Major Project II

“PERFORMANCE AND EMISSION STUDIES OF A COMPRESSION IGNITION ENGINE FUELLED WITH JATROPHA METHYLE ESTER AND ETHANOL”

Submitted to Delhi Technological University in partial fulfillment of the requirement for the award of Degree of

Master of Technology

In

Thermal Engineering

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2K10/THR/16

UNDER THE SUPERVISION OF

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July 2013

DECLARATION

I,hereby declare that the work embodied in the dissertationentitled **“PERFORMANCE AND EMISSION STUDIES OF A COMPRESSION IGNITION ENGINE FUELLED WITH JATROPHA METHYLE ESTER AND ETHANOL”** in partial fulfillment for the award of degree of MASTER of TECHNOLOGY in “THERMAL ENGINEERING”, is an original piece of work carried out by me under the supervision of Prof. Naveen Kumar, Mechanical EngineeringDepartment, Delhi Technological University. The matter of this work either full or in part have not been submitted to any other institution or University for the award of any other Diploma or Degree or any other purpose what so ever.

Dated30 July 2013

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CERTIFICATE

This is to certify that the work embodied in the dissertation entitled "**PERFORMANCE AND EMISSION STUDIES OF A COMPRESSION IGNITION ENGINE FUELLED WITH JATROPHA METHYLE ESTER AND ETHANOL**" by SUNIL KUMAR SINHA, (Roll No.-2K10/THR/16) in partial fulfillment of requirements for the award of Degree of Master of Technology in Thermal Engineering, is an authentic record of student's own work carried by him under my supervision.

This is also certified that this work has not been submitted to any other Institute or University for the award of any other diploma or degree.

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ABSTRACT

Diesel engines are extensively used in transportation, decentralized electric generation and agricultures sectors. The current state of environmental degradation and limited availability of fossil fuels have been a matter of concern throughout the world and it is becoming necessary to explore renewable alternative fuel from locally available resources within the country whose properties are comparable with mineral diesel and could be used in the existing C.I. engine without any major hardware modification.

The bio origin fuels in this context can provide a feasible solution. Biodiesel is the one of such fuels derived from variety of vegetable oil or animal fats.Vegetable oils are essentially triglycerides and have high viscosity (20.5-76.4mm^2/s) than mineral diesel due to high molecular weight and complex molecular structure. Due to high viscosity,vegetables oilare unsuitable to unmodified diesel engine.

There are many methods for reducing the viscosity of vegetable oil and transesterification is considered the most promising route. However, despite converting vegetable oils into biodiesel through transesterification, its viscosity is still higher than diesel. Many researchers have reported poor atomization and higher NOx emission of neat biodiesel due to high viscosity which is the main obstacle in use of biodiesel. In this perspective, blending of biodiesel with other bio-origin fuels such as alcohol makes it very attractive.The ethanol is also a bio origin fuel and abundantly produce and successively used in gasoline engine, blending with Gasoline in many country.

The objective of present work is developed atest rig of medium size diesel engine to evaluate the performance and emission analysis of different blends of ethanol and Jatropha biodiesel at different loads to able to provide an alternative bio origin fuel.

The blend of Ethanol in biodiesel is improving the fuel property and combustion processof biodiesel. The both fuel are bio origin product which provide alternative to mineral diesel and sustainable energy growth.

The experimental results suggest that the BTE of the engine is slightly higher when biodiesel is used than base diesel fuel but by blending of ethanol in biodiesel up to certain percent BTE is significantly improved. The BSEC is similar when engine is fuelled with biodiesel or diesel but by increasingthe percentage of ethanol in biodiesel blendsits gradually decrease due to oxygenated fuels and lower viscosity of blends which improve the combustion process. The exhaust emission i.e. CO,UB,HC,PM arelowerwhen used biodiesel than diesel and in addition of ethanol in biodiesel its further considerably decreases however,NOx emission is more for biodiesel but by blending of ethanol in biodiesel it is going down but still NOx is marginally higher than diesel.

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NOMENCLATURE

@	At the rate
A/F	Air to Fuel
AC	Alternate Current
AN	Acid Number
ASTM	American Society for Testing and Materials
ATDC	After Top Dead Center
AVL-437	AVL-437 Smoke Meter
BIS	Bureau of Indian Standard
BMEP	Break Mean Effective Pressure
BSEC	Brake Specific Energy Consumption
BSFC	Brake Specific Fuel Consumption
BTE	Brake Thermal Efficiency
BTDC	Before Top Dead Center
^{o}C	Degree Celsius
^{CA}	Crank Angle
cc	Cubic centimeter
CFPP	Cold filter plugging point
C/H	Carbon to Hydrogen ratio
CI	Compression Ignition
cm^{-1}	Per Centimeter
CN	Cetane Number
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COME	Cotton seed methyl ester
CPP	Cold plugging point
cSt	Centi Stoke
Cu	Copper
CV	Calorific Value
D100	Neat Diesel
DI	Direct Injection
DF	Diesel fuel
EBP	Ethanol blending program
EOI	End of Injection
EV	Electric Vehicle
ºF	Degree Fahrenheit
F/A	Fuel to Air
FDI	Foreign direct investment
FFA	Free Fatty Acid
g	Gram
g/cc	Gram per cubic centimeter
GOI	Government of India
HC	Hydrocarbon
H_2O	Water
HP	Horse Power

HRR	Heat release rate
Hz	Hertz
IC	Internal Combustion
IDI	Indirect Injection
IR	Infra Red
IS	Indian standard
JB100	100% Jatropha biodiesel
JB95E5	95% JB and 5% Ethanol
JB90E10	90%JB and 10% E
JB85E15	85%JB and 15% E
JB80E20	805JB20% E
JOME	Jatropha oil methyl ester
Kg	Kilogram
KOH	Potassium Hydroxide
KOME	Karanja oil methyl ester
KVA	Kilo Volt Ampere
kW	Kilo Watt
kW-h	Kilo Watt Hour
LHE	Latent heat of evaporation
LPM	Liter per Minute
LSD	Low Sulphur Diesel
LTC	Low combustion temperature
LOME	Linseedoil methyl ester
1M	1 Mole
Min.	Minute
MJ	Mega Joule
ml	Milliliter
mm	Millimeter
MOME	Mahua oil methyl ester
MPP	Minimum purchase price
MSP	Minimum support price
Mt	Million Tonnes
Mtoe	Million Tonne of Oil Equivalent
NO	Nitric Oxide
Nos.	Numbers
NO_2	Nitrogen Di-oxide
NO_x	Oxides of Nitrogen
NOME	Neem oil methyl ester
O_2	Oxygen
PM	Particulate Matter
ppm	Parts per million
rpm	Revolutions Per Minute
ROME	Rubber oil methyl ester
SAE	Society of Automobile Engineering
sfc	Specific Fuel Consumption
SVO	Straight vegetable program
TDC	Top Dead Center
THC	Total Hydrocarbon
ULSD	Ultra Low Sulphur Diesel
UBHC	Unburnt Hydrocarbon

Vs	Versus
v/v	Volume/ Volume
ρ	Density
%	Percent

CHAPTER 1

INTRODUCTION

1.0 ENERGY CRISIS AND ALTERNATIVE FUELS

Universal availability and access to clean energy are considered as the most important factors for sustainable economic growth and prosperity. Indiscriminate extraction and lavish consumption of fossil fuels have led to reduction in underground-based carbon resources [1]. Heavy reliability on fast depleting fossil fuels as primary energy resources lead to energy crisis. On the other hand, rapid consumption of fossil fuels, their combustion and emissions led to environmental degradation and increased carbon foot prints in the energy sector. Therefore, reliability on non-renewable resources such as, coal, petroleum derived products, natural gas, or uranium to fulfil the growing energy demands leads to a bleak future with a set of looming crises like reduced energy security, pollution leading to serious health issues, environmental anomaly like acid rain, climate change and global warming[2]. Inexpensive and seemingly abundant non-renewable energy drove the twentieth century economy, but looking at the twenty first century, it seems that cleaner and greener form of energy in complete congruence with environment are the only hope for a sustainable future. In this context, the gulf crisis was an eye opener for both developed and developing countries and it was then for the first time the world seriously started looking for alternative source of energy along with efficient utilization. The recent volatility in petroleum prices and the growing awareness related to the clean environment have stimulated the recent interest in alternative energy sources [3].

In this context, the scenario in India is no different. With a humongous population, rapid economic growth and huge potential for massive upward swing in energy intensive sectors such as industry, infrastructure, transportation etc. the resurgent India is consuming more energy than it consumed in its entire course of existence. Amongst various energy intensive sectors, transport, agriculture and decentralized power etc. are the matter of great concern. The common denominators in all these sectors in India are characterized by the popular diesel engines. India does not have large oil reserves and relies on imported crude oil to fuel its domestic demands of petroleum diesel. On account of fluctuating international crude oil prices, increasing oil imports and the consequent widening in trade deficit, there is an urgent need to substitute mineral diesel by locally available alternative and renewable fuels. [4]

In the light of the above fact, scientists around the world have explored several alternative energy resources, which have the potential to quench the ever-increasing energy thirst as well as hazardous emissions of the contemporary human civilizations. In this context, various bio-origin fuels such as biomass, biogas, primary alcohols, vegetable oils, etc are seriously evaluated as potential renewable substitutes for mineral diesel in various capacities [5].

1.1 GLOBAL ENERGY OUT LOOK

Global energy requirement is mainly derived from fossil fuels comprising of oil, natural gas and coal which constitute nearly 90% of total primary energy requirements. Global primary energy consumption has increased from 11,843.8 mtoe in 2010 to12079.8 in 2011 showing an annual increase of nearly 2% [4-5].

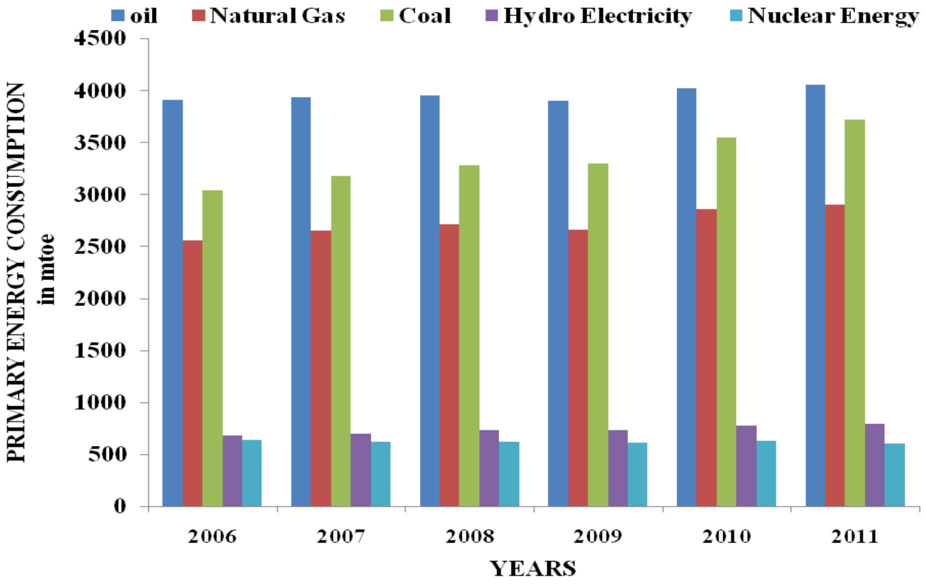

Fig 1.1:- World's primary energy consumption in mtoe [6-7]

1.1.1.FUTURE GLOBAL ENERGY OUT LOOK

The Fig. 1.2 show Global primary energy demand from 1980 to 2030 was expected to grow steadily from 7261 mtoe to 17095 mtoe at a rate of 2.75% average per year. Global oil demand was expected to grow in 50 years gradually at an average 1.58% per year and its reached from 3107 mtoe to 5575 mtoe ,coal demand at an average 2.97% per year, 1785 mtoe to 4441 mtoe and gas demand at an average rate 4.25% per year 1237mtoe to 3869 mtoe. [9] .

