases, which was due to complete combustion. The CO emission were also decreased for the biodiesel. The NO_x emission was increased with increase in compression ratio and concentration SME in the blend. The smoke opacity was lower for all the blends as compared to the diesel. It was concluded that B20% has better results as compared to others blends.

4 SCOPE OF THE STUDY

Biodiesel produced from the non-edible plants of argemone mexicana and mahua are reported to be a possible choices for countries like India, where cost and consumption of the edible oil is very large. The selection of economical and existing feedstock for production of biodiesel inside the country is major concern. Before presenting the biodiesel in our country, the following points have to be considered:

- The performance, combustion and emission parameters of dual biodiesel blends in a single cylinder, four stroke diesel engine were evaluated with variation of load. The effect of other parameters like compression ratio vary, speed and injection timing on the performance of the engine may be study.
- The NO_x emission was found to be increased for the dual biodiesel blend. Therefore the further study can be done to reduce the NO_x emission.
- The long term stability of the biodiesel blends can be studied.
- The long term run of the engine and wear analysis can be studied.
- The further study can be done to enhance the performance of the engine using various nanoparticles as additive in the biodiesel.

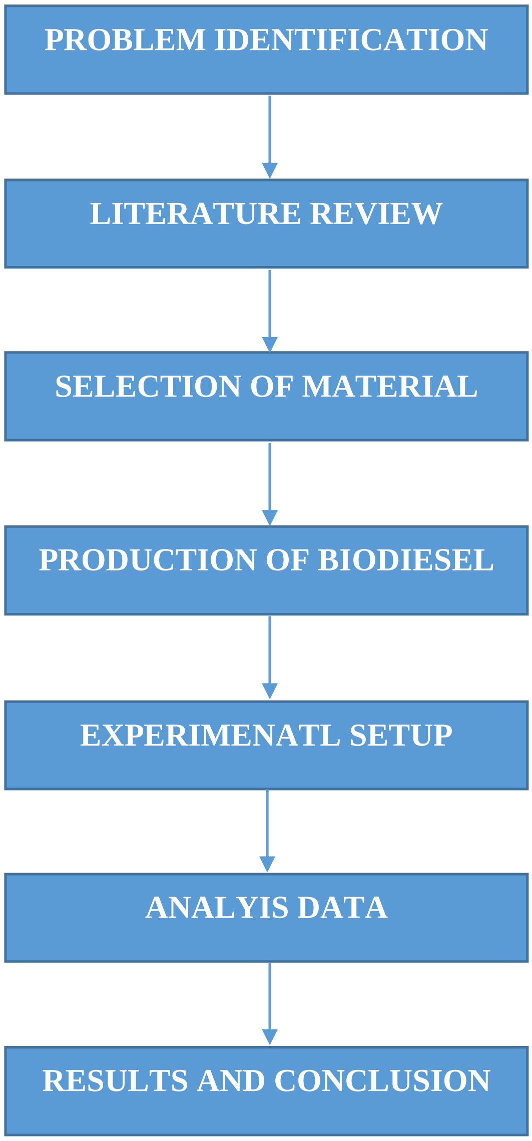
5 OBJECTIVE OF THE STUDY

In present work, the two non-edible plants Mexicana argemone and mahua are used for the production of biodiesel. A number of researchers have worked with various biodiesel in various diesel engines. However, Based on the literature author concluded that no research was studied yet on the combination of Mexicana argemone and mahua biodiesel blend as a fuel for the diesel engine. The aim of the present study to analyse the performance, combustion and emission characteristics using dual biodiesel blends of AMME and MME.

- Production of biodiesel from the crude Mexicana argemone and mahua oil.
- Experimentation with biodiesel blends of Mexicana argemone and mahua.
- To analyse the performance parameters like Brake thermal efficiency, brake power and specific fuel consumption with variation of load.
- To observe the combustion characteristics like net heat release rate and cylinder pressure.
- To observe emission characteristics like CO, HC, NO_x, CO_2 and O_2.

6 RESEARCH METHODOLOGY

In research methodology chapter, we mainly focus over the method, equipment which were the requirement of thesis or problem. For example in this thesis, I have used transesterification method for the production of biodiesel graphs. The results were obtained for the blends of biodiesel and the obtained results were compared with the standard diesel..



6.1 Selection of material

The mexicana argemone and mahua non-edible were selected for this study.

6.1.1 Argemone mexicana

In this study argemone mexicana is selected as non-edible source of production of biodiesel**.** It belongs to poppy family. The whole species belongs to the mexicana prickly poppy. it is generally found in most parts of the Mexico. It is known as satyanashi in India. It can be found on the road side, fields and on the waste land. The flowers of the plants are yellow in colour. The height of the plant is upto 0.12m. The seeds of plants are black in colour. Argemone mexicana plants does not require a large rainfall. It can be grow in poor sand and low rainfall area. It has low free fatty acid. Therefore biodiesel can be produced in a single step transesterification. The plants like jatropha, karnaja, neem and tobacco are having high free fatty acid. Therefore, cost of the biodiesel production is increase. This is a major drawback of the most of non-edible plants.

Figure 1: Argemone mexicana plant

The seeds of the plants are of very small size. The seeds are of black colour. The oil yield in the seeds of mexicana argemone 35 to 40%. The seeds were purchased form the market of Ludhiana.

Figure 2: Argemone mexicana seeds

The table below shows the fatty acid composition of the mexicana argemone plant. The fatty acid is carboxylic acid with a long aliphatic chain. The may be either saturated or the unsaturated. The most of the plants have carbon atom number varies from 4 to 22. The fatty acid generally derived from the triglycerides.

Table 1: Fatty Acid composition Argemone mexicana

Fatty acid composition (%)	Carbon number	Argemone oil
Oleic acid	18:1	40.0
Linoleic acid	18:2	36.6
Palmitic acid	16:0	14.7
Stearic acid	18:0	6.75
Palmitoleic acid	16:1	1.3
Arachidic acid	18:3	0.3
Behenic acid	20:0	0.2
Myristic acid	22:0	0.1
Linolenic acid	14:0	0.3

6.1.2 Mahua

Mahua is also known as Madhuca indica. It is a non-edible plant having large production capacity. It is arid land and forest borne plant. This tree is mostly found in India. The oil yield in the seeds of mahua plant is from 34 to 37%. The fresh oil is yellow in colour, while the commercial oil is greenish yellow. It is used for many purposes. Many researchers used this oil as alternative oil in their studies.

Figure 3: Mahua plant

Figure 4: Mahua seeds

Table 2 Fatty Acid Composition of Mahua plant

Fatty acid name	**Carbon number**	**Composition %**
Oleic acid	18:1	53
Linoleic acid	18:2	3
Palmitic acid	16:0	23
Stearic acid	18:0	19
Palmitoleic acid	-	-
Arachidic acid	20:0	0.40
Behenic acid	22:0	0.15
Linolenic acid	18:3	10

6.2 Production of Biodiesel

In this study two non-edible plants were selected for the production of biodiesel. The process for the production of biodiesel is discussed below:

6.2.1 Transesterification

Plant oils and animal fats are comprised of a family of chemicals called triglycerides. Triacylglycerides (TAGs) are esters derived from three fatty acids and a glycerol. Glycerol is a polyhydric alcohol that has three hydrophilic alcoholic hydroxyl groups. Fatty acids are carboxylic acids with long hydrocarbon chains. The hydrocarbon chain length may vary from 10- 30 carbons. In the structure of TAGs, three fatty acids R'-COOH, R''-COOH and R'''-COOH are linked chemically to the glycerol. Under certain conditions, fatty acids in glycerides may dissociate and become free fatty acids (FFAs). The general structure of a TAGN is shown below, where R_1, R_2, and R_3 are alkyl chains

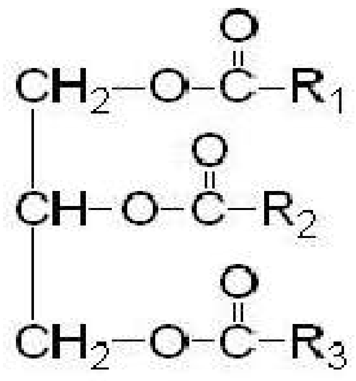


Figure 5: General structure of tag

Transesterification is the reaction between an alcohol and an ester which produces a new alcohol and a new ester. In transesterification, a simple alcohol such as methanol is used with a catalyst. Figure shows the transesterification reaction for a generalized triglyceride with methanol to form fatty acid methyl esters (FAMEs), more commonly known as biodiesel. Chemically, transesterification involves taking a triglyceride molecule or a complex fatty acid, neutralizing the free fatty acids, removing the glycerol, and creating an alcohol ester. After the reaction, FAMEs rise to the top of the mixing tank while the glycerol and catalyst settle at the bottom. After some time, the glycerol and catalyst are drawn off the bottom, leaving FAMEs in the tank. In most cases, the FAMEs need to be washed with water to remove any remaining traces of alcohol, catalyst, and glycerol.