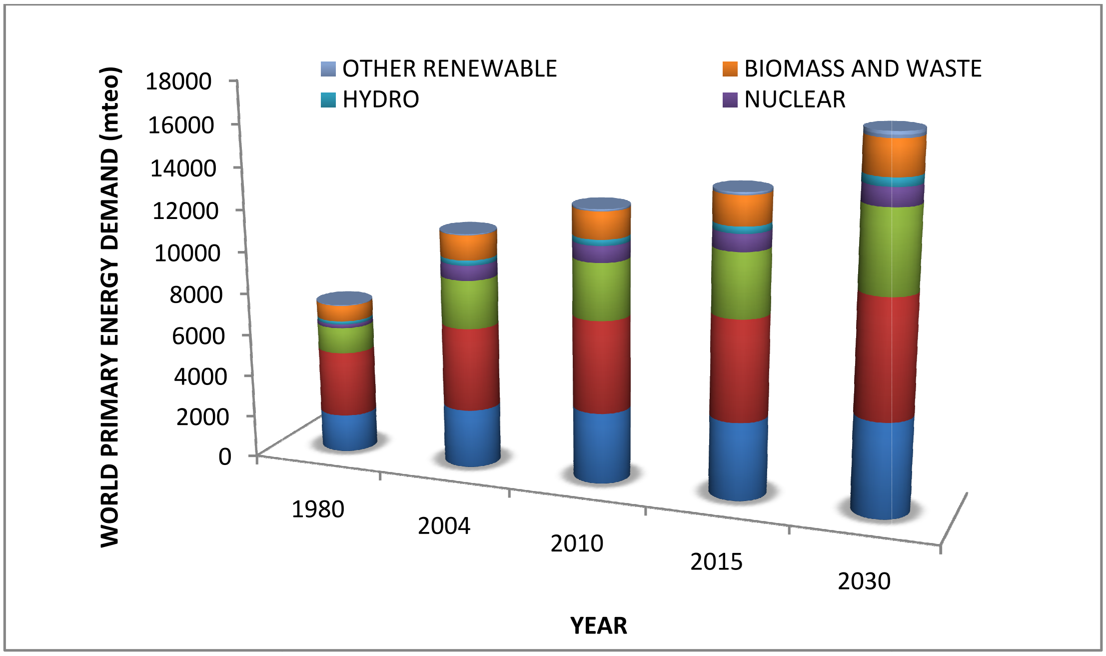

Fig1.2:- World Primary Energy Demand Growth

The above fact showed that fossil fuels remains dominant resource of primary energy.

1.2 INDIA ENERGY SCENARIO

Energy is the most important factors in the entire process of evolution, growth and survival of all living beings and it plays a vital role in the socio-economic development and human welfare of a country. Energy has come to be known as a `strategic commodity' and any uncertainty about its supply can threaten the functioning of the economy, particularly in developing economies. Achieving energy security in this strategic sense is of fundamental importance not only to India’s economic growth but also for the human development objectives that aim at mitigation of poverty, unemployment and meeting the Overall Development goals. Many developing countries are not able to hit the bull’s-eye their energy demand from the resources available in their own country and have to depend on other countries for accomplishing it.

At present fuel economy and energy poverty create interruption the socio-economy development of large population of India.

Supply and use to fuel economic development at present, energy poverty hinders the economic and social development of very large numbers of people. India is the fourth largest consumer of energy in the world after USA, China and Russia but it is not endowed with abundant energy resources but it is rich in coal and abundantly endowed with renewable energy in the form of solar, wind, hydro and bio-energy, however, the exploitation of these resources are very much limited. India accounted for 11.63% of Asia-Pacific primary energy consumption and 4.5% of world consumption in 2011. However, its hydrocarbon reserves represent only 0.3% of the global reserves. India is mainly dependent upon crude import to cater its need for automobiles and other applications despite larger initiative by government and exploration of new resources sustain its growth [6] and its per capita consumption is very low at 560 KGOE as compared to the world average of 1790 KGOE (2009) [4-7].

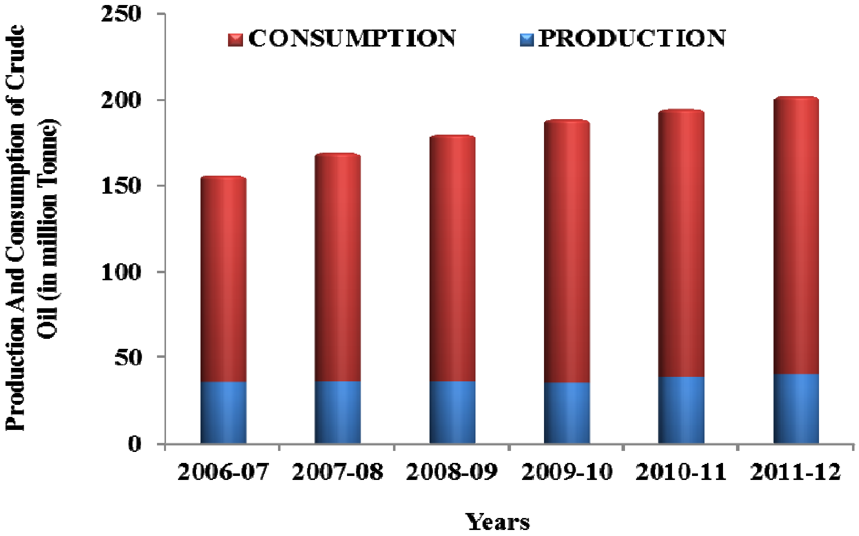

Fig 1.3:- Indian Production and Consumption of Crude oil (in million tons) over the year. [6]

Sky roaring price of crude oil, insufficient supply and limited reserve of petroleum have imposed an enormous burden on country foreign exchange which is clearly seen from Fig 1.3 that India is importing around 80% of its crude requirements. In 2011-12, India spent 129 billion US $ (6995.39 billion Indian Rs.) towards import of crude oil. High reliance on imported energy is costly given the prevailing energy prices which are not likely to soften; it also impinges adversely on energy security. Meeting the energy needs of achieving 8 % to9 % economic growth while also meeting energy requirements of the population at affordable prices therefore presents a major challenge.

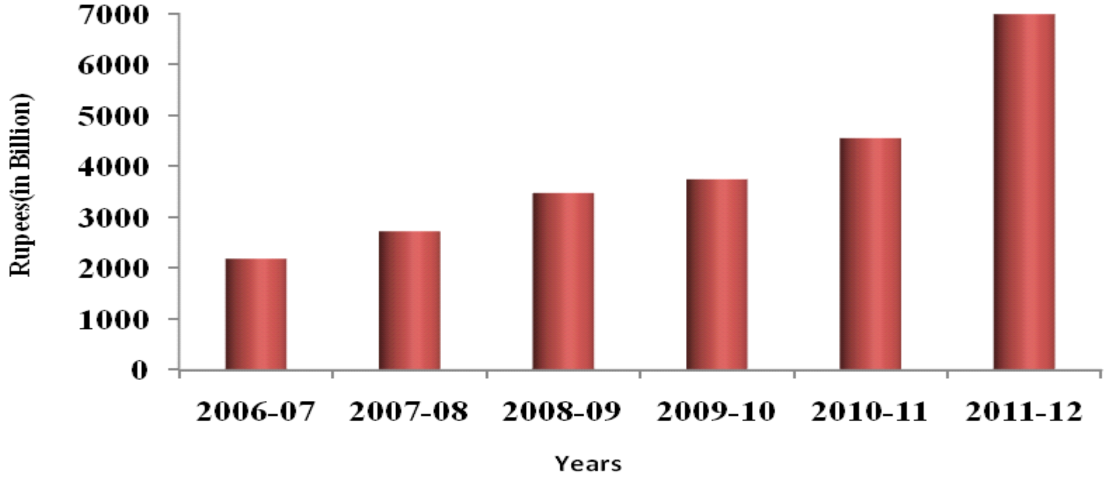

Figure 1.4:- Expenditure incurred in importing Crude oil (in Billion Rupees). [7]

To improve the energy crisis and climate change, future energy conversion in India should be sustainable which include increase share of renewable fuel, increase efficiency of fuel conversion, reduce climate impacts and increase knowledge to use energy efficiently and precisely.

1.2.1 .FUTURE ENERGY OUTLOOK

The demand for energy during the 12thPlan will increase as the economy grows and as access in rural areas expands. Table 1.1 presents estimates of the total primary energy demand projected to the end of the Thirteenth Plan. The annual average growth rate of the total energy requirement is expected to accelerate from 5.1 percent per year in the Eleventh Plan to 5.7 percent per year in the Twelfth Plan and 5.4 percent per year in the Thirteenth Plan. The faster growth in supply in the Twelfth Plan is in part a reflection of the need to meet suppressed demand. The demand for non-commercial energy is expected to decline with increasing expansion of the network and access to commercial energy. As shown in Table 1.1 whereas commercial energy is expected to grow at 6.91 percentduring 10th to 11th five years plan up to 2011–12, non-commercial energy is projected to grow at only 2.6 percent in the same period. The growth of non-commercial energy is projected to decline to around 1.5 percent in the next 10 year [7].

Table1.1:- Trends in Supply of Primary commercial Energy(mtoe)[7]

DOMESTIC PRODUCTION	**2000–01(Actual)**	**2006-07 (Actual)**	**2016–17(Projected)**	**2021–22 (Projected)**
Coal	130.61	177.24	308.55	400
Lignite	6.43	8.76	16.8	29
Crude Oil	33.4	33.99	42.75	43
Natural Gas	25.07	27.71	76.13	103
Hydro Power	6.4	9.78	12.9	17
Nuclear Power	4.41	4.91	16.97	30
Renewable Energy	0.13	0.87	10.74	20
Total Domestic commercial Energy	206.45	263.28	481.84	642
Non-commercial Energy 1	136.64	153.28	187.66	202.16
Total	**343.09**	**416.56**	**669.5**	**844.16**
IMPORTS				
Coal	11.76	24.92	90	150
Petroleum Products	77.25	98.41	152.44	194
LNG	0	8.45	24.8	31
Hydro power	0	0.26	0.52	0.6
Total Net Imports	89.01	132.04	267.76	375.6
Total Commercial Energy (growth over the previous five years)	295.46	396.32	749.6	1017.6
Total Primary Energy	**432.01**	**549.6**	**937.26**	**1219.76**

1.3ENVIRONMENTAL DEGRADATION AND ITS GLOBAL EFFECT

Energy is the major concern around the globe not because it is limited but also due to its environmental effects, greenhouse gas emissions and ozone layer depletion. Policy makers around the world are looking for the alternate solution but the steps taken to overcome these issues were not very fruitful till now.

Indiscriminate usage of fossil fuels and deforestation has raised the quantity of harmful emissions gas, particulates in the environment and resulted in serious ozone layer depletion. Due to the consumption of various forms of energy for power generation, transportation and other sectors, there is also an increase in air pollution greenhouse effect; global warming, acid rain, smog, deforestation, shift in climatic conditions etc. are some of the signals of over usage of fossil fuels which seriously affect nature.

1.3.1 OZONE LAYER DEPLETION

The ozone layer is a layer in Earth's atmosphere which contains relatively high concentrations of ozone (O_3). This layer absorbs 97–99% of the Sun's high frequency ultraviolet light, which potentially damages the life forms on Earth. It is mainly located in the lower portion of the stratosphere from approximately 15 to 30 kilometres above Earth, though the thickness varies seasonally and geographically. The ozone layer can be depleted by free radical catalysts, including nitric oxide (NO), nitrous oxide (N_2O), hydroxyl (OH), atomic chlorine (Cl), and atomic bromine (Br) [9].

Effective utilization of renewable fuels, strict restriction of using CFCs and stern government regulations throughout the world has certainly reduced the ozone layer depletion.

1.3.2 GLOBAL WARMING

Global warming is caused by rising level of carbon dioxide in the atmosphere that acts as a blanket to contain radiated heat and raises overall global temperature to dangerous level ,leading to melting glaciers,resulted rise in sea levels,unpredictable weather and climate changing patterns.

Not only the ozone layer depletion but also global warming is a serious concern around the globe that is to be dealt by humans. The main cause of global warming is increase in CO_2 and other harmful emissions liberated in atmosphere. Fig .1.5 show that by increasing CO2 in atmosphere results in rise of average global temperature.

As per world energy report (2013) annual temperature in cities increase much faster than the global average temperature .An average global warming of 4.6^{o}C above pre industrial level by 2100(as in IPCC'sRCP 8.5Scenario) is projected to result in maximum summer temperature in New York increasing by 8.2 ^{o}C (Hempel et. al.2013). In such a case,the extreme summer experienced in Moscow in 2010 may be closer to the norm experienced in 2100 while the Europeans summer of 2003 could be cooler than the average by that time[9].

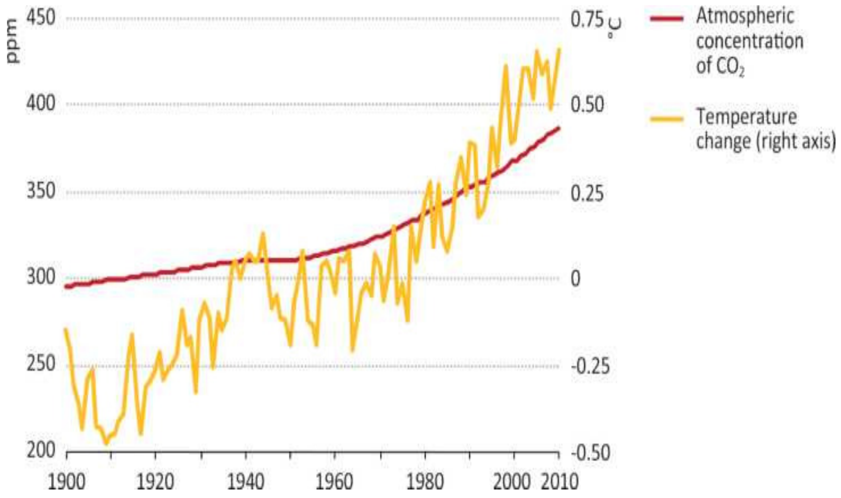

Fig1.5:-World atmospheric concentration of CO_2 and average global temperature change

From last few decades the four main greenhouse gases i.e. CO_2,CH_4,O_3, NO_X and CFC liberated due to industrialization and modernization and it plays a major role in causing global warming. Out of which CO_2 is produced in abundance due to use of fossil fuels.

In order to compare the effect of the amount of greenhouse gases emitted, the speed at which the gases are degraded or in some other way eliminated from the atmosphere must be taken into account. Initially the carbon dioxide is rapidly absorbed by the oceans and to some extent by vegetation but today situation is different for CO_2.The transfer of CO_2 to the deep ocean is avery slow process which means that several century pass before a CO_2 has been eliminated from the atmosphere.

Table1.2:- Remaining amount of GHG (kg) in the atmosphere after different period

Greenhouse gas	After 50 years	After >400 years
Carbon dioxide	24	100
Methane	10	10
Nitrous oxide	42	150
CFC-11	35	65
CFC-12	41	120
HCFC-22	18	20

Table 1.2 and Fig .1.6show that how much of different GHG remain in the atmosphere at an emission rate 1 Kg per year of each gas.The graph and table show that the NO_2 and CO_2 takes longest time to grade or eliminate from the atmosphere WMO (1985) and Rodhe (1989). [36]

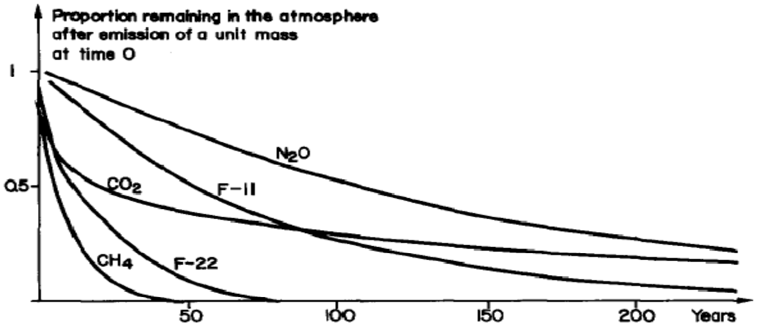

Fig1.6:- Decay sequence for different GHG in the atmosphere

CO_2 being a greenhouse gas has adverse effects on atmosphere which are the possible consequences of global warming.

1.3.3 GREENHOUSE EFFECT

The greenhouse effect mainly occurs due to the interaction between the Earth's atmosphere and surface to absorb, transfer, and emit energy as heat, cycling it through the atmosphere and back to the surface. The natural greenhouse effect is necessary for life as it exists on Earth today.

The amount of radiation which escapes the earth's atmosphere depends upon the concentration of greenhouse gases (i.e carbon dioxide, methane, nitrogen oxide etc.)
If the amount of carbon dioxide emissions increases, then the following problems may come into effect:

- Rise in Sea level
- Reduction of ozone layer
- Increased extreme weather
- Impacts on agriculture
- Spread of diseases
- Ecosystem change

The effects of carbon dioxide emissions could be extremely far reaching and cause major problems. Even a small reduction in harmful emissions could help to solve the problem of global warming that future generations are likely to face.

1.3.4 CO_2 EMISSION OUTLOOK

The global carbon-dioxide emission is expected to increase by 2.5 % average per year over the period (1980-2030).They will reach 40.55 giga tone in 2030 over a period of 50 year (1980-2030). The mian source of CO_2 emissions are power generation industries,trasportation .The global warming is mainly the result of CO_2 levelsprogressively rising in the Earth's atmosphere. Climate scientists say we have years, not decades, to stabilize CO_2 and other greenhouse gases.IEA predicted the amount of CO_2 emissions for few major countrires shown in Fig. 1.8 In India the amount of CO_2 emssions has already increased by nearly four times between the years 1980-2006 with a further expected to increase of 2 times from 2006 to 2020 as compared to World's increase expected of nearly 45% during 2006 to 2020. So it is a matter of concern for india to inhibit the quantity of CO_2 emissions to atmosphere.

Table 1.3:- CO_2Emissions Based On Region (Gigatonnes)

Region	**1980**	**1990**	**2000**	**2006**	**2020**	**2030**
United States	4.66	4.85	5.66	5.67	5.77	5.8
Europe	4.12	3.89	3.9	4.06	4.16	3.99
Japan	0.88	1.07	1.19	1.21	1.15	1.06
Russia	n.a.	2.18	1.5	1.57	1.92	2
Asia	2.14	3.52	5.2	8.36	14.17	17.3
China	1.42	2.24	3.08	5.65	10	11.71
India	**0.29**	**0.59**	**0.98**	**1.25**	**2.19**	**3.29**
Middle East	0.34	0.59	0.97	1.29	2.09	2.61
Africa	0.41	0.55	0.69	0.85	1.08	1.17
World	**18.05**	**20.95**	**23.41**	**27.89**	**36.4**	**40.55**

In 2013 the CO_2 emissions reaches as high as around 400 ppm in May 2013 in the atmosphere [10].

The measurements were made at the Mauna Loa Astronomical Observatory which is at the summit of an inactive volcano in Hawaii. Mauna Loa was chosen because it is far from major sources or sinks of carbon dioxide. Carbon dioxide concentrations measured at Mauna Loa are a good proxy for the average of the whole Earth.

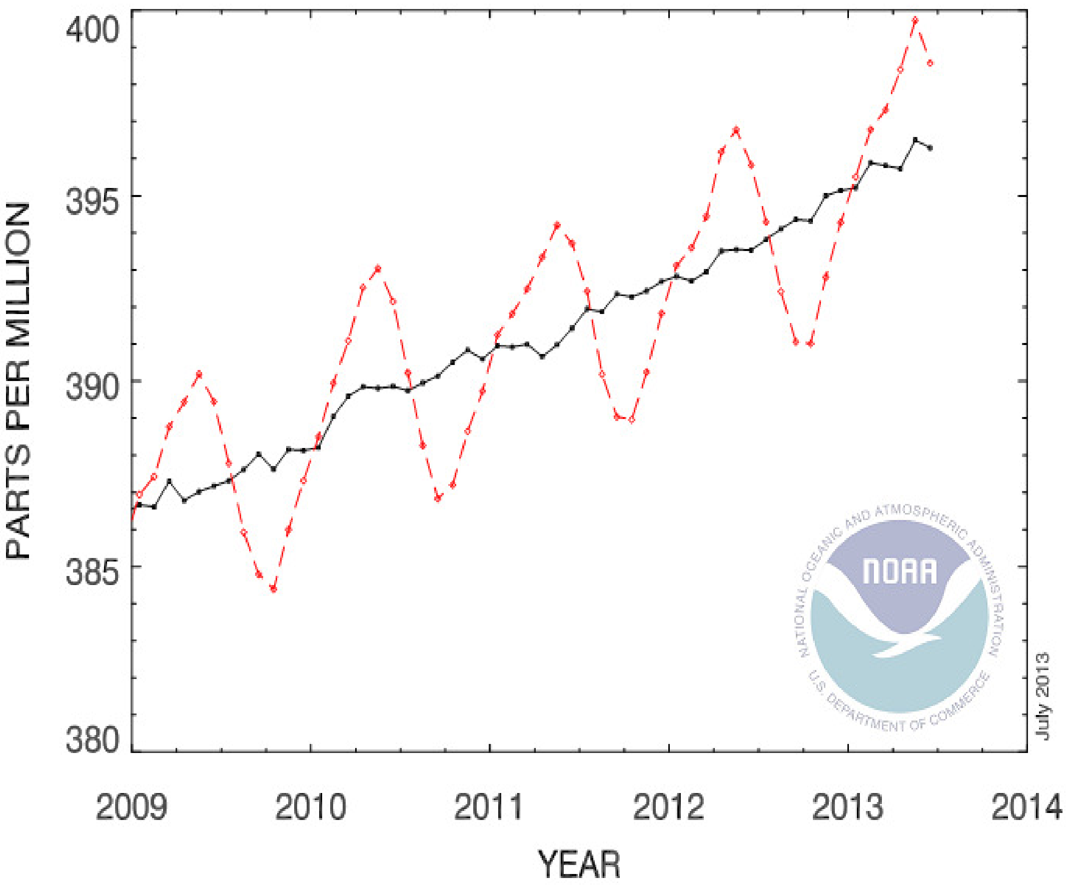

Fig:-1.7Recent monthly mean carbon dioxide measured at mauna Loa Observatory, Hawaii[10]

1.4 IEA (International Energy Agency)

The **International Energy Agency** is a Paris-based autonomous intergovernmentalorganization established in the framework of the Organization for Economic Cooperation and Development (OECD) in 1974 in the wake of the 1973 oil crisis. The IEAwas initially dedicated to responding to physical disruptions in the supply of oil, as wellas serving as an information source on statistics about the international oil market andother energy sectors.

The IEA acts as a policy adviser to its member states, but also works with non-membercountries, especially China, India, and Russia. The Agency's mandate has broadened tofocus on the **"3Es"** of effectual energy policy: **energy security, economic development and environmental protection**. The latter has focused on mitigating climate change. The IEA has a broad role in promoting alternate energy sources (including renewableenergy), rational energy policies, and multinational energy technology co-operation.

1.5 THE KYOTO PROTOCOL

The Kyoto Protocol is an international agreement linked to the United NationsFramework Convention on Climate Change. The major feature of the Kyoto Protocol isthat it sets binding targets for 37 industrialized countries and the European community for reducing greenhouse gas (GHG) emissions .These amount to an average of five percent against 1990 levels over the five-year period 2008-2012.

Mainly that developed countries are principally responsible for the current highlevels of GHG emissions in the atmosphere as a result of more than 150 years ofindustrial activity, the Protocol places a heavier burden on developed nations under theprinciple of “common but differentiated responsibilities.” The Kyoto Protocol wasadopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February2005. The detailed rules for the implementation of the Protocol were adopted at seventh session of conference of the parties in Marrakesh in 2001, and are called the **“Marrakesh Accords.”**

Kyoto was an offshoot of the UN Framework Convention on Climate Change—the pact signed by more than 190 countries in 1992 in a bid to prevent dangerous anthropogenic interference with the climate system.” By the mid- 1990s it was clear that the efforts being made internationally under the UNFCCC were insufficient and a group of 37 industrialized nations agreed at a meeting in 1997 in Kyoto, Japan, to go further and set a collective, legally-binding greenhouse gas emissions reduction target of 5.2% for the period 2008-12, against a 1990 baseline. However, Kyoto covered only around 27% of global emissions, leaving China, India and other fast developing major economies free of binding emissions reduction obligations.

It was also never ratified by the US—largely because of those exemptions. Kyoto's first commitment period expires at the end of 2012, and no agreement has yet been made to renew it. A powerful negotiating block of fast emerging economies—Brazil, South Africa, India and China, the so-called BASIC group, want to preserve Kyoto's theme of binding targets for industrialized countries only. In stark contrast, Japan, Canada and other big industrialized economies do not. For its part, Europe has pledged a 20% emissions cut by 2020 and has said it will go deeper to 30%, if other industrialized nations take on comparable targets. Given these vastly differing stances on how to address climate change, observers are watching to see what the big emerging economies can offer to persuade Europe to keep Kyoto alive.

1.6 ROLE OF IEA ON BIO-FUELS

IEA analyses show that bio-fuels may have to play an important role if the world is tomake meaningful reductions in carbon dioxide emissions, and reduce reliance on crudeoil at costs similar to those of gasoline and diesel in the medium-term. However, currentproductionprocesses do not always meet expected net life-cycle greenhousegas (GHG) emission and cost performance targets, and certain conventional bio-fuelshave been criticized for causing deforestation and adding to pressure on agriculture land needed for food and fodder production. The IEA considers it important to distinguish between different types of feedstock and conversion routes, and ensure deployment of land-use efficient, low-carbon bio-fuels to meet growing demand.

The IEA calls on governments to ensure that their bio-fuel support policies foster thetransition towards fully sustainable bio-fuels, including advanced bio-fuel technologies.Internationally aligned sustainability certification schemes for bio-fuels will be vital to ensure a positive environmental and social impact, and create an international market for sustainable bio-fuels. The IEA emphasizes the importance of continuing to supportadvanced bio-fuels research, development and demonstration, and provide soundsupport mechanisms to ensure that the new technologies reach full market deployment.