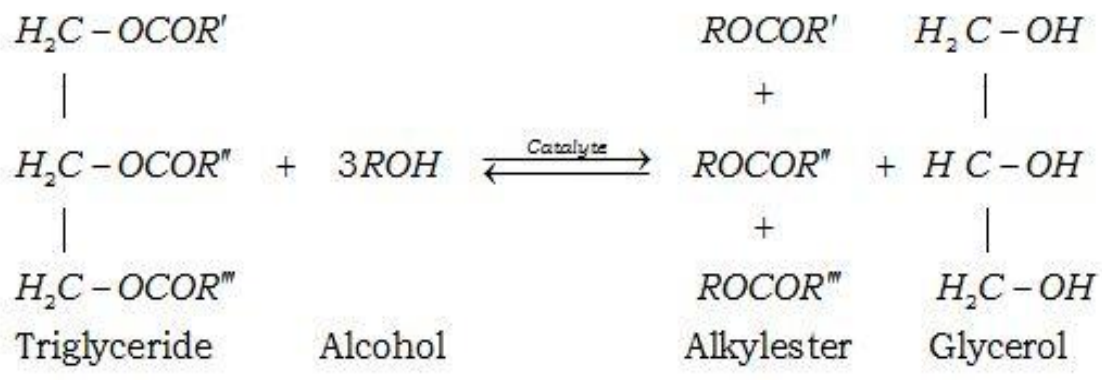


Figure 6: Generalized transesterification reaction

It is important to understand the different parameters involved in the transesterification reaction. The alcohol used in the process is usually ethanol or methanol in industry. Methanol is usually preferred because it is cheaper and has a tendency to produce a more predictable reaction. On the down side, methanol dissolves rubber, and must be handled with extreme caution. Ethanol is generally more expensive and may not always produce a consistent, stable reaction. An advantage of ethanol is that it is less toxic. Another important parameter in the transesterification process is the catalyst that is used to initiate the reaction.

6.3 Experimental setup

6.3.1 Biodiesel setup

The transesterification reaction was carried out in biodiesel redley reactor. It was equipped with magnetic stirrer, thermometer and reflux condenser. It consists of heater and external jackets to maintain the temperature constant throughout the process. The supplementary impeller was provided for the proper mixing. The condenser was used to condense the methanol escaping out from the reactor.

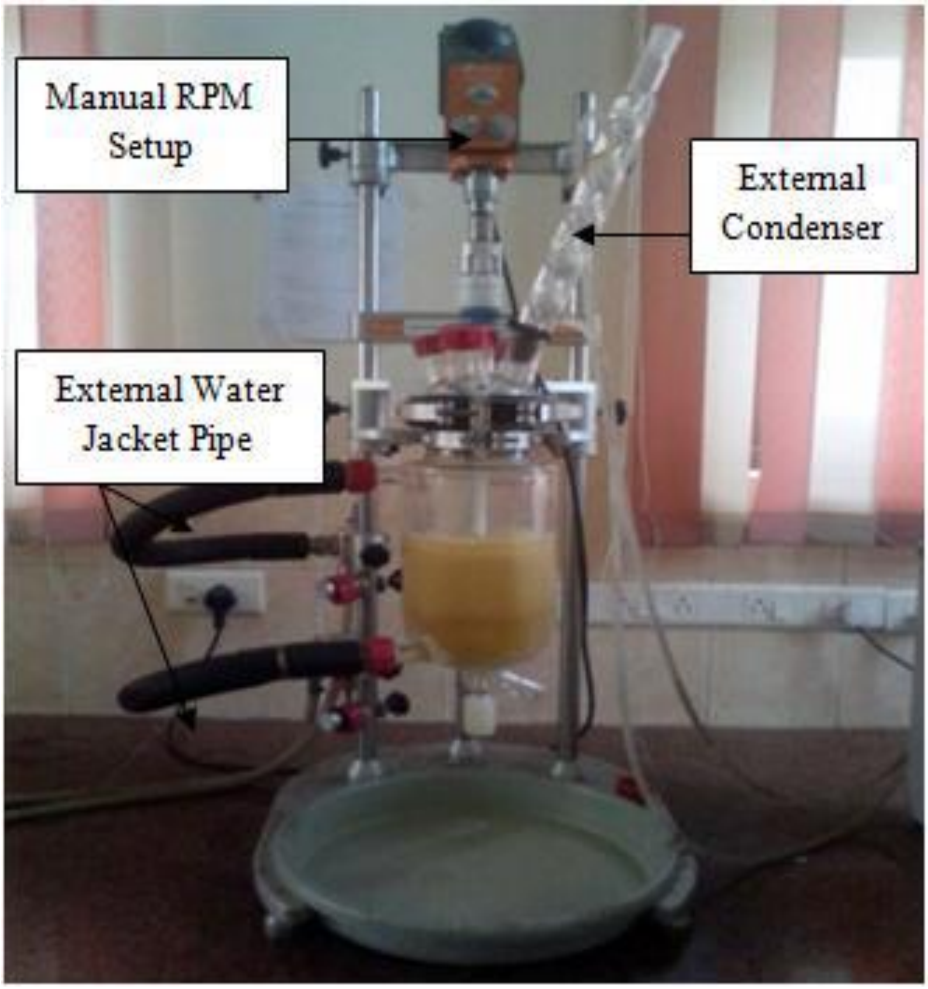


Figure 7: Biodiesel setup

6.3.2 Engine setup

After the production of biodiesel blends were prepared and were fuelled in engine. The engine used for the experiment was single cylinder, 4 stroke, Di Ci and water cooled engine. The eddy current type dynamometer was provided for the load. The engine was running at a constant speed of 1500rpm. The experiment was performed using diesel and dual biodiesel blends of biodiesel. The specification of the engine are given below:

Table 3: Specification of the engine

Engine	Kirloskar engine setup
Cylinder	Single cylinder
Strokes	4 strokes
Power rating	3.5KW
Engine Speed	1500RPM
Cylinder bore	87.50mm
Stroke length	110mm
Connecting rod length	234mm
Orifice diameter	20mm
Dynamometer arm length	185mm
Cooled type	Water cooled
Compression ratio	17.5
Dynamometer	Type eddy current, water cooled
Load indicator	Digital, supply 230AC
Software	“EnginesoftLV”

6.4 Process for production of biodiesel

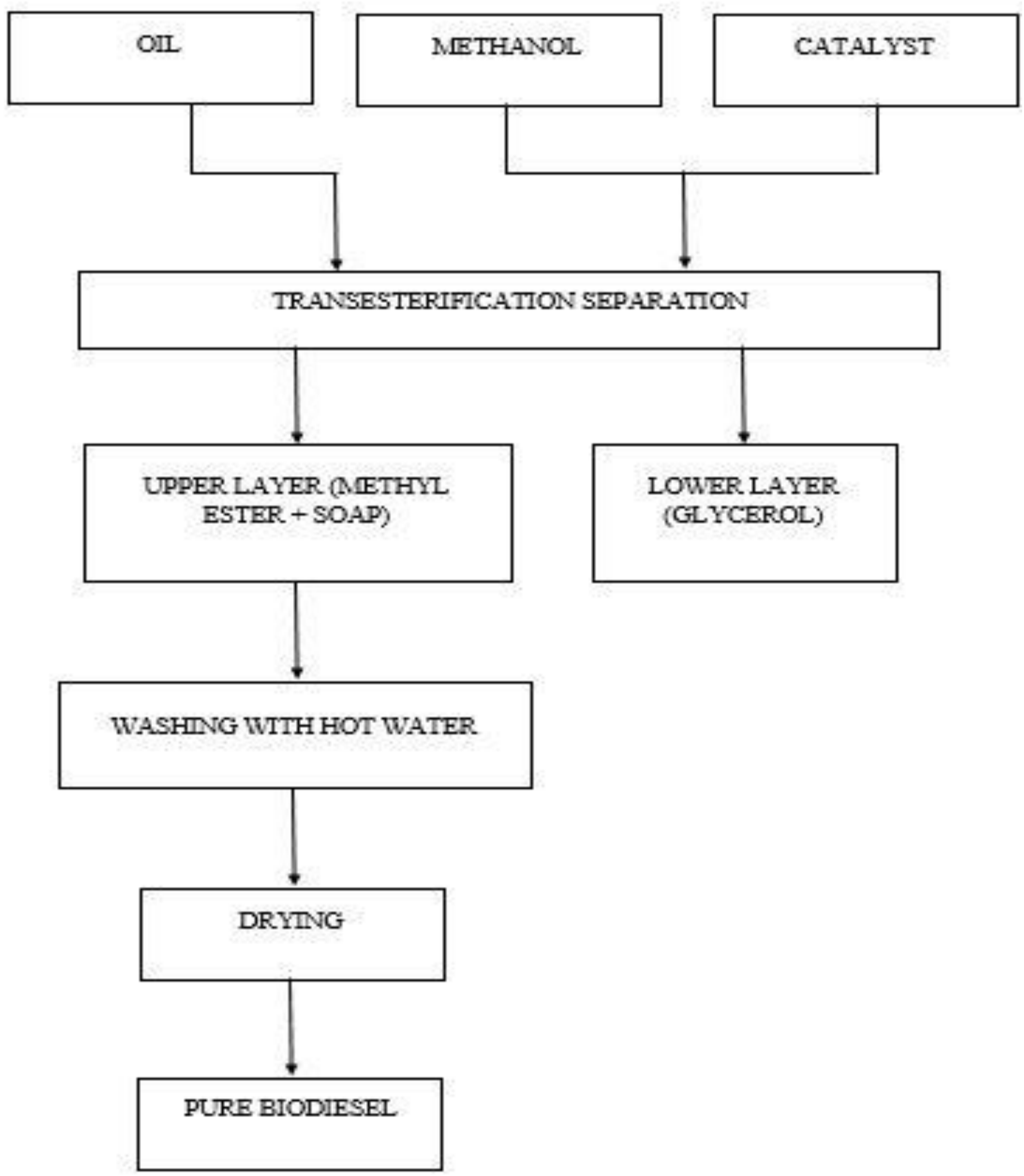


Figure 8 Flow chart for production of biodiesel

7 EXPERIMENTAL WORK

In this experiment firstly biodiesel is produced from the non-edible oils of argemone mexicana and mahua. After the production of biodiesel blends of biodiesel with diesel were prepared then fuelled in a diesel engine. The detailed experimental work is discussed below:

7.1 Production Of Biodiesel

As the viscosity of argemone oil and mahua oil are very high as compared to diesel, therefore, they could not directly use in the diesel engine as they can lead to many engine life problems Therefore, it is necessary approach to reduce the viscosity of the oil so that we can use them in the unmodified engine. There are various methods for the reduction of viscosity. The method used in this experiment is transesterification. . In this process the triglyceride or fats of the oil reacts with methanol or ethanol in the presence of catalyst. In present study the argemone oil reacts with methanol in the presence of Na (metal) as a catalyst. The following steps were used for the transesterification process.

- Methanol and Na were mixed in measured quantity.
- Raw argemone oil was heated at a constant temperature of 70˚C.
- Methanol and Na were mixed with argemone oil at constant temperature of 70˚C.
- Argemone methyl ester and glycerine were separated out after interval of 24hours.
- The argemone methyl ester was washed with the water for 10 to 12 times.

The argemone seeds were purchased from the market and then processed to extract the oil from them. The seeds were black in colour. The oil yield in seeds was 35%. The colour of the oil was pale yellow. Table below presents the proportion of methanol, catalyst and the oil used for the production of biodiesel from the Argemone mexicana oil.

Table 4: Composition of Argemone Biodiesel

S.No	Chemicals	Proportion
1	Argemone oil	1500ml
2	Catalyst Na (metal)	10gm
3	Methanol	375ml

Table 5: Properties of Argemone Mexicana

PROPERTY	UNIT	ARGEMONE OIL	ARGEMONE BIODIESEL	DIESEL
Density at 15°C	Kg/m^3	932	886	850
Viscosity at 40°C	mm^2/s	35	5.07	2.60
Flash point	°C	220	130	68
Pour point	°C	-	-	-20
Water content	%	0.7	0.2	0.02
Ash content	%			0.01
Carbon residue	%	0.61	0.02	0.17
Acid value	Mg KOH/g	4.7	0.34	0.35
Calorific value	MJ/kg	36.72	39.41	42

The same method is used for the production of mahua methyl ester. The mahua seeds contain 50-55% of oil. It was greenish yellow in colour. The catalyst used for the production of mahua methyl ester was sodium hydroxide (NaOH). Table below presents the proportion of methanol, catalyst and the oil used for the production of biodiesel

- Methanol and Na were mixed in measured quantity.
- Raw mahua oil was heated at a constant temperature of 70°C.
- Methanol and Na were mixed with argemone oil at constant temperature of 70°C.
- Mahua methyl ester and glycerine were separated out after interval of 24hours.
- The mahua methyl ester was washed with the water for 10 to 12 times.
- Methyl ester was collected in a flask.

Table 6: Composition of Mahua Biodiesel

S.No	Chemicals	Proportion
1	Mahua oil	1500ml
2	Catalyst NaOH	10gm
3	Methanol	375ml

Table 7: Properties of mahua oil

PROPERTY	UNIT	MAHUA OIL	MAHUA BIODIESEL	DIESEL
Density at 15˚C	Kg/m^3	960	880	850
Viscosity at 40˚C	mm^2/s	24.58	3.98	2.60
Flash point	˚C	232	208	68
Water content	%	1.6	0.04	0.02
Carbon residue	%	3.70	0.20	0.17
Acid value	Mg KOH/g	38	0.41	0.35
Calorific value	MJ/kg	36	37	42

7.2 Separation

After the stirring the mixture was allowed to settle down for the two days. The two layers were formed, upper is biodiesel and the lower layer is glycerine. The glycerine is much denser than the Biodiesel. The glycerine can be further used in for various purposes like in medicines and cosmetics creams. The biodiesel was separated in a separating funnel and the glycerine was separated out. After separating the glycerine from the methyl ester, the product was washed with hot water from 10 to 12 times to remove the soap from it. The product formed was pure biodiesel. The biodiesel obtained was 1 litre. After separating out the biodiesel was allowed for the drying. The blends were prepared on the volumetric basis, simply by mixing of biodiesel and diesel

.

Figure 9: Sepration

7.3 Blend Preparation

After the preparation of biodiesel the blends are prepared. The blends were prepared by simply the mixing of diesel and biodiesel. The diesel was purchased from local the petrol pump. The four blends prepared were B10, B20, B30 and B40.

The below sample is pure diesel. It was purchased from the local petrol pump.

Figure 10: Pure Diesel

The sample below is pure biodiesel that is B100. It was produced from the argemone mexicana oil. The method used for the production was transterification method. In this process 1.5 litre of oil is heated at 70˚C. After that mixture of 375ml methanol and the 10gm sodium metal is poured into the oil. The oil was heated continuously at a constant temperature of 70˚C. The reaction was continuously stirred with blender for 2 hours. Then the mixture is allowed to settle down for one day. The two layers were formed the upper layer is biodiesel and the lower layer is glycerol. The glrcerol is separated out in a separating funnel. The pure methyl ester was washed with the hot water from 8 to 10 times.

Figure 11: B100 (Argemone)

The below sample is pure biodiesel produced from the mahua oil. The process used for the production of the biodiesel was same as for the mexicana argemone oil. The catalyst used for the production of mahau biodiesel was NaOH. The 1.5 lite of oil heated at constant at constant temperatue of $70^{\circ}C$. After that mixture of 375ml methanol and the 10gm sodium hydroxide (NaOH) is poured into the oil. The reaction was continuously stirred with blender for 2 hours. The reaction was continuously stirred with blender for 2 hours. Then the mixture is allowed to settle down for one day. The two layers were formed the upper layer is biodiesel and the lower layer is glycerol. The glrcerol is separated out in a separating funnel. The pure methyl ester was washed with the hot water from 8 to 10 times.

Figure 12: B100 (Mahua)

The Sample in the below figure is B10.The sample is mixture of diesel and the biodiesel. In the mixture there is 5% mahua biodiesel , 5% mexicana argemone and 90% diesel.

Figure 13: B10

The below sample is B20 is that mixture of 10% mexicana argemone biodiesel, 10% mahua biodiesel and the 80% diesel.

Figure 14: B20

The below sample is B30 is that mixture of 15% Mexicana argemone biodiesel, 15% Mahua biodiesel and 70% diesel.

Figure 15: B30

The below sample is B40 is that mixture of 20% Mexicana argemone biodiesel, 20% Mahua biodiesel and 60% diesel

Figure 16: B40

7.4 Engine Testing

The experiment was performed on the single cylinder, four stroke, and variable loading engine. The engine was connected to the dynamometer to provide load to the engine. The engine was made to run over the various loads of 0kg, 3kg, 6kg, 9kg, 12kg and 15kg. The emission such as unburnt hydrocarbons (HC), carbon monoxide (CO), nitric oxides (NOx) were measured by the AVL exhaust gas analyser. The circulation of water was provided for the cooling of engine with the help of pump. The piezoelectric pressure transducer and a crank angle encoder was provided at the cylinder head for measuring the combustion pressure and crank angle. The cylinder pressure and the net heat release rate were observed at the full load of 15kg. The engine was first operated on diesel to obtain the standard parameters for the diesel. The test was conducted with the various blends of Mexicana argemone and mahua prepared by volume basis i.e A5M5D90 (B10), A10M10D80 (B20), A15M15D30 (B30) and A15M15D70 (B40). The performance parameters, combustion characteristics and the emission parameters were evaluated at different loads. The engine setup is shown in the figure below:

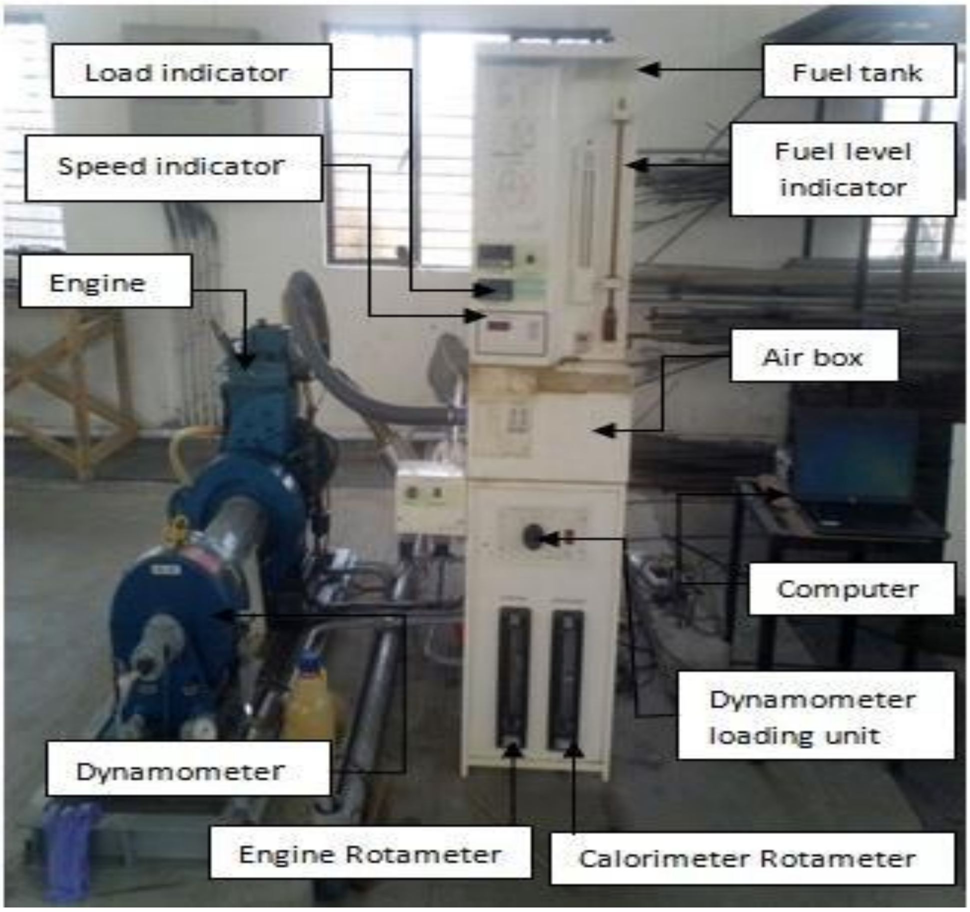


Figure 17: Testing engine setup

8 RESEULTS AND DISCUSSION

In this study the performance, combustion and emission characteristics were obtained using dual biodiesel blends of argemone mexicana and mahua. The results obtained were compared with the diesel

8.1 PERFORMANCE PARAMETERS

The performance paramters like brake power, indicated power, specific fuel consumption, brake thermal efficiency and brake mean effective pressure were observed for the dual bioidesel blends. The results obatianed were discussed below:

8.1.1 Brake power

The brake power is the total power available at the crank shaft. Figure shows the variation of brake power for the various biodiesel samples with the variation of load.. The brake power increases with increase in load for all the blends. D80AB10MB10 shows 4.39kw of brake power at full load, which was 4.30kw for the Diesel. The sample D80AB10MB10 showed higher brake power among all others biodiesel blends. This is due to fact that biodiesel having higher density than the diesel. Therefore the engine consumes more fuel for producing same brake power, which compensate the lower heating value.

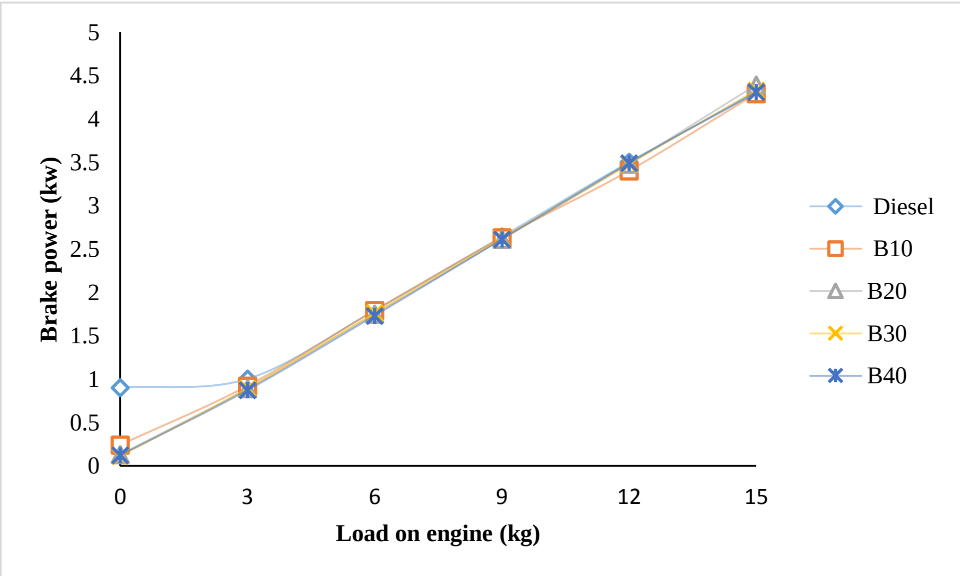


Figure 18: Variation of brake power with load

8.1.2 Indicated Power

The indicated power is the total power developed in engine cylinder. The indicated power was increases with increase in load for all the blends. The indicated power was observed highest for the B10, after that brake decreases with increase in the concentration of biodiesel in blend. The diesel shows the lowest indicated power. The reason for the highest indicated power for B10 was its better combustion characteristics due to rich oxygen content in it. As concentration of biodiesel increases in blend the density of blend increase, which results in poor combustion. All the biodiesel blends showed higher indicated power as compared to diesel.

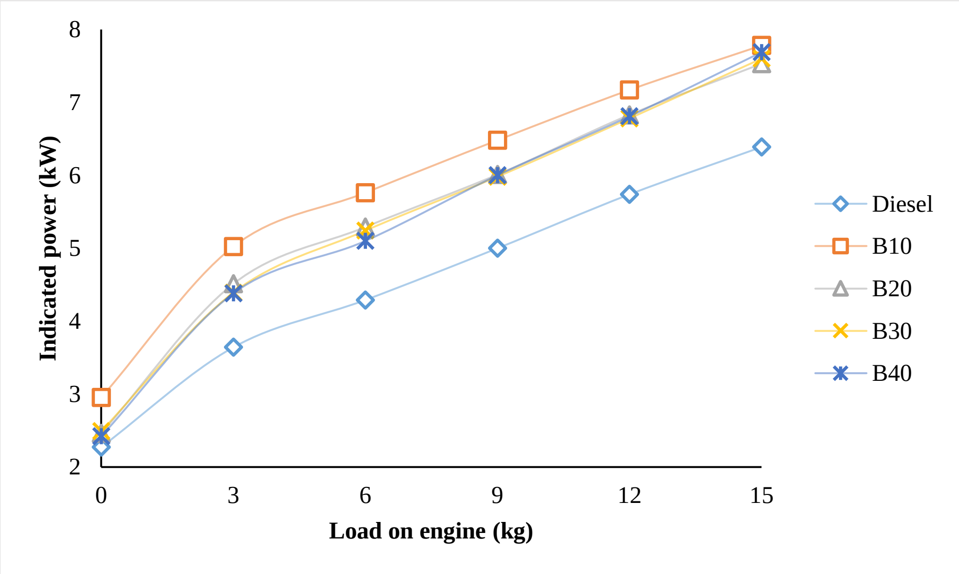


Figure 19: variation of indicated power with load

8.1.3 Specific fuel consumption

The Specific fuel consumption is mass of fuel consumption in kg by engine per unit of work done by the engine. Figure shows the variation of specific fuel consumption with respect to load. The specific fuel consumption decreases with increase in load for all the blends. The specific fuel consumption for the blends B10, B20, B30 and B40 were 0.31 kg/Wh, 0.33kg/Wh, 0.31kg/Wh, 0.31kg/Wh. The minimum specific fuel consumption was for the diesel, which was 0.26kg/Wh. The reason for the higher specific fuel consumption of the biodiesel was its higher density. As the concentration of the biodiesel increases in blend the specific fuel consumption increases for the biodiesel blends. It was due to increase in density of biodiesel blend. Therefore, the specific fuel consumption increases for the biodiesel blends with increases in percentage of biodiesel.