1.7 ALTERNATIVE FUELBIODIESEL

Biodiesel is an alternative or substitute to mineral diesel fuel that is usually made from plant oils or animal fat through a series of chemical reactions. It is renewable in nature. It can be used directly in the diesel engine or with a little modification. Because biodiesel essentially comes from plants and animals, the sources can be replenished through farming and recycling. Biodiesel is basically a fuel composed of mono-alkyl esters of long chain fatty acids derived from variety of edible, non-edible oils, animal fats and from othersource like microalgae, etc. It is designated as B100, and confirming to different quality standards e.g. ASTM D 6751, IS 15607.

1.8 NEED OF BIODIESEL

An ever increasing demand of fuel has been achallenge for world scientist .The fissile fuels resources are dwindling day by day and its lavish consumption createsenvironmental degradation. So biodiesel seems to be solution for above crisis by reduction of carbon monoxide, overall carbon dioxide, hydrocarbons, Particulate matters help in economic development,including the creation of new jobs and new sources of income for farmers. When compared to several other alternative fuels available, Biodiesel comes out wayahead. Most alternative fuels required alteration and modification to a vehicle to be used. In most cases, once a vehicleundergoes the conversion necessary to run on the alternative fuel that cannot switch back to mother fuel again.Unlike other alternative fuels, Biodiesel can be used in unmodified diesel engine.

Due to the growing interest in the use of biodiesel, the EPA had conducted a broad study of the emission impacts of biodiesel This investigation made use of statistical regression analysis to compare the concentration of biodiesel in conventional diesel fuel with changes in regulated andUnregulated pollutants. The average effects are shown in fig.1.8 [47].

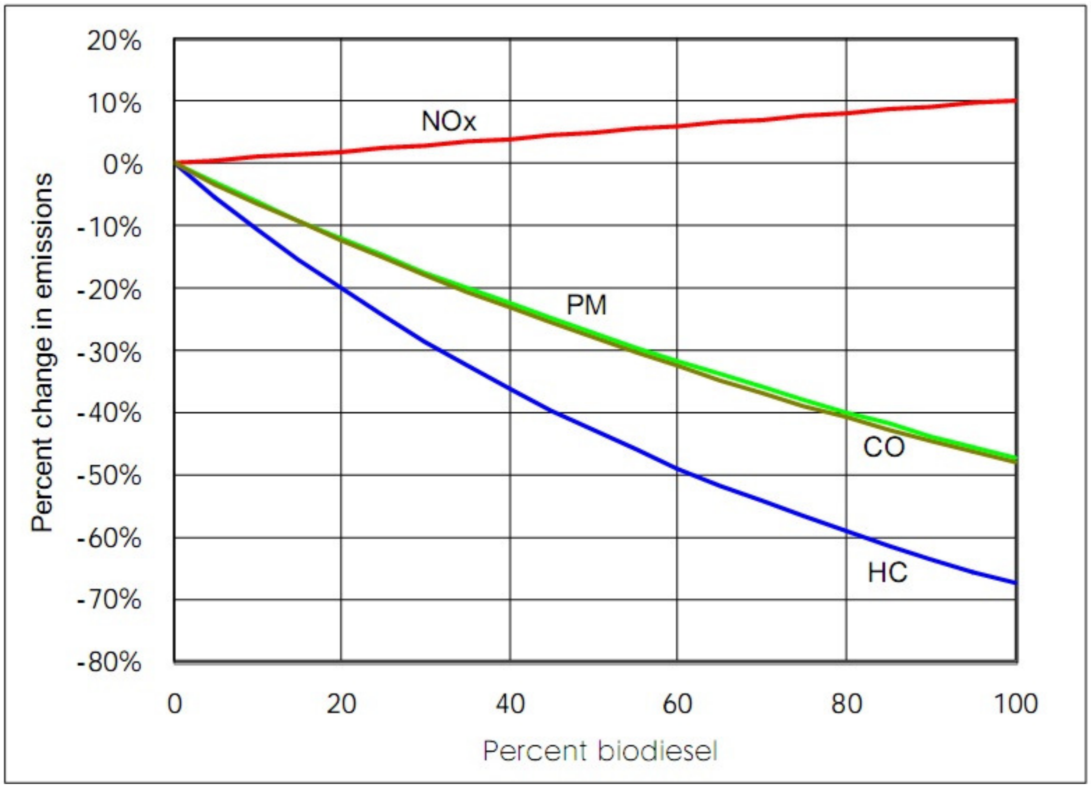

Fig 1.8:- Average emission impacts of biodiesel for heavy-duty highway engines.

1.9 INDIA'S BIOFUEL POLICY

National Bio fuel Steering Committee (NBSC) under the Prime Minister to set policy to Strengthen India's energy security by encouraging use of renewable energy resources to supplement transport fuels. An indicative 20-percent target for blending of bio fuel for both biodiesel and bio ethanol [7-33] which help to meet the energy needs of India's vast rural population, stimulating rural development and creating employment opportunities, address global concerns about net reduction of carbon emissions through use of environmentally friendly bio-fuels, derive bio-fuel from inedible feedstock grown on degraded soils or wastelands unsuited to food or feed production, thus avoiding a possible conflict of fuel- versus food security facilitate optimal development and utilization of indigenous biomass feedstock for production of bio-fuels.

The policy also envisages development of next-generation, more efficient bio fuel conversion technologies based on new feedstocks, fixed the minimum Support Price (MSP) mechanism to ensure a fair price for biodiesel oilseed growers..The state-owned Indian oil marketing companies propose to purchase bioethanol at a minimumPurchase Price (MPP) based on the actual cost of production and import price of bioethanol. Inthe case of biodiesel, the MPP should be linked to the prevailing retail diesel price..If necessary, the GOI proposes to create a National Biofuel Fund for providing financialincentives, including subsidies and grants, for new and second-generation feedstock's, advancedtechnologies and conversion processes, and production units based on new and second generation feedstock.

Bio-fuel technologies and projects would be allowed 100-percent foreign equity through anautomatic approval route to attract foreign direct investment (FDI), provided the biofuel is fordomestic use only, and not for export. Planting of inedible oil bearing plants would not be opento FDI participation.

1.10 ETHANOL POLICY

Ethanol is produced in India from sugarcane molasses for blending with gasoline. Beginning January 2003, the GOI mandated a 5-percent ethanol blend in gasoline through its ambitious Ethanol Blending Program (EBP). Ethanol and alcohol production in India depends largely on availability of sugar molasses (a by-product of sugar production). Since sugarcane production in India is cyclical, ethanol production also varies with sugar and sugarcane production and therefore does not assure optimum supply levels needed to meet the demand at any given time. Lower sugar molasses availability and consequent higher molasses prices affect the cost of production of ethanol, thereby disrupting the supply of ethanol for the blending program at pre-negotiated fixed ethanol prices [7].

1.11 BIO-DIESEL POLICY

The GOI had launched the National Bio-diesel Mission (NBM) after identifying Jatropha (Jatrophacurcas) as the most suitable tree-borne oilseed for biodiesel production. The Planning Commission of India set an ambitious target of planting 11.2 to 13.4 million hectares of land to Jatropha by the end of the 11thFive Year Plan (2011/12) to meet its mandate of 20% blending with diesel. The central government and several state governments provide fiscal incentives in support of planting Jatropha and other inedible oilseeds. Several public institutions, government departments, state biofuel boards, state agricultural universities and cooperative sectors are also supporting the biofuel mission in various capacities [33].

1.12 PRESENT WORK

In context of present work, a comprehensive discussion on adaptation of bio-origin oil is made. The bio origin fuel can provide a feasible solution. Biodiesel is the one of the bio-origin fuels, it can derived from vegetable oil (edible or inedible), animal fats .However in India it is not viable to produce biodiesel using edible oil to produce biodiesel because of a big difference in demand and supply of edible oil so biodiesel produce by inedible oils are viable. The inedible feedstock provide a benefit of growing on degraded soils or wastelands unsuited to food or feed production, thus its avoiding a possible conflict of fuel-versus food security.

Vegetable oils are the mixture of organic compound which contain straight chain compound to complex structure of proteins and fat which called triglycerides. Triglyceride made of one mole of glycerol and three moles of fatty acids. The vegetable oil has high viscosity (20.5-76.4mm^2/s) [34] than mineral diesel due to high molecular weight and complex molecular structure.

The neat vegetable oil is unsuitable for unmodified diesel engine due to high viscosity and poor volatility and presence of high free fatty acid .This result in high carbon deposit, injector cocking, piston ring sticking and lubrication dilution.

There are many methods for reducing the viscosity of vegetable oil by modifying its composition, namely blending of SVO with suitable solvent, micro emulsification, thermal cracking, pyrolysis and transesterification.

The transesterification is defined as the process of removal of all glycerine and fatty acid from the SVO. Its convert the triple chain triglyceride SVO molecule to three single chain methyl or ethyl ester molecules but the chain length of fatty acid is remains same. Biodiesel has lower viscosity than SVO because of removal of all glycerol and fatty acid from SVO.As per ASTM D6751 biodiesel has high cetane number (47-65) than diesel (40-55) means that biodiesel ignite more easily but have high viscosity (1.9-6.0)mm^2/s than diesel (1.3-4.1)mm^2/s it means slightly poor atomization While ethanol have low cetane number (6) and low viscosity (1.2 mm^2/s).The blend of Ethanol in biodiesel is improve the fuel property of biodiesel both fuel are bio-origin product which provide alternative to mineral diesel and sustainable energy.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

As already explain in previous chapter that arbitrary extraction and generous consumption of fossil fuels have led to reduction in underground based carbon resources. However, Fossils fuels are obtained from limited reserved which are highly concentrated in certain region of earth.The world reserves of primary energy and raw materials are, obviously, limited. According to world energy report 2011, the world has in reserves 861 billion tons of coal, 187 trillion cubic meters of natural gas, and 1383 billion barrels of crude oil. These numbers seems to be huge at a glance, but taking into account today's level of extraction proved the reserves will last for 118 years for coal, 46 years for oil, and 59 years for natural gas [5].The search for alternative fuels, which promise a sustainable development, energy conservation, efficiency and environmental protection, has become priority in the present context.

The fuels of bio-origin can provide a feasible solution to this worldwide fossil fuel crisis. The automobilesemissions are the major sources of environmental degradation. A renewable fuel such as biodiesel and ethanol with lesser exhaust emissions is the need of the day. Hence, worldwide researchers and scientific community have focused on performance and emission study of use of biodiesel and ethanol to meet the standards and specifications needed for the fuel to be used commercially without compromising on the durability of engine parts and shield the environment. For last 2-3 decades alcohol are use with 5% to 20% blend with gasoline worldwide due to their renewable in nature and low emission but their use in C.I. engine due to high octane number and high self ignition temperature are main impediment. For past few decade world-wide researchers conducted experiment and study the performance of using blend of ethanol with biodiesel and diesel fuel on C I engine as renewable fuel.

2.1 BIOFUEL AS POTENTIAL OF C.I.ENGINE FUEL

Rudolf's diesel's first engine ran on peanut vegetable oil at the world co-exhibition in Paris in 1900 because he was able to see the advantage of vegetable oil in agriculture and environment, before his vision of vegetable oil became a reality, he died. The engine was only named on his name "**DIESEL**" but apart from running on vegetables oils, the technology is adapted to run it on petroleum. Now the world has awakened because the fossil fuel resources are dwindling day by day.

Many bio fuel, energy resources were explored include biomass, biogas, vegetable oils, biodiesel, alcohols, etc. in the past few decades. Out of above vegetable oils, biodiesel and alcohols are considered as very much appropriate for diesel engine.

Table2.1:-Properties of neat inedible vegetable oils & diesel [34]

PROPERTY	JATROPHA	KARANJA	MAHUA	LINSEED	RUBBER SEED	COTTON SEED	NEEM	DIESEL
Density(Kg/m3, 40°C	901-940	870-928	891-960	865-950	910-930	911-921	912-965	0.82302
Viscosity(mm^2/s, 40°C)	24.5-52.76	27.8-56	24.6-37.6	16.2-36.6	34.0-76.4	32.8-36.0	20.5-48.2	1.3-4.1
Flash point(C)	180-280	198-263	212-260	108-242	144-198	210-243	34-285	45 min
Pour point(C)	-3 to5	-3to6	12-15	-15 to -4	-1	-10 to 16	-	-20 to 5
Cloud point(C)	8-10	13-15	12	1.7-2.0	14	-8.7 to 1.7	-	-
Cetane number	33.7-42.15	45-67	43.5	28-35	37	41.2-59.5	51	45
Calorific value (MJ/kg)	38.20-42.15	34.0-38.8	35.6-38.9	37.7-39.8	37.5	39.5-40.1	33.7-39.5	45.669

The interest in the use of renewable fuel started with the direct use of vegetable oils as a substitute for diesel. However, their direct use in compression ignition engines was restricted due to high viscosity 35-60 cSt compared to 4 cSt for diesel which resulted in poor fuel atomization, high flash point 150-293 ^{o}C attributes to its lower volatility characteristics. This results in high carbon deposit formation, injector coking, piston ring sticking and lubrication oil dilution and oil degradation. The combination of high viscosity and low volatility of vegetable oils cause poor cold starting, misfire and ignition delay.

Extensive efforts have been made to develop vegetable oil derivatives that approach the properties and performance of mineral diesel oil. Vegetable oils can be used through at least four ways:

- Direct use and blending.
- Micro-emulsion.
- Pyrolysis (thermal cracking).
- Transesterification.
-

Many oxygenated fuels are investigated for lowering the harmful exhaust emissions from the diesel engine, which have the potential for use as the diesel fuel. Those oxygenates can be classified as alcohol, ether, ester, carbonate and acetate compounds. The biodiesel which is one of substitute for diesel fuel belongs to ester compound in the above classification. The term ‘‘biodiesel’ commonly refers to an oxygenated diesel fuel made from various feedstock’s by conversion of the triglyceride fats to mainly methyl or ethyl esters via esterification followed by transesterification. In general, biodiesel feedstock can be categorized into four groups [4]: oilseeds (edible or inedible oil), animal fats, waste materials and algae [23].

Table:-2.2 properties of biodiesel and ASTMstandards of biodiesel [34]

PROPERTY	JOME	KOME	MOME	LOME	ROME	COME	NOME	ASTM
Density(Kg/m3,40oC	862-886	865-898	828-865	874-920	858-900	872-885	820-942	870-900
Viscosity(mm2/s, 40oC)	3.0-5.65	3.8-9.6	2.7-6.2	3.36-8.91	1.9-6.0	3.6-5.94	3.2-10.7	1.9-6.0
Flash point(C)	180-280	110-187	56-208	161-181	130-174	70-200	-	>130
Pour point(C)	2-6	-6 to 14	1-6	-18 to14	-15 to 10	-15 to 6.0	-	-15 to 10
Cloud point(C)	4-10	-2 to 24	3-5	-3.5	-3 to 12	-	-	-
Cetane number	43-59	36-61	47-51	48-59	49-57	45-60	51-53	47 min
Calorific value (MJ/kg)	37.2-43.0	36.0-42.1	36.8-43	37.5-42.2	36.5-42.1	40.1-40.8	39.6-40.2	-

2.2 ETHANOL AS A C.I. ENGINE FUEL

Ethanol is suitably used in gasoline engines for many decades. Raw material used for producing ethanol varies from sugar in Brazil, cereals in USA, sugar beet in Europe to molasses in India. Brazil uses ethanol as 100 % fuel in about 20% of vehicles and 25% blend with gasoline in the rest of the vehicles. USA uses 10% ethanol-gasoline blends while India use 5-20% blend with gasoline.

Ethanol is one of the possible fuels for diesel replacement in compression ignition (CI) engines also. The application of ethanol as a supplementary CI engine fuel may reduce environmental pollution, decentralized the production, results reduce the transportation cost, strengthen agricultural economy, create job opportunities, reduce diesel fuel requirements, save foreign exchange and thus contribute in conserving a major commercial energy resource. Ethanol was first suggested as an automotive fuel in USA in the 1930s, but was widely used only after 1970 [31].

Despite the fact that transesterification reduces the viscosity and increases the volatility of esters derived from vegetable oils but when compared to diesel, it is still having quite higher viscosity and lower volatility. To overcome these problems, addition of some oxygenated compounds like alcohols in biodiesel fuel is found to be helpful.

So addition of ethanol will solve the above problems by giving some other advantages of reduction in emissions and balance between different crops.

2.3 LITERATURE REVIEW

Prommes et.al. studied the phase diagram of diesel-biodiesel-ethanol blends at different purities of ethanol (95%,99.5% and 99.9%) at different temperature and also find out the physical chemical properties of selected blend and examined the emission performance in a diesel engine and compared with base diesel. Diesel and ethanol with 95% purity were Insoluble. In case of 99.5% ethanol, the inter solubility of three components was not limited. They could be mixed into a homogeneous solution at any ratio. However 99.55% ethanol was much cheaper than 99.9% ethanol so they recommended for 99.5% ethanol.

At the temperature of 10^{o}C the mixture of diesel and ethanol in the range of 20-80 %by volume were in clear liquid and crystalline phase. The mixture of biodiesel and ethanol form true solution, which can easily blend. Therefore at 20^{o}C, ethanol was completely miscible in diesel, when diesel concentration was lower than 30% or higher than 70%.At 30^{o}C all blend were liquid 1-phase.

It observed that the blend of 90% diesel,5%ethanol and5% biodiesel had very closed fuel properties compared to diesel. Emission of the blends CO and HC reduce significantly at high engine load, where NOx increased when compare with diesel [11].

Di et. al. conducted experiment on four cylinder direct injection diesel engine using ultra low sulphur diesel blended with biodiesel and ethanol at maximum torque speed of 1800 rpm at varies load and investigate regulated and unregulated gaseous emission and found that the Brake specific HC and CO emission decrease while NOx and NO_2 emission increases in case of diesel –biodiesel fuel. The emission of formaldehyde, 1, 3 but aldehyde, toluene, and overall BTX (benzene, toluene, xylene)in general decreases, however acetaldehyde and benzene emissions increases. In case of diesel-ethanol fuel Brake specific HC and CO emission increases significantly and NOx emission decreases at low engine load. The emission of benzene and BTX vary with engine load and ethanol contents. Similar to the biodiesel-diesel fuel the formaldehyde, 1,3 butadiene, toluene, xylene emission decreases while the acetaldehyde and NOx emission increase. It was observed that there are significant difference in the gaseous emission between the biodiesel-diesel blend and the ethanol-diesel blend. [25].

Han et. al. investigated the injection and atomization characteristics of biodiesel-ethanol blend and found that ethanol will affect the decrease of peak injection rate and shortening of the injection delay due to decrease of fuel properties such as: density and dynamic viscosity in addition to that, the ethanol improves the atomization performance of biodiesel fuel because the ethanol blended fuel have a low kinematic viscosity and surface tension, then that has more active interaction with the ambient gas, compared to biodiesel [23].

Zhu et.al.studied emission characteristics of four cylinders direct injection diesel engine at 1800 rpm operating on biodiesel and biodiesel blended with ethanol and methanol and compare with euro V diesel fuel and concluded that, bsfc of the blended fuel increase with increase the percentage of ethanol or methanol in blend. The effect of CO and HC emission depend on the percentage of alcohol in blended fuel. For the 10 % and 15% blends, the HC and CO emissions increase compared with biodiesel and euro V diesel fuel. Moreover the methanol blends give higher HC and CO emission than the ethanol blend. The blended fuel can reduce the NOx emission to level lower than that of diesel fuel. The NOx reduction increases in the percentage of ethanol and methanol in the blended fuel while the methanol blends were more effective due to higher latent heat of evaporation. The particulate mass concentration were also decrease with the blended fuels except for the 15% blends at the engine load at 0.08 MPa [18].

Randazzo et.al. investigated the exhaust emission from a diesel powered vehicles fuelled by soybean biodiesel blends (B3-B20) with ethanol as an additives (B20E2-B20E5).The blends of diesel oil and soybean biodiesel with concentration of 3% (B3), 5%(B5) 10% and 20% were used as fuels on a passenger vehicles and also the effect of anhydrous ethanol as an additive to B20 fuel blends with concentration with 2 % (B20E2) and 5 %(B20E5).The emission tests were carried out following the new European driving cycle (NADC).It was found that increasing the percentage of biodiesel in the fuel blend,increase CO_2 and NOx emission while CO, HC and particulate matter (PM) emission were reduced. The addition of anhydrous ethanol to B20 fuel blend show that it can be used to control exhaust NOx and global warming effect through the reduction of CO_2 but it also requires fuel injection modification as it increases CO, HC and PM emissions [12].

Zhu et.al. has studied combustion, performance and emission characteristics of direct injection diesel engine fuel with ethanol-biodiesel blend and compared with euro V fuels for biodiesel, the maximum pressure was higher at high engine loads, and the maximum heat released rate of premixed combustion phase was lower in all test modes and occurs earlier. Combustion starts earlier and combustion duration was shorter. It was observed that maximum pressure and heat release rate of BE blends increases with increase of ethanol percentage in the blended fuel and occurs further away from the TDC, when compared with biodiesel, the start of combustion was retarded and combustion duration was shortened. The BTE was increased slightly with BE5 while there were no significant difference with BE10 and BE15. Biodiesel produce lower BSCO,BSHC and BSPM emission while higher BSNOx and $BSNO_2$ emissions in comparison with the euro V diesel fuels.When compared with biodiesel BE5 give slightly lower BSCO and BSHC emissions in all test modes while BE10, BE15 have higher BSCO and BSHC emissions at light and medium engine load but similar level of emissions at medium and high engine load, biodiesel give lower PM but higher NOx emissions. However BE blends give lower PM emissions as lower NOx emissions [13].

Hulwan et.al. Explored the feasibility of using high percentage of ethanol in diesel blends with use of Jatropha derived ethyl ester as a co-solvent and property enhancer. The blend tested were D70E20B10 (blend A), D50E30B20 (blend B), D50E40B10 (blend C), and diesel (D100).The experiments are conducted on a multi-cylinder, direct injection diesel engine whose original injection timing was 13 degrees CA BTDC and found that the engine did not run on blend B and C at this injection timing and it was required to advance time to 18^o and 21^o CA BTDC to enable the use of blends B and C respectively. However advancing in injection timing almost double the NOx emission and increase peak firing pressure and combustion process of this blend delay with low load, but approached to the diesel fuels at high load. The results compared with base line diesel and observed that BSFC increase considerably while thermal efficiency improves slightly, smoke opacity reduce remarkably at high load. Variation of NO emission depends upon operating condition while CO emission drastically increase at low load, blend B which has given satisfactory performance for steady state running of diesel engine up to 1600 rpm.[19].

Mendow et.al. Carried experiment of biodiesel production by two stage transesterification with ethanol. Two stage processes consisting of two reaction steps of glycerine separations and ethanol/catalyst addition in each of them was optimized for ethyl ester productions. The optimal reaction temperature was 55^oC at an ethanol/oil molar ratio of 4.25:1(25% V/V alcohol with respect to oil), 99% conversion value was obtained with low ethanol conversion. In view of above contrast two methoxides catalyst, sodium and potassium hydroxide catalyst severely complicate the purification since no phase separation took place under most condition with a total sodium methoxide concentration of 1.06 gm catalyst/100 gm oil and adding 50% of the catalyst in each reaction step. Biodiesel with total glycerine contents of 0.172% was obtained. The optimal condition was found in this study make it possible to use the same industrial facility to produce either methyl or ethyl ester[24].

Barros et. al. developed a method for determination of the sodium and potassium in biodiesel by flame atomic emission spectrometry(FAES) with dissolution in ethanol as a single sample preparation step.The presence of metals in biodiesel can cause various mechanical problems in vehicles such as corrosion of engine parts and deactivation of catalyst which consequently contributes to environmental degradation. Several metals can be incorporated into biodiesel during its manufacturing.One of the most common process employed for biodiesel production is catalytic transesterification in which sodium and potassium hydroxide were used as catalyst.This procedure can introduce large amount of sodium and potassium into the final composition of biodiesel.

Investigation showed that FAES was a simple, relatively inexpensive analytical technique for determination of sodium and potassium in biodiesel. In this process washing of biodiesel was used to adjustment of viscosity and free of an alights[15].

Botero et.al. examined free-falling droplets of ethanol, diesel, biodiesel(castor oil) and their mixture in a high temperature combustion chamber and studied combustion characteristics including the burning rate, micro explosion, sooting propensity. It was found that biodiesel to diesel significantly reduce the extent of soots formation and slightly reduce the burning rate in addition to higher soot formation of methyl stearate than castor oil biodiesel. By adding of ethanol to diesel and biodiesel, micro explosion is observed, .The biodiesel/ethanol mixture exhibiting stronger propensity,leading to significantly reduce gasification time and extend of soot formation [16].

Yilmaz et.al. analyzed operation of a diesel engine on biodiesel-ethanol and biodiesel-methanol blends and compare with diesel and biodiesel. The fuel D100,B100, B85M15 and B85E15 were used on a two cylinder, 4 stroke direct injected water cool diesel engine at 5 loads between low load to full load at 3000 rpm and found that biodiesel alcohol blends as compared to diesel reduce NO emission while increasing CO and HC emission at below 70% load. It was also found that biodiesel ethanol blends is more effective than biodiesel methanol for reduction emissions and overall engine performance[21].

Carareto et. al. measured the flash point of some pure fatty acids ethyl ester and their mixture ethanol and formulate the empirical models to predict the flash point(FP) of pure fatty acids and ethyl ester FAEE and show that FP of pure FAEE as a function of the number of carbon strong an double bond of acidic chain. The above relationalso measure the flash point for binary and multi component mixture containing methyl and ethanol [17].