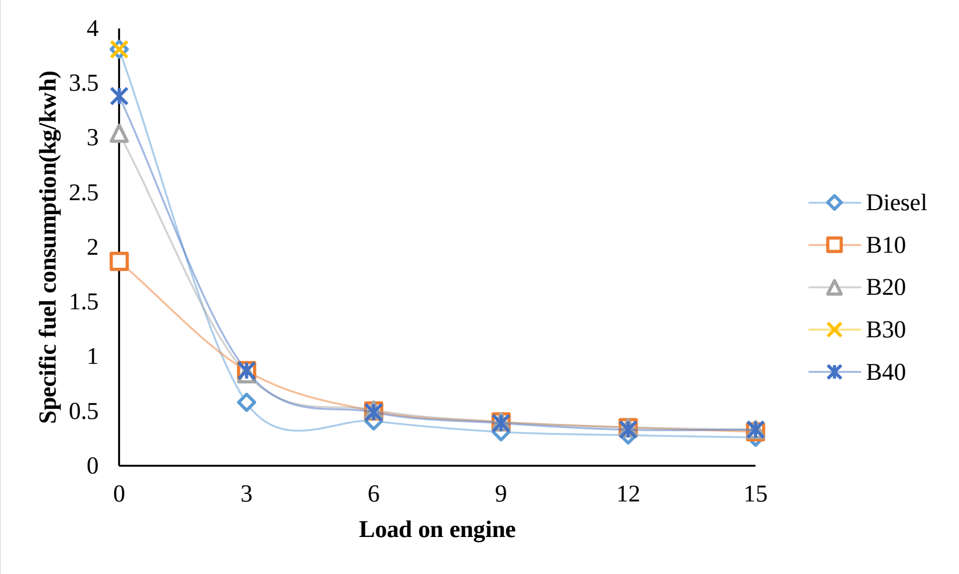


Figure 20: variation of specific fuel co with load

8.1.4 Brake thermal efficiency

The brake thermal efficiency indicates how well an engine convert chemical energy in the mechanical energy. Figure shows the variation of brake thermal efficiency with respect to load. It was observed that efficiency increases with increase in the load. This is due to increase in power developed and reduction in heat losses with increase in load. The highest brake thermal efficiency was found maximum for the diesel, which was 32.39%. The maximum brake thermal efficiency for the biodiesel blends B10, B20, B30 and B40 were 24.86%, 24.24%, 25.37% and 24.80% respectively at maximum load. All the biodiesel blends showed lower brake thermal efficiency as compared to diesel.

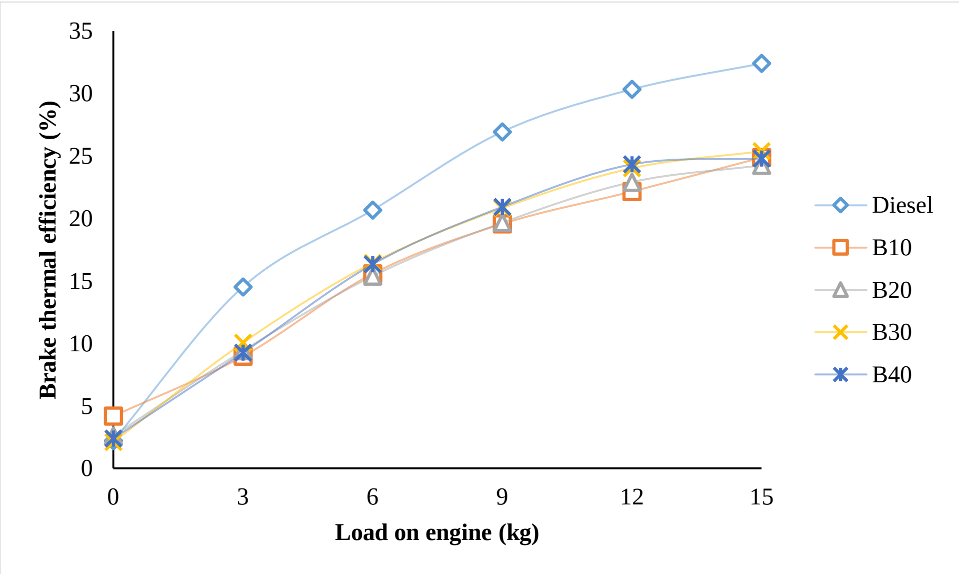


Figure 21: variation of brake thermal efficiency with load

8.1.5 Engine torque

Torque is a measure of work. Figure shows the variation the engine torque for the diesel and its blends with biodiesel with the variation of load. The maximum torque for the blends of biodiesel were, 28.42Nm, 28.73Nm, 27.25Nm and 27.44Nm for the B10, B20, B30 and B40, which was 27.19Nm for the diesel. The engine torque increases with increase in load for all the blends. The samples B10 and B20 shows higher engine torque as compared the Diesel and other biodiesel blends. B20 shows highest engine torque of 28.73 Nm at full load, which was 27.19 Nm for the diesel. The torque was maximum for the lower biodiesel blends was due to proper combustion of the fuel.

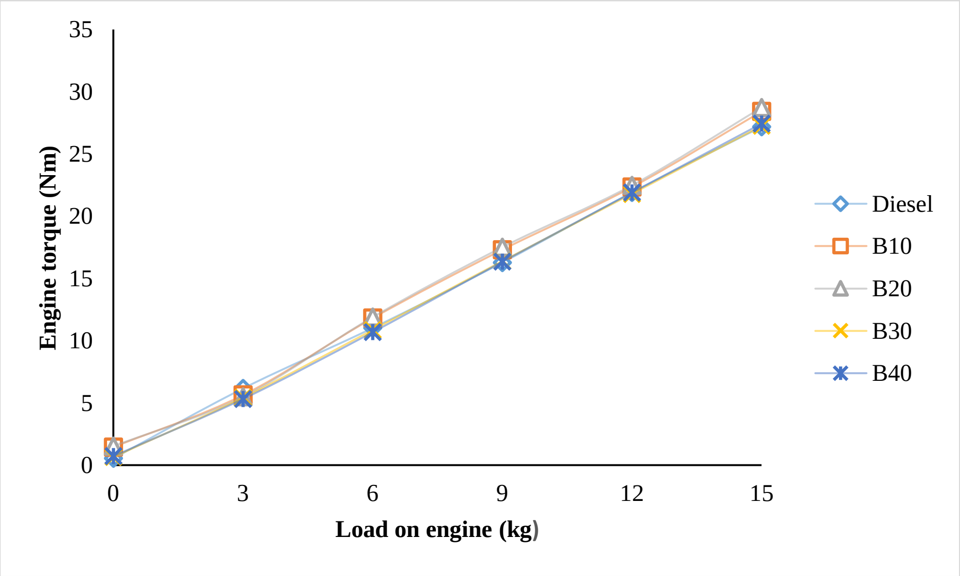


Figure 22: variation of engine torque with load

8.1.6 Volumetric efficiency

Volumetric efficiency is the ratio of mass density of the air-fuel mixture drawn into the cylinder to the mass density of same volume of air in the cylinder. Figure shows the variation of volumetric efficiency for all the blends with the variation of load. The Volumetric efficiency decreases with increase in load. It was maximum at no load and decreases linearly with increase in load. The biodiesel blends showed higher volumetric efficiency as compared to diesel. The volumetric efficiency observed for the blends B10, B20, B30 and B40 at full load were 80.80%, 81.55%, 81.33% and 81.18% respectively, which was 80.24% for the diesel. B20 has reported maximum volumetric efficiency at full load of 15kg, while it was maximum for the blend B10 at no load conditions and decreases gradually with increase in load. Diesel has reported lowest volumetric efficiency as compared to the other biodiesel blends. It was due to fact that biodiesel is having higher density as compared to standard diesel.

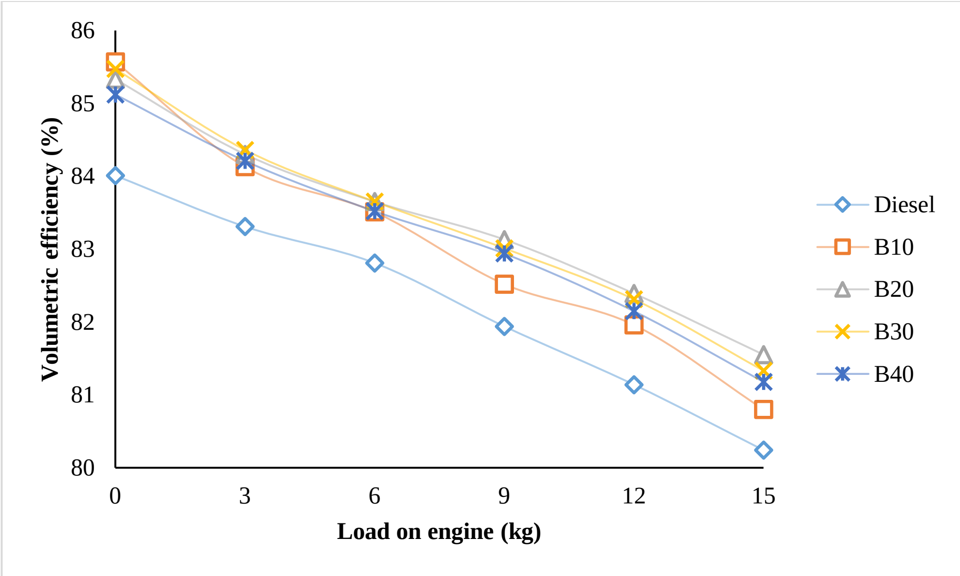


Figure 23: variation of volumetric efficiency with load

8.1.7 Indicated thermal efficiency

The indicated thermal efficiency is the ratio of indicated power to the fuel power. Figure shows the variation of indicated thermal efficiency for the diesel and its biodiesel blends with the variation of load. It was observed from graph that indicated thermal efficiency decreases gradually with increase in load. The indicated thermal efficiency observed for the blends B10, B20, B30 and B40 at full load are 45.07%, 42.44%, 44.69% and 44.05% respectively. The maximum indicated thermal efficiency observed for the diesel was 48.15% at full load, which was 3.08% more than the B10. All the blends of the biodiesel blends showed lower indicated thermal efficiency as compared to standard diesel.