Hussan et.al. studied chemical properties of biodiesel are tailored by ethanol and optimum formulations are derived mathematically. Ethanol is used as control proportion 6 % with palm oil methyl ester (POME) as a additive to reduce the higher viscosity of POME. This optimum palm oil biodiesel- ethanol blends were mixed at various proportions i.e. (0-30%) with diesel to produce ternary blends of palm biodiesel. Cold-flow properties such as core pour point of this ternary blends has improved by adding of a minute percentage of ethanol adding did not adversary the oxidation stability and corrosiveness of the fuel blends. Ethanol has significantly reduced the flash point but the flammability of ternary blend is similar to that of diesel. Cetane number were reduced in ternary blends by adding ethanol [22].

Lin et.al. studied the profit and policy implications of producing biodiesels-ethanol-diesel fuels blends to specification and developed a non-linear optimization model to analyze biodiesel, ethanol & diesel (BED).This model establish optimum blends to improve the system profitability given production cost, market demand and fuel price while meeting multiple property criteria such as kinematic viscosity, density, lower heating value, cloud point, cetane number. The proposed optimization model in this study integrated with pertinent mixing rules of fuel properties enables stabilizing the optimum recipes to improve the system profitability by meeting multi objectives and promoting opportunity to develop potential additives to improve blend fuel quality[20].

Fang et.al. investigated the effect of ethanol on combustion and emission in premixed low temperature combustion (LTC) in a four cylinder heavy duty diesel engine. In this investigation biodiesel was used as additive to prevent the stratification of ethanol and diesel blends. The premixed low temperature combustion was achieved by the medium level of exhaust gas recirculation and the prolonged ignition delay. The lower combustion temperature, lead to higher HC and CO emissions. It was found that ethanol-diesel-biodiesel is effective in reducing NOxemissions and smoke simultaneously in premixed LTC. The EBD blends fuels were also good to extend the load range of premixed LTC [26].

Sahoo et.al. evaluated performance and emission characteristic of Jatropha, karanja and polanga bio diesel of 20%,50% blend with mineral diesel and observed that trasesterification process of vegetable oil, improved the fuel property of the oil which was relatively closer to mineral diesel. During the full throttle engine performance test, significant change in power was not observed for the three cylinder tractor engine at lower speed of 1200 and 1400 rpm for all the biodiesel blends. However slight reduction in power was observed at all speed with biodiesel blends of KB20,KB100,JB100,PB20 and PB100.The maximum increase in power was observed for JB50 at 2000 and 2100 rpm for all the biodiesel blends. The investigation showed that higher percentage of biodiesel in diesel, tends to decrease the exhaust smoke, HC, and PM substantially, however slightly increase of NOx [35].

Karnwal et.al. analysed the optimisation of transesterification process to prepared the Thumba oil methyl ester which depends on various processed variables, like temperature, catalyst concentration, amount of methanol and reaction time. It was observed that optimum condition for transesterification of Thumba oil with methanol and KOH as catalyst was to be 60^oC reaction temperature, 6:1 molar ratio of Thumba oil to methanol, 0.75% catalyst (w/w_{oil}) and one hour reaction time [37].

Chauhan et.al. explored the feasibility to use neat Jatropha oil as fuel in unmodified diesel engine .It were observed that performance of the engine fuelled with neat Jatropha oil was slightly inferior than diesel.The BTE of the engine was lower and BSFC was higher on Jatrophaoil than diesel. The NOxemission of Jatropha oil during entire experiment were lower while HC,CO, and CO_2 emission is higher than diesel respectively [38].

Sukumaran et.al. investigated the prospect, challenges and feedstock availability of lignocelluloses ethanol in India and discuss the current status of molasses based ethanol production in India and its limitations, the state of technology for second generation ethanol production and availability of feedstock for bio-ethanol production. It was observed that the Lignocellulosic biomass only resource that can be used,since India doesnot have surplus grains or other starchy biomass to spare for fuelapplications. However, the technologyfor ethanol production from lignocellulosic biomass was complex and more challenging. The country lack mature technologies for ethanol production from lignocellulosic biomass and though biomass itself is cheap, the costs of its processing are relatively higher. Technologies for biomass toethanol conversion were also under preliminary stages of development.Various bottle necks in such technologies include the pre-treatment of biomass, enzymatic scarifizcation of the pre-treated biomass, and fermentation of the hexose and pentose sugars releasedby the hydrolysis and saccharification. Each of these problems needs substantial R&D efforts for improved efficiency andprocess economics. Major initiatives are needed in overall processintegration and working out the process scenario, cost inputs andpotential gains weighed against it [39].

Pugazhvadivuet.al. conducted the experiment to study performance and emission characteristics of diesel engine by ethanol addition to pongamia biodiesel and diesel in different ratio and find that the addition of ethanol to B100 and D50B50fuels result marginal decrease in thermal efficiency.TheNOxemissions decreased at low or medium power output significantly but marginally decrease at rated power output. He was concluded that the addition of 5% to 10% ethanol with biodiesel fuels can extend the availability of diesel and reduce the NOx and smoke emission simultaneously[41].

Qi et. al. aimed on the efficient use of ethanol–biodiesel–water micro-emulsions in a diesel engine. In this experiment neat biodiesel and the micro-emulsions as fuels under variable operating conditions were used and compared with biodiesel and observed that the peak cylinder pressure of the micro-emulsions is almost identical, and the peak pressure rise rate and peak heat release rate are higher at medium and high engine loads however at low engine loads, those of the micro-emulsions were lower. The start of combustion was later for the micro-emulsions than for biodiesel. For the micro-emulsions, there wasslightly higher brake specific fuel consumption (BSFC), while lower brake specific energy consumption (BSEC). Drastic reduction in smoke is observed with the micro-emulsions at high engine loads. Nitrogen oxide (NOx) emissions were found slightly lower under all rang of engine load for the micro-emulsions. But carbon monoxide (CO) and hydrocarbon (HC) emissions were slightly higher for the micro-emulsions than that for biodiesel at low and medium engine loads [40].

Bawankure et.al. evaluated the performance of diesel engine by diesel, ethanol and methyl ester blends. He use diesel blended with ethanol at 10, 20,30 and 40% respectively with addition of small amount of biodiesel as additive and observed that BSFC increase gradually by addition of ethanol, the BTE with diesel ethanol blends increase for low and medium load compared to diesel fuel by addition of ethanol and biodiesel improve the combustion characteristics of diesel fuel [42].

Krishnaswamy et.al. evaluated the performance of biodiesel with oxygenated biofuel blends and found that EBD blends at similar viscosity as diesel and good phase stability than ethanol diesel blends. The BSFC slightly increase and BTE improve with respect to base diesel.CO emission and HC slightly increase at low load while NO emission decrease. Blending of renewable fuels with diesel helps to achieve low carbon emissions from diesel engine [43].

Chauhan et al. compared performance, emission and combustion characteristics of biodiesel derived from Jatropha oil in a dual fuel diesel engine with base line results of diesel fuel. The brake thermal efficiency of Jatropha methyl ester and itsblends with diesel were lower than diesel and brake specific energy consumption was found to be higher.However, HC, CO and CO_2 and smoke were found to be lower with Jatropha biodiesel fuel. NOx emissionsonJatropha biodiesel and its blend were higher than Diesel[48].

Agarwal et al. studied, performance, emission and combustion characteristics of Karanja oil blends (K10,K20, K50 and K100) with mineral diesel in unheated conditions in a direct injection CIengine at different engine loads and constant engine speed (.1500 rpm.) and compared to baseline data frommineral diesel. Detailed combustion analysis revealed that the combustion duration increased significantly even with smaller concentration of Karanja oil in the fuel blend. HC, CO, and Smokeemissions were found to decrease for 20-50% (v/v) Karanja oil content in the fuel blends. [49]

2.4 STATEMENT OF PROBLEM

There are very few research on biodiesel blended with ethanol used as a CI engine fuel.

On the basis of the exhaustive literature review, it has been observed that biodiesel and ethanol are easily miscible and blending of ethanolandbiodieselshall result in decreases of viscosity of biodiesel result improve atomisation combustion quality and the emission characteristics of biodiesel. So it can be used as a potential substitute of mineral diesel without any modification in the existing engine.Using of biodiesel and ethanol is beneficial for the balance of carbon.

The main objectives for the present research works are as follows:-

1. Comprehensive literature review.
2. Preparation of Jatrophamethyl ester or Jatropha biodiesel
3. Preparation of Ethanol and Jatropha biodiesel blends in different ratio.
4. Determination of important Physico-chemical properties of neat Jatropha biodiesel, ethanol,Ethanoland Jatropha biodiesel blends and mineral diesel.
5. Development of diesel engine test rig.
6. Exhaustive experiments to evaluate performance and emission characteristics of engine on Jatropha biodiesel and Ethanol and Jatropha biodiesel blends and compare them with base line data.
7. Analysis of Results

CHAPTER 3

SYSTEM DEVELOPMENT & EXPERIMENT PROCEDURE

3.0 INTRODUCTION

Diesel engine are most versatile efficient engine which are mostly use as main prime movers in transportation, decentralized electric generation ,agricultures, which produce environment degradable emission and create long term energy security threat due to limited resources of mineral diesel.In view of above fact it has become necessary to explore renewable alternative fuel from resources available locally within the country such as alcohol, biodiesel, vegetable oils etc. whose properties are comparable with mineral diesel and it can be used in the existing C.I. engine without any major hardware modification.

Also the fuel should meet the energy needs of India’s vast rural population, stimulating rural development and creating employment opportunities. Apart from this, it should address global concerns about net reduction of carbon emissions. Biofuels derived from inedible feedstock provide a benefit of growing on degraded soils or wastelands unsuited to food or feed production, thus avoiding a possible conflict of fuel versus food security.

3.1 JATROPHA PLANT DESCRIPTION

The Jatropha plant (JatrophaCurcas) or physic nut is a shrub or a small tree belonging to the genus Euphorbiaceae. The Jatropha plant originated from South America, but now the plant can be found worldwideeverywhere in arid and semi arid tropical and sub-tropical countries. The Jatropha plant can be grown in almost all types of soils. It can even be grown in very poor soil and still produce a high average yield of seeds. However, light sandy soil is the most favourable. The Jatropha plant is a multiple use plant. Jatropha can be found from sea level to high altitudes. The tree grows to a maximum height of nearly 8m. The Jatropha fruit maturation takes 45 to 50 days.

The plant starts producing yield 4 to 5 months after planting. The Jatropha trees produce a round fruit with a soft brownish skin, which have 1.5 – 3 cm in diameter and weigh 1.5 – 3 g. The seeds contain about 30-35% oil.

3.2. CONVERSION OF JATROPHA CURCAS OIL TO JATROPHA METHYL ESTER

The production of Jatropha biodiesel is a chemical process whereby the oil molecules (triglycerides) are cut to pieces and connected to methanol molecules to form the Jatropha methyl ester. An alkali normally sodium hydroxide (caustic soda) is needed to catalyze the reaction. Glycerine (glycerol) is formed as a side product. Methanol is normally used as the alcohol for reasons of cost and technical efficiencies. This process is summarized in Fig.3.1.

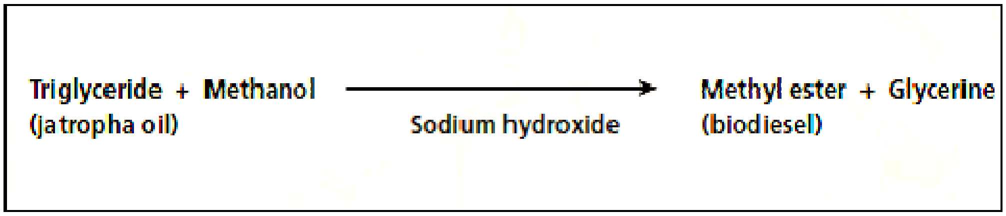

Fig:-3.1Process of conversion of vegitable oil to biodiesel

Sodium hydroxide is dissolved in methanol to form sodium methoxide, which is then mixed with Jatropha oil. The glycerine separates out and is drained off. The raw biodiesel is then washed with water to remove any remaining methanol and impurities.

As already seen in literatures, the viscosity, volatility and exhaust emissions of vegetable oils deviate far away from properties of diesel. To make use of vegetable oils in a effective way it should be converted into biodiesel using a single or a two step conversion process which depend upon the free fatty acid. Normally the free fatty acid (FFA) of Jatropha oil is quite high i.e. over 5 %. So we need to undergo Esterification process with the help of alcohols like methanol, ethanol etc. and acid catalyst like PTSA or H_2SO_4 etc. which reduces the amount of FFA in oil. This Esterified oil of nearly 1% FFA is now Transesterified with the help of alcohols and base catalyst like NaOH and KOH to get biodiesel.

Plate 3.1:- Biodiesel reactor(10 litre capacity)

.By gradually adding of solution of KOH and methanol, after some time glycerol is separated.

Now cold liquid put up in separating funnel allowing glycerol and methyl ester to separate by gravity for overnight. Washing of methyl ester by luke warm water to remove the catalyst and methanol. Now the mixture is heated at 100^0C, therefore the final outcome is biodiesel.

3.3 DEVELOPMENT OF JATROPHA BIODIESEL AND ETHANOL BLEND

The mixture of biodiesel and anhydrous ethanol (99.5%) form a true and stable solution [11].The blending of Jatropha biodiesel and ethanol is a very easy process.The blend is prepared by addition of Ethanol in Jatropha biodiesel volume by volume.

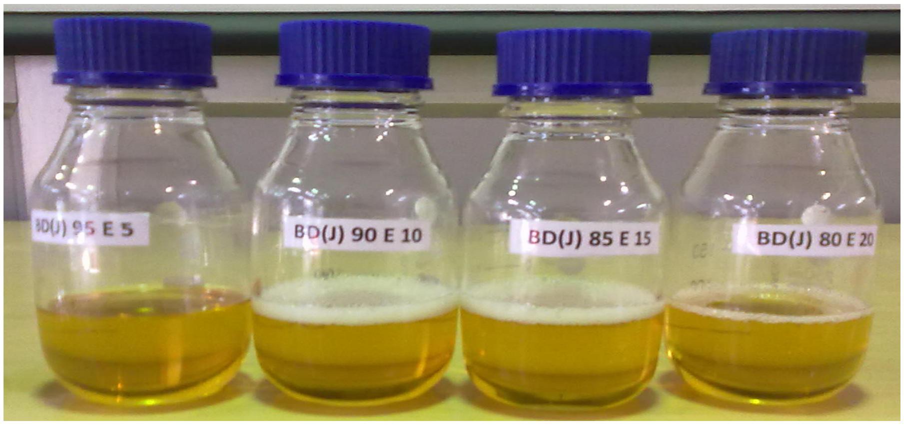

Plate 3.2 :- Different % of blend Jatropha biodiesel and Ethanol

3.4 DETERMINATION OFPHYSICO-CHEMICAL PROPERTIES

The process and instrument used to measure the physical-chemical property of testing fuel blend during the presentinvestigation are summarised below**.**

3.4.1 PHASE SEPARATION & HOMOGENEITY

No phase separation was observed in the blend even after four month.The sample was kept in air tight glass bottle and they remained homogeneous which was regularly observed in interval of one month.

3.4.2 DENSITY

Density is the mass per unit volume. The measurement was made at room temperature. The density was measured with the help of a U-Tube Oscillating True Density meter. The density of Jatropha oil and micro emulsion with ethanol was measured and then compared with that of diesel fuel. The equipment used for density determination is shown in Plate 3.3.

Plate 3.3:- U-Tube Oscillating True Density Meter

3.4.3 KINEMATIC VISCOSITY

When a fluid is subjected to external forces, it resists flow due to internal friction. Viscosity is a measure of internal friction. The viscosity of the fuel affects atomization and fuel delivery rates. It is an important property because if it is too low and too high then atomization and mixing of air and fuel in combustion chamber gets affected. Kinematic viscosity of liquid fuel samples were measured using Kinematic viscometer shown in fig. 3.2 at 40^0C as per the specification given in ASTM D445. A suitable capillary tube was selected, and then a measured quantity of sample was allowed to flow through the capillary viscometer. Efflux time was measured by stop watch for calculating Kinematic viscosity.

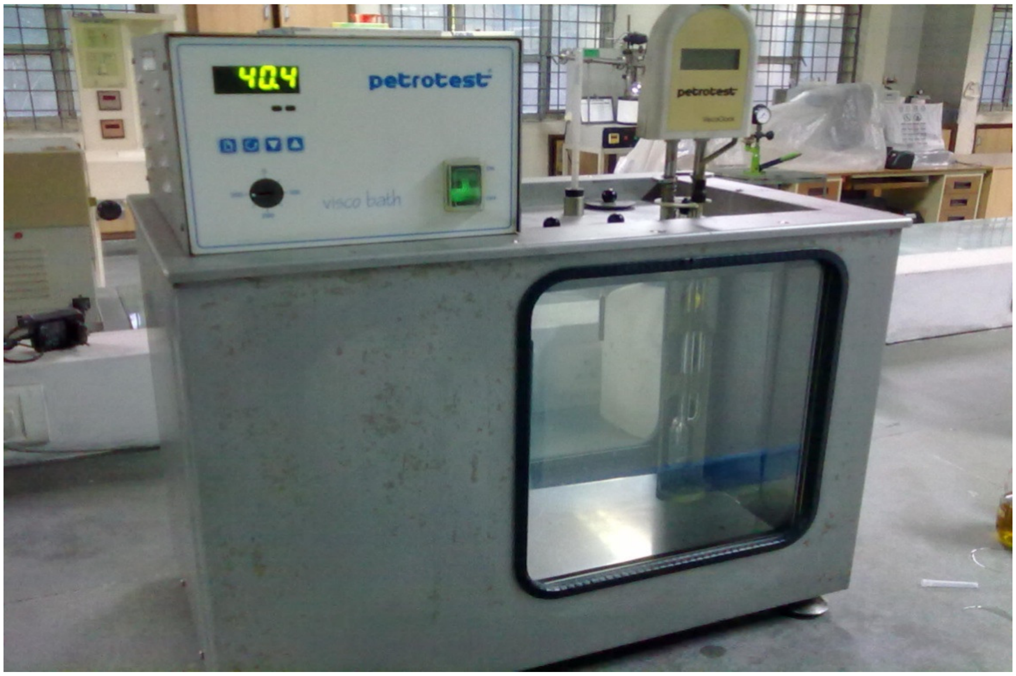

Plate 3.4:- Kinematic Viscometer

3.4.4 CALORIFIC VALUE

The calorific value is defined in terms of the number of heat units liberated when unit mass of fuel is completely burnt in a calorimeter under specified conditions. Higher calorific value of fuel is the total heat liberated in kJ per kg or m3. All fuels containing hydrogen in the available form will combine with oxygen and form steam during the process of combustion. If the products of combustion are cooled to its initial temperature, the steam formed as a result will condense. Thus maximum heat is abstracted. This heat value is called the higher calorific value.

The calorific value of the fuel was determined with the Isothermal Bomb Calorimeter as per the specification given in ASTM D240. The combustion of fuel takes place at constant volume in a totally enclosed vessel in the presence of oxygen. The sample of fuel was ignited electrically. The water equivalent of bomb calorimeter was determined by burning a known quantity of benzoic acid and heat liberated is absorbed by a known mass of water. Then the fuel samples were burnt in bomb calorimeter and the calorific value of all samples were calculated. The Bomb Calorimeter used for determination of calorific value.

Plate:- 3.5 Bomb calorimeter Plate:-3.6 Sample weight machine

3.4.5 COLD FILTER PLUGGING POINT

The cold filter plugging point is defined as the highest temperature (expressed as a multiple of 1^{o}C) at which the fuel, when cooled under the prescribed conditions, will not flow through the filter or requires more than 60 seconds for 20 ml to pass through or fails to return then completely to the test jar.

This method describes a procedure for the determination of the low temperature operability of distilled fuels. In this method, the fuel sample is cooled under the prescribed intervals of 1^{o}C, a vacuum of 200 mm water gauge is applied to draw the fuel through a fine wire mesh filter in to the aspiration pipette. As the fuel cools below its cloud point, increasing amount of wax crystals will be formed. These will cause the flow rate to decrease and eventually complete plugging of the filter will occur. When the aspiration time took more than 60 second, the temperature of the sample at that time of the beginning of the aspiration test is recorded as result value.

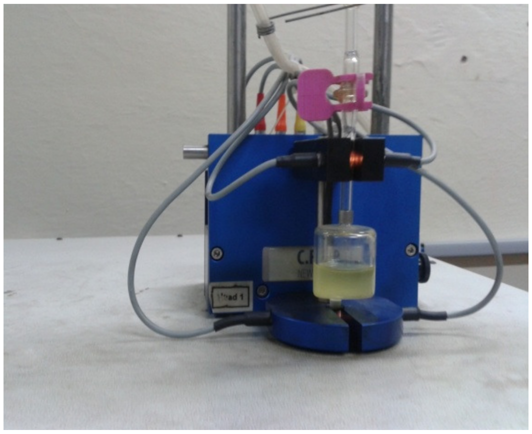

Plate:-3.7Aspiration Pipette of CFPP Meter

Plate:-3.8 CFPP METER NEWLAB 200

3.5 SELECTION OF DIESEL ENGINE

Due to the low operation cost in India, simple robust structure and high load carrying capacity diesel engines are preferred more than the petrol engine in agriculture, small scale electric generation in village, marine and other load carrying locomotives. The price difference between diesel fuel and petrol in India has attracted the manufacturers to make vehicles having diesel engine.

Air Pollution created by diesel engine is also more severe than the petrol engine. Due to the large scale uses of diesel engine create more air pollution. So it is necessary to search an alternative renewable fuel which is able to decrease the air pollution and harmful emissions in considerable amount.

3.6 DEVELOPMENT OF AN EXPERIMENTAL TEST RIG

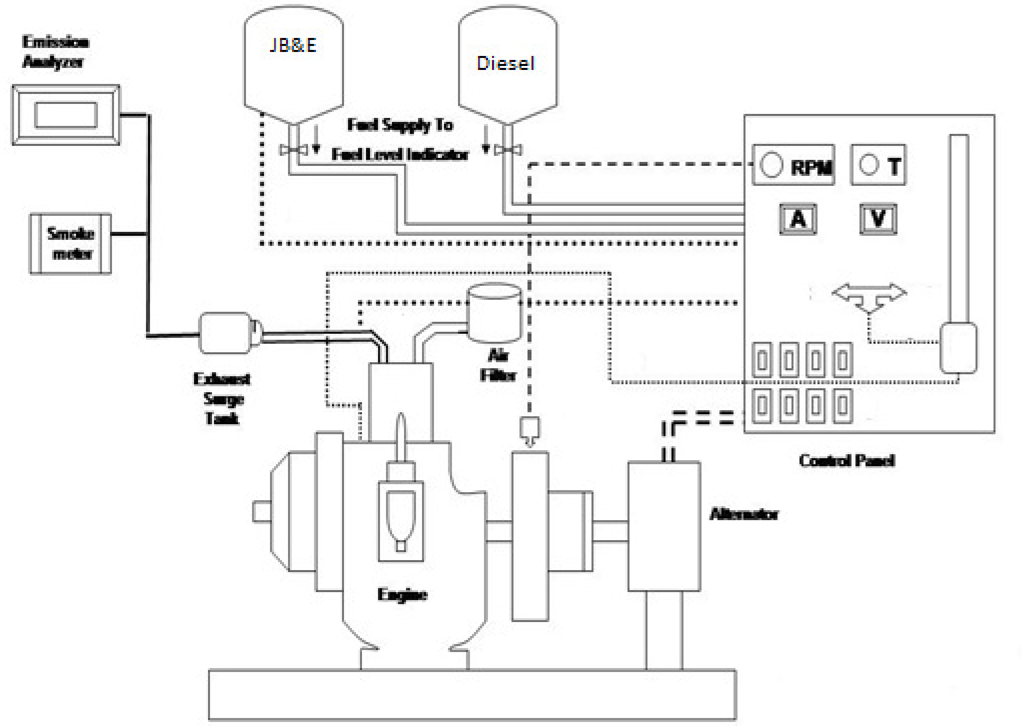

Fig:- 3.2 Line Diagram of Experimental set up

A Kirloskar make, single cylinder, constant speed, air cooled, direct injection, CAF 8 model diesel engine was selected for the present research work, which is primarily used for agricultural activities and household electricity generations as shown in Plate 3.9.

It is a single cylinder, naturally aspirated, four stroke, vertical, air-cooled engine. It has a provision of step loading electrically (Resistive) since it is coupled with single phase alternator through flexible coupling. The engine started by using a detachable handle to rotate the main shaft using decompression lever. The engine speed on varying load is control by centrifugal speed governor. The cylinder is made of cast iron and fitted with a hardened high-phosphorus cast iron liner. The lubrication system used in this engine is of wet sump type, and oil is delivered to the crankshaft and the big end by means of a pump mounted on the front cover of the engine and driven from the crankshaft. The inlet and exhaust valves are operated by an overhead camshaft driven from the crankshaft through two pairs of bevel gears. The fuel pump is driven from the end of camshaft.