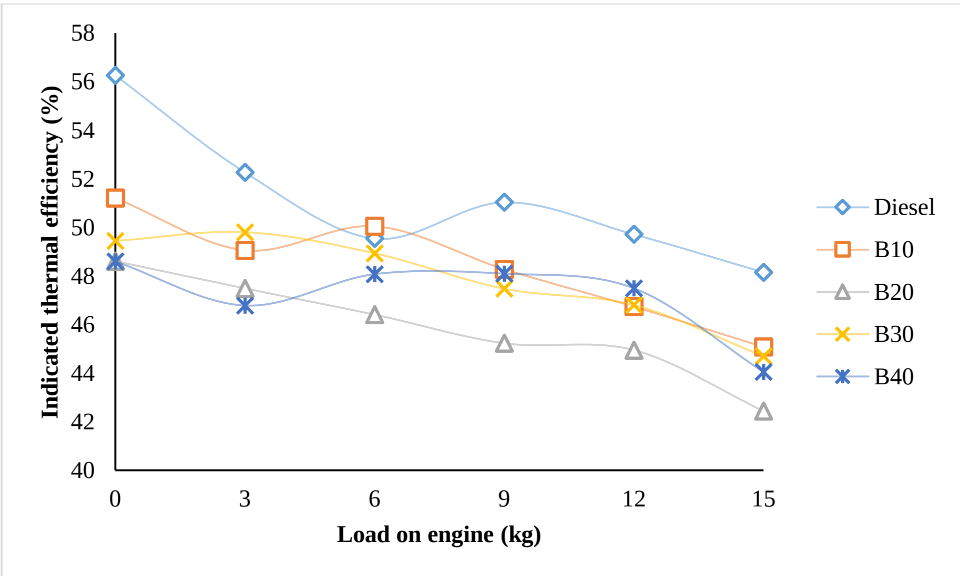


Figure 24: variation of indicated thermal efficiency with load

8.1.8 Mechanical efficiency

The mechanical efficiency is the effectiveness of machine to transform the energy. It is the ratio of brake mean power to the indicated mean power. The figure depicts the variation of mechanical efficiency with the variation of load for the various blends. The mechanical efficiency increases with increase in load. The mineral diesel shows the highest mechanical efficiency among all the blends. The mechanical efficiency was 55.16%, 57.10%, 55.77 and 56.30% for the B10, B20, B30 and B40 respectively, which was 67.27% for the diesel. This is due to highest indicated power for the biodiesel blends, resulted in lower mechanical efficiency for the biodiesel blends as compared to diesel. All the biodiesel blends showed lower mechanical efficiency as compared to the standard diesel.

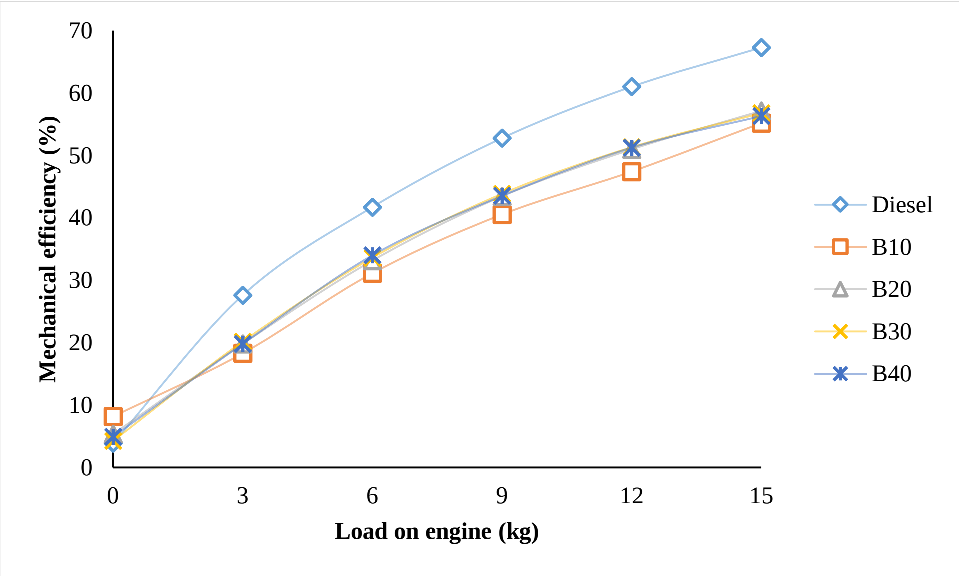


Figure 25: variation of mechanical efficiency with load

8.1.9 Brake Mean Effective Pressure

The brake mean effective pressure is the average pressure that ensures useful work for the power of the engine. The graph shows the variation of brake mean effective pressure with the variation of load for the diesel and the biodiesel blends. The BMEP observed was 5.17bar, 5.17bar, 5.18bar and 4.33bar for the B10, B20, B30 and B40, which was 5.15 bar for the diesel. The BMEP increases with increase in load for all the blends. The brake mean effective pressure for the diesel and the biodiesel blends was almost similar, except for B40. B40 shows lowest BMEP as compared to other blends, which was due to higher density of the biodiesel.. The average reduction in BMEP for the B40 was 2.57 bar as compared to standard diesel. B40 shows 4.33 bar BMEP, which was 5.15bar for the diesel.

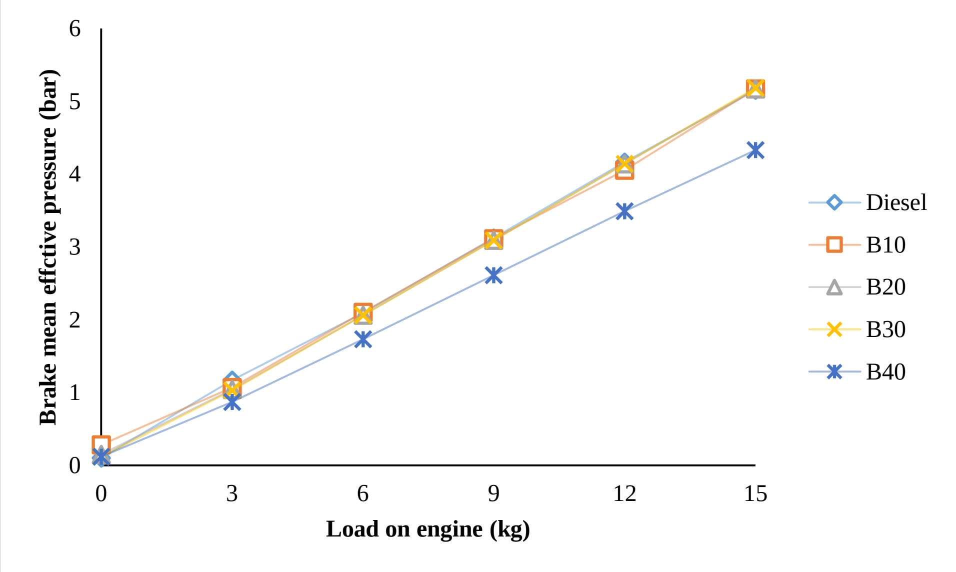


Figure 26: variation of Brake mean effective pressure with load

8.1.10 Indicated Mean Effective Pressure

The indicated mean effective pressure is the average pressure produces in the combustion chamber. The graph depicts the variation of indicated mean effective pressure with the variation of load for the diesel and biodiesel blends. The IMEP observed was 9.36bar, 9.06, 9.12 and 9.26 for the B10, B20, B30 and B40 respectively. The indicated mean effective pressure increases with increases in load for all the diesel and blends of biodiesel. The IMEP decreases as the concentration of the biodiesel increases in the blend. The highest IMEP pressure found for the B10 was 4.2 bar at full load of 15kg, which was 2.51 bar for the diesel.

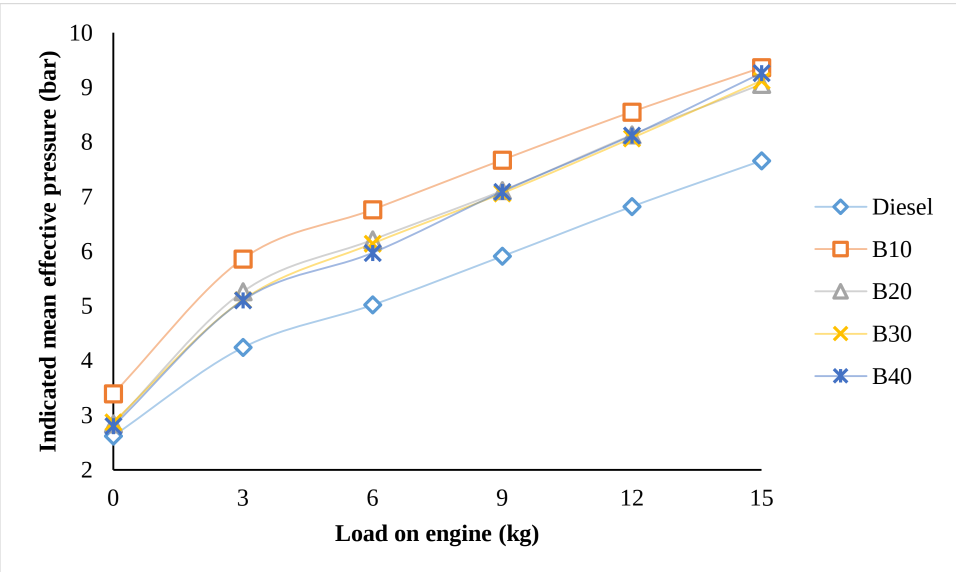


Figure 27: Variation of indicated mean effective pressure with loads

8.2 COMBUSTION CHARACTERISTICS

The combustion characteristics like cylinder pressure and NHRR were observed for the diesel and its biodiesel blends. The results obtained were discussed below:

8.2.1 Cylinder pressure

In a CI engine combustion pressure indicates capability of fuel to mix well with air. The figure depicts the variation of cylinder pressure with the crank angle at full Load. It was observed that combustion starts former for the biodiesel blends due to shorter ignition delay, which results in higher peak pressure. It was observed from the graph that biodiesel blends have higher cylinder pressure as compared to mineral diesel at peak load. The B40 has reported maximum cylinder pressure of 67.4 bar at angle 370°, which might be due to more fuel accumulated in the combustion chamber. The peak pressure observed for the diesel was 65.65 bar at full load.

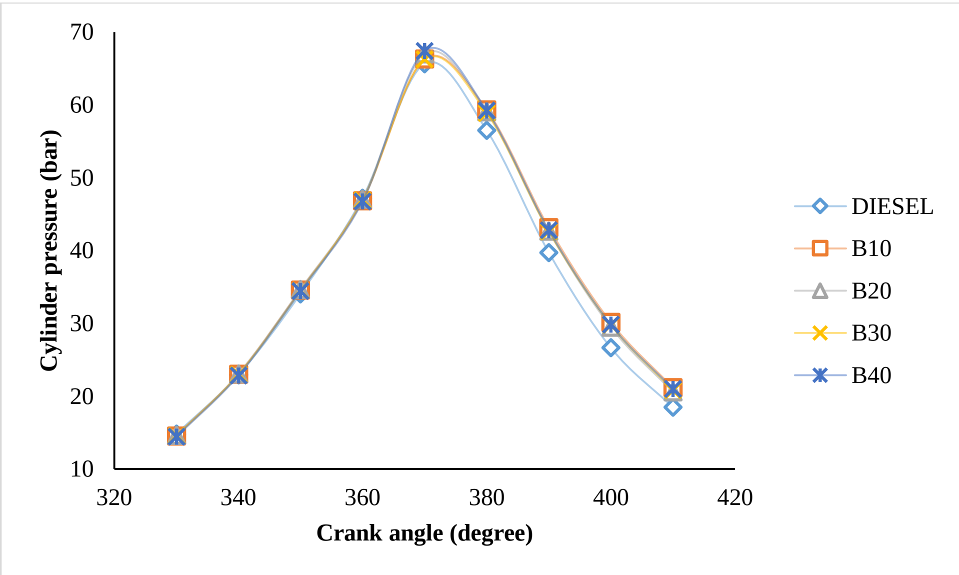


Figure 28: variation of cylinder pressure with crank angle

8.2.2 Net heat release rate

Figure shows the variation of net heat release rate with crank angle at full load. It is observed that net heat release rate is higher for the diesel as compared to biodiesel blends. This may be due to better mixing of diesel fuel with air and its higher volatility. Another reason may be due to longer ignition delay of diesel as compared to biodiesel blends. B40 has comparable heat release rate to the diesel. The maximum heat release for the biodiesel blends B10, B20, B30 and B40 reaches upto 32.35J/deg, 32.15J/deg, 30.56J/deg and 32.53J/deg respectively. The maximum heat release for the diesel is 35J/deg. The reason for the lower heat release of biodiesel blends may be due to its lower calorific value as compared to the diesel.

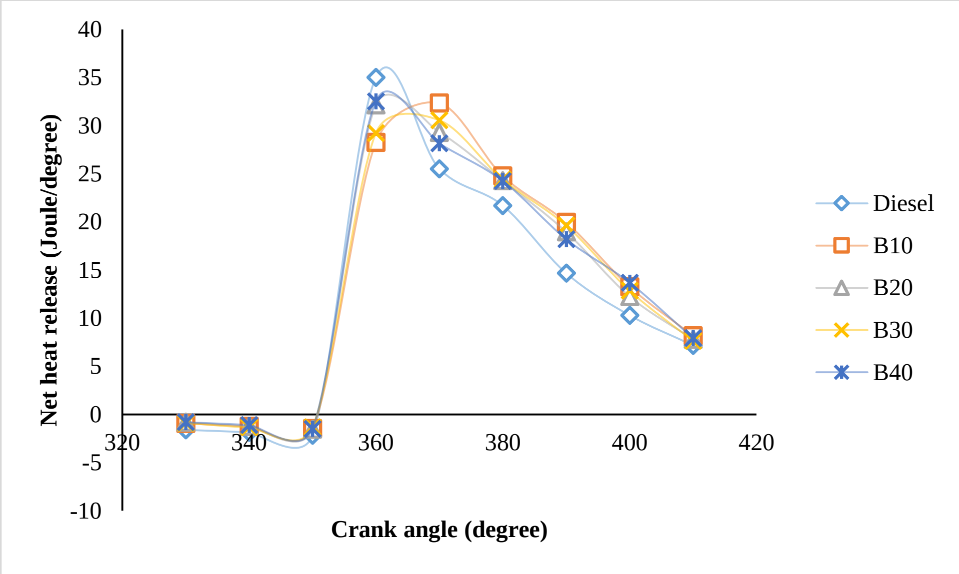


Figure 29: Variation of net heat release with load

8.3 EMISSION CHARACTERISTICS

The emission characteristics like carbon monoxide, carbon dioxide, oxides of nitrogen and unburnt hydrocarbons were observed for the diesel and its biodiesel blends. The biodiesel blends showed reduction in the carbon monoxide, carbon dioxide and unburnt hydrocarbons, but increase in oxides of nitrogen due to inherent oxygen in biodiesel. The results obtained were discussed below one by one for the carbon monoxide, unburnt hydrocarbons, carbon dioxide and oxides of nitrogen.

8.3.1 CO Emission

The figure represents the variation of carbon monoxide with respect to load. Incomplete combustion of fuel results in formation of carbon monoxide. Diesel fuel does not contain any inherent oxygen, therefore combustion does not take place completely. As the biodiesel is oxygen rich fuel, therefore results in reduced carbon monoxide emission. The carbon monoxide produced during combustion of biodiesel might have been converted into CO2 by the extra oxygen molecules present in the biodiesel chain. The carbon monoxide increases with increases in load for all the fuels. The carbon monoxide produced was less for all the blends as compared to diesel fuel. The carbon monoxide emission decreases with increase in biodiesel concentration upto B20, but CO starts increases with further increase in the concentration of biodiesel. It was due to higher density of the biodiesel results in incomplete combustion of the fuel. Therefore B30 and B40 shows the higher carbon monoxide emission as compared to diesel and biodiesel blends.

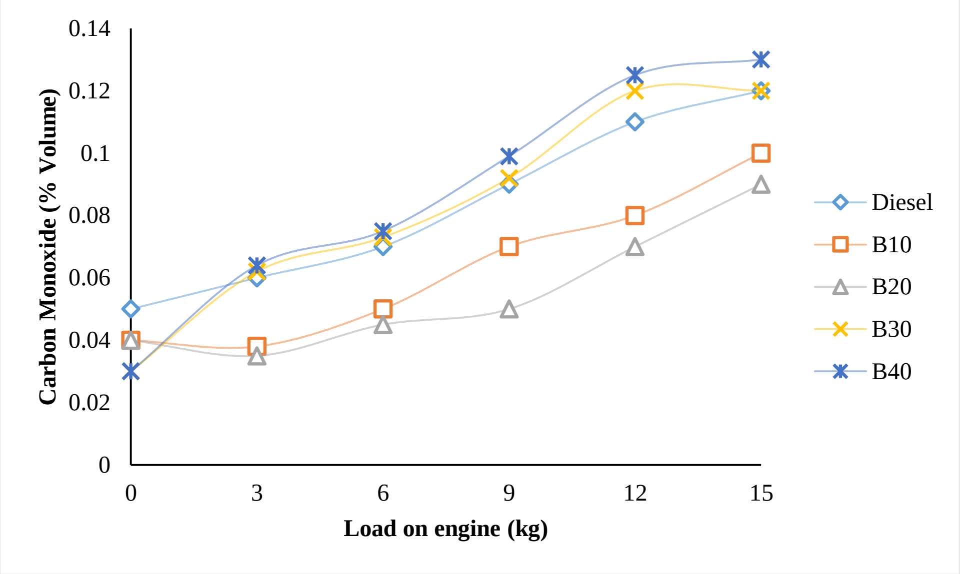


Figure 30: variation of CO with load

8.3.2 HC Emission

The unburnt hydrocarbons are the results of incomplete combustion of the fuel. The figure represents the variation of Hydrocarbons with respect to load. There is significant reduction in unburnt hydrocarbons using biodiesel blends. It was observed that there is increase in unburnt hydrocarbons with increase in load and decrease with increase in amount of biodiesel in blend. Complete combustion takes place results in reduction of UHC due to rich oxygenated fuel. The trend is similar as for the earlier studies. The unburnt hydrocarbons decreases with increase in concentration of biodiesel upto B20, but hydrocarbon emission starts increase with further increase in the concentration of biodiesel.

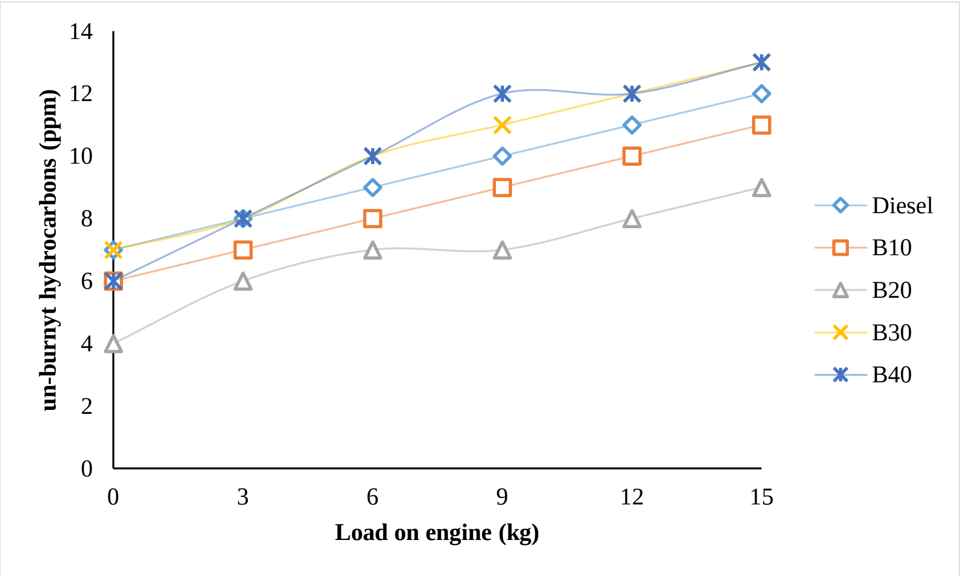


Figure 31: variation of unburnt hydrocarbons with load

8.3.3 Oxides of nitrogen

The oxides of nitrogen are results of higher peak cylinder pressure. The figure represents the variation of Nitrogen Oxides with respect to load. The biodiesel blends showed higher oxides of nitrogen emission as compared to the diesel, which was due to more complete combustion of the biodiesel due to presence of rich oxygen content in it. The NOx emission increases with increase in load. At lower loads the NOx emission was more for the diesel as compared to biodiesel blends, but at higher loads the NOx emission was more for the biodiesel blends. The increase in NOx emission for the biodiesel blend is due to higher combustion chamber temperature.

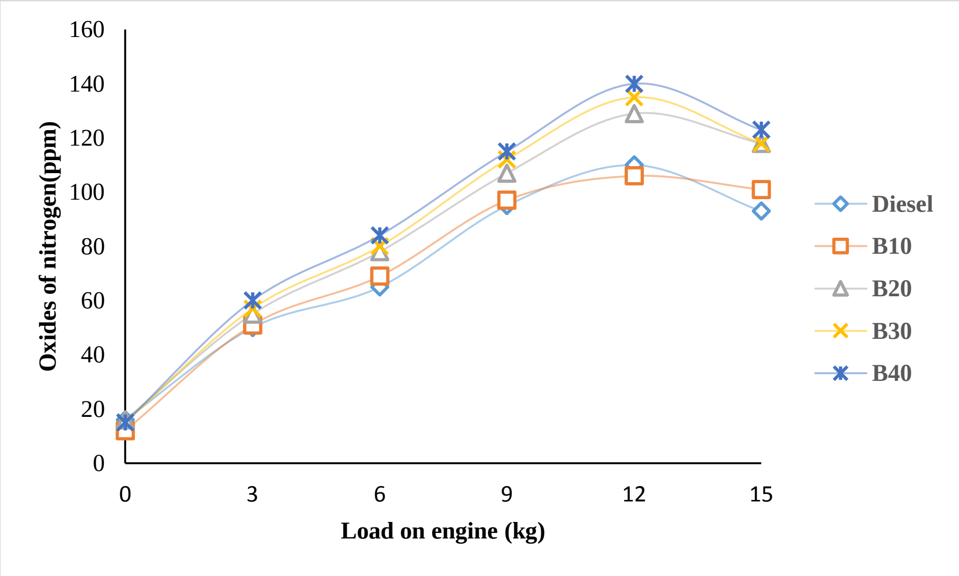


Figure 32: variation of NO_x with load

8.3.4 CO_2 Emission

The CO_2 formation is result of complete combustion. The graph shows the variation of carbon dioxide with the variation of load for the diesel and the biodiesel blends. The more the CO_2 lesser will be the carbon monoxide. The Blend B10 shows highest CO_2 emission as compared to other biodiesel blends and the diesel. All the blends of biodiesel shows higher CO_2 emission as compared to diesel fuel. This is due fact that, biodiesel contains inherent oxygen. The CO_2 formation decreases with increase in concentration of biodiesel, which was due to higher density of biodiesel. Higher density of biodiesel results in incomplete combustion of fuel. Therefore CO_2 formation was found maximum for the lower blends of biodiesel. Blends B20 and B10 shows higher carbon dioxide formation due to better combustion characteristics as compared to other blends.

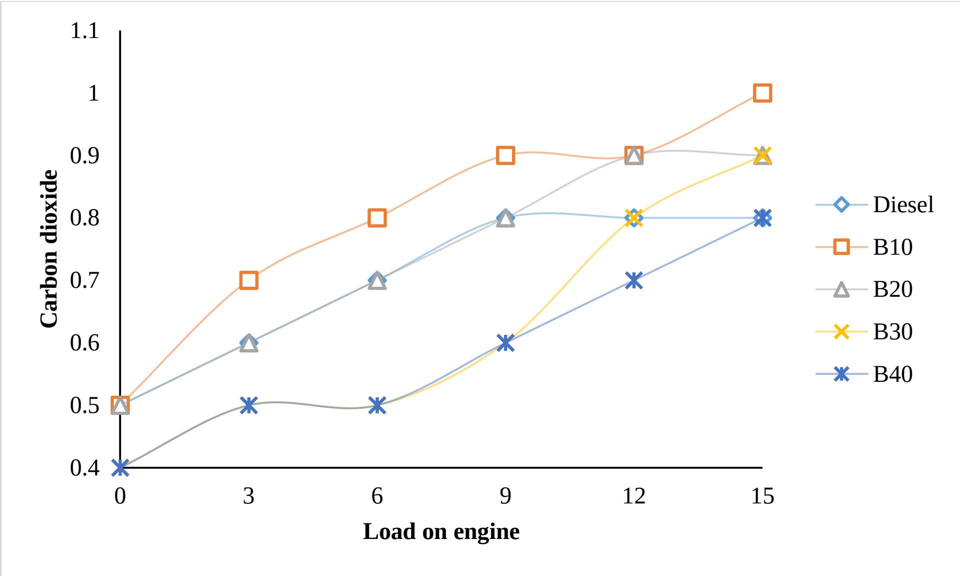


Figure 33: Variation of CO with load

9 CONCLUSION

In this study dual blends of argemone mexicana and mahua were used for the experimental investigation of performance, combustion and emission characteristics. The engine used for the experimental investigation was single cylinder, 4 stroke and water cooled. First the engine was made to run on the dual biodiesel blends of biodiesel. The blends prepared were A5M5D90 (B10), A10M10D80 (B20), A15M15D70 (B30), and A20M20D60 (B40). The results obtained were compared with the standard diesel. The following conclusion were made after the experimental study:

- BP increases with increasing load for all the fuels. The highest BP was founded for the B40 which was 4.33kW.
- SFC decreases with increasing load and increases with increase in biodiesel percentage. The biodiesel blend have slight higher fuel consumption as compared to diesel. SFC for all the blends are almost same.
- BTE increases with increasing load for all the fuels. B30 blend register highest BTE among the four biodiesel blends, but it was 7.02% less than the diesel.
- The indicated thermal efficiency observed is slight higher for the diesel as compared to B10. The indicated thermal efficiency values for the mineral diesel and B10 are 48.15% and 45.07% correspondingly at peak load.
- The volumetric efficiency observed is higher for the B10 as compared to diesel by 1.31%.
- Biodiesel blends have shown reduction in HC and CO emission.
- NOx emission was more for the biodiesel blends as compared to diesel at higher loads.
- The maximum cylinder pressure is observed for the diesel, which was 67.4 bar at peak load.
- The net heat release rate is lower for the dual biodiesel blends as compared to mineral diesel.

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List of Publications

[1]. "**Experimental analysis of engine performance and combustion characteristics using dual biodiesel blends" .**Accepted for Publication in **" International Journal of Control Theory and Applications**

[2]. **"Experimental Investigation of Performance and Emission characteristics of DI CI Engine with Dual Biodiesel Blends of Mexicana Argemone and Mahua".** Accepted for Publication. "**Elsevier Material Proceedings: Today".**