Plate:- 3.9 Test rig of Diesel engine

Table:-3.1 Technical specifications of the diesel engine

Make	Kirloskar
Model	CAF 8
Rated Brake Power (bhp/kW)	8 / 5.9
Rated Speed (rpm)	1500
Number of Cylinder	One
Bore X Stroke (mm)	95 x 110
Compression Ratio	17.5:1
Cooling System	Air Cooled (Radial Cooled)
Lubrication System	Forced Feed
Cubic Capacity	0.78 Lit
Inlet Valve Open (Degree)	4.5 BTDC
Inlet Valve Closed (Degree)	35.5 ABDC
Exhaust Valve Open (Degree)	35.5 BBDC
Exhaust Valve Closed (Degree)	4.5 ATDC
Fuel Injection Timing (Degree)	26 BTDC

Table:-3.2 Technical specifications of the Alternator

Make	Kirloskar Electric
Output	5.0 Kva
Rated Speed	1500 RPM
Volt	230 V
Current	21.7 A
Phase	Single
Frequency	50 Hz

For conducting the desired set of experiments and together required data from the engine, it is essential to get the various instruments mounted at the appropriate location on the experimental setup. Apart from this, a dual fuel system has been developed for diesel and blend of Jatropha biodiesel and ethanol.

The schematic diagram of overall pictorial view of the test rig along with instrumentation used in the present investigations is shown in Plate 3.9.

3.7 INSTALLATION OF THE INSTRUMENT CONTROL PANEL

After finalizing the procedures for data collection and procurement of the desired instruments, they were put on a panel. A cubical stand was fabricated with slotted angle and a Bakelite sheet was mounted on it. Instruments such as voltmeter, ammeter, six channels digital temperature display, SPN as main switch, step wise electric loading-unloading switch, fuel measuring tube, fuel diversion valves were mounted on the front side of the control panel (Plate 3.9). Electrical load banks, i.e., 12 bulbs each of 500 watts, were mounted on the rear side of the control panel.

A voltmeter and ammeter were connected between alternator and load bank. The speed of the engine was measured by Digital Tachometer on flywheel. The thermocouples were mounted in the exhaust manifold to measure the exhaust temperature. The AVL 437 smoke meter and AVL Di- Gas Analyzer were also kept in proximity for the measurements of various exhaust gas parameters. Thus such a system was chosen to examine the practical utility of Agriculture product micro emulsion oil in small single cylinder ,air cooled CI engine which is light in weight easily maintain in remote area for electric generation and agriculture ,being an air cooled engine it was suitable for hot climate. The absence of radiator, water body and pump has made the system more suitable for the tests.

3.8 PARAMETERS SELECTION

The selections of appropriate parameters were essential for engine calculations, and parameters were selected very judiciously. The engine test was done as specified by IS: 10000. The main parameters desired from the engine are listed below.

1. Power produced by the engines
2. Engine speed (Rev/min)
3. Fuel consumption
4. Exhaust gas Temperature
5. Exhaust gas emission

With a view to calculate the parameters mentioned above, it was essential to pick up the following signals from the test bench.

1. Voltage generated by the alternator
2. Current generated by the alternator
3. RPM of the engine
4. Exhaust gas temperature
5 Fuel measuring tube.
6. Stop watch
7. AVL 437 smoke meter
8. AVL Di Gas analyzer

Once the parameters were selected, the essential instruments required for sensing these parameters were installed at the appropriate points in the experimental set-up.

3.9 MEASUREMENT METHODS

As already explain the main components of the experimental kit, one fuel tank filled with diesel while other fuel tank filled with Jatropha biodiesel(JB) and blend of JB and ethanol of different ratio one by one than engine started on diesel fuel and run at list 30 minutes for warm up the engine and stabilized the engine parameters than taken all initial reading such as voltage ,current, rpm ,exhaust gas temperature ,exhaust emission than gradually increase the load and measured definite quantity of fuel consumed on different load in different time period beside this all reading have been taken along with varying load as mention above. Now fuel mode switch over to Jatropha biodiesel and ethanol oil by diverting valve and after running some time when we see the diesel oil is exhausted from fuel line and engine run on different ratio blend of JB and E i.e.JB95E5, JB90E10, JB85E15 and JB80E20, with varying load and the measurement process is repeated.

The brake specific fuel consumption is calculated by using the relationship given below:

$$\mathbf{bsfc = (Vcc \times \ell \times 3600) / (hp \times t)} \quad (3.3)$$

Where,

bsfc = Brake specific fuel consumption, g/kW-h

Vcc = Volume of fuel consumed, cc

ℓ = Density of fuel, g/cc

Hp = Brake horsepower, kW

t = Time taken to consume, cc of fuel, sec.

The brake thermal efficiency of the engine on different fuel blends at different operating conditions was determined using the equation as given below:

$$\boldsymbol{\eta_{th}} \mathbf{= Ks / (HV \times bsfc)} \quad (3.4)$$

Where,

η_{th} = Brake thermal efficiency, %

Ks = Unit constant, 3600

HV = Gross heat of combustion, kJ/kg

bsfc = Brake specific fuel consumption, g/kW-h

3.10 EXHAUST EMISSION ANALYSIS

The major pollutants appearing in the exhaust of a diesel engine are the oxides of nitrogen. Exhaust gas analysis was done for exhaust smoke opacity, UBHC, CO, CO_2 NOx.

Plate:- 3.10 AVL Smoke analyzer and AVL Di-Gas Analyzer

For measuring the smoke opacity, AVL 437 smoke analyzer was utilized. This instrument gave reading in terms of percentage opacity. Of the light beam projected across a flowing stream of exhaust gases, a certain portion of light is absorbed or scattered by the suspended soot particles in the exhaust. The remaining portion of the light falls on a photocell, generating a photoelectric current, which is a measure of smoke density.

For measurement of UBHC, CO, CO_2 and NOx, AVL 4000 Light Di-Gas Analyzer was used.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.0 INTRODUCTION

The literature review shows that in general biodiesel could reduce significantly CO, HC and smoke emissions while increasing NOx emissions slightly in comparison to diesel fuels. For a blend of biodiesel and diesel (20% volume), CO, HC and PM decreased by 11%, 21.1% and 10.1% respectively whereas NOx emission increased by 2% [47]. The increase in NOx emission is the main hurdle to implement the use of biodiesel. This problem may be overcome by adding of alcohol in biodiesel. Alcohol has the potential for reducing NOx and PM because it has high latent heat of evaporation (840 KJ/kg) and higher oxygen contents (34.8%). It is worth relevant to mention that the use of alcohol diesel blends has some disadvantages such as reduced lubricity, viscosity, cetane number and ignitability. However, in case of biodiesel alcohol blends, these difficulties are over come as biodiesel has higher viscosity and better lubricity.

Therefore the main objective of study was to prepare alcohol biodiesel blends in different proportion (5,10,15 and 20%)and evaluatetheperformance and emission parameters of an unmodified diesel engine fuelled with neat biodiesel and ethanol biodiesel blendsandcompare the result with baseline diesel.

4.1 COMPARISION OF PHYSICO CHEMICAL PROPERTY

The physico-chemical property i.e. density, specific gravity, kinematic viscosity, calorific value and cold filter plugging point of diesel,neatJatrophabiodiesel (JB), ethanol (E) and blend of ethanol and Jatropha biodiesel in different proportion(5%,10%,15%,20%) by volume was evaluated and summarized in the Table 4.1.It has observed that by increasing the amount of ethanol blend in biodiesel reduced the specific gravity, calorific value and kinematic viscosity. The viscosity of neat Jatropha biodiesel is more than the diesel fuel, however, with blending of ethanol it gradually decreases. The reduction of viscosity results inimproved volatility, proper atomization and proper mixing of fuel with air whereasreduction in calorific value and high heat of evaporation of ethanol helps in reduction of NOx.

Table:-4.1 Test fuel blend nomenclature .

S.No.	Nomenclature	% Ethanol(vol.)	% Jatropha biodiesel (vol.)	% Diesel
1.	D100	0	0	100
2.	JB100	0	100	0
3.	E5JB95	5	95	0
4.	E10JB90	10	90	0
5.	E15JB85	15	85	0
6.	E20JB80	20	80	0

Table4.2:-Physico-Chemical Properties of Diesel (D),Ethanol (E),Biodiesel(JB) and blend oil (BJ&E)

Property	Density (kg/m³),40°C	Specific gravity	K. Viscosity (mm²/s)	Calorific Value(MJ/kg)	Cold flow property(°C)
Diesel	**823.02**	**0.823**	**2.7**	**45.66**	**-5**
Ethanol	**805.46**	**0.8062**	**0.875**	**26.82**	**≤ -35**
JB-100	**880.02**	**0.8808**	**5.936**	**40.26**	**-8**
JB95E5	**879.01**	**0.8798**	**5.0359**	**38.87**	**-8**
JB90E10	**875.46**	**0.8762**	**4.4269**	**38.207**	**-6**
JB85E15	**873.72**	**0.8745**	**4.0385**	**37.866**	**-6**
JB80E20	**867.62**	**0.8684**	**3.6916**	**36.747**	**-7**

4.2 Engine Performance and emissions

The mass consumption rates of the fuel were calculated by measurement of volumetric flow of fuel at different loads. Brake thermal efficiency and brake specific energy consumption werecalculated at different load for different fuels blends. Emissions i.e. UBHC, CO,CO_2,NOx and smoke opacity were measured by AVL Di-Gas gas analysers and AVLsmoke meter.

4.2.1 BRAKE THERMAL EFFICIENCY

Fig.4.1 shows the variation of brake thermal efficiency (BTE) with respect to brake mean effective pressure (BMEP) for various test fuels. From the experimental investigation it has been found that BTE for all the test blends was found to be higher in comparison to baseline diesel fuel and JB100. At full load condition the BTE for JB95E5, JB90E10, JB85E15, JB80E20, D100 and JB100 is 24.02%, 24.93%, 25.53%, 26.10%, 22.94% and 23.91 % respectively.

This is due to the fact that biodiesel ethanol blend contains around 15-25%in-built oxygen and higher cetane number than diesel fuels. Due to this, bettercombustion take place hence there is improvement in the brake thermal efficiency in case of biodiesel ethanol blends. Itcan also be seen that the increasing the percentage of ethanol in blends improved the BTE. These results are in agreement with the result obtained byAgrawal [31],Zhu et.al. [18], Sahoo et al[35].

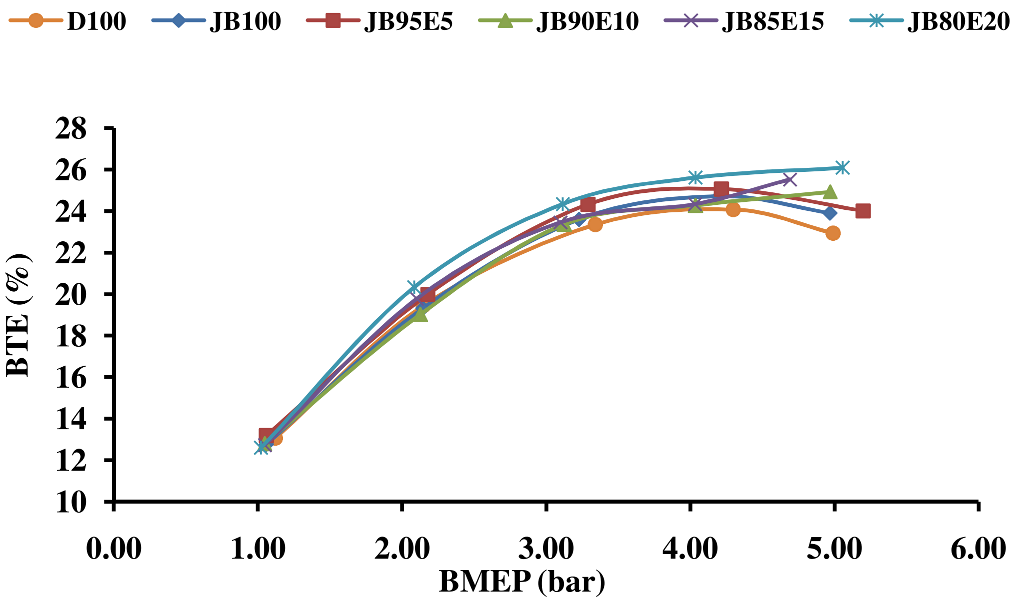

Fig:-4.1BTE Vs BMEP

4.2.2 BRAKE SPECIFIC ENERGY CONSUMPTION

Brake specific energy consumption (BSEC) measures the amount of input energy required to develop one-kilo-wattpower. The BSEC is an important parameter of an enginebecause it takes care of both mass flow rate and heating valueof the fuel. Basic specific energy consumption is an essentialand ideal parameter for comparing engine performance of thefuels having different calorific value and density. The Fig.4.2 shows the variation of brake specific energy consumption (BSEC) with respect to brake mean effective pressure (BMEP) for various test fuels. From the experiment it has been observed that BSEC for various biodiesel-ethanol blendsare lower in comparison to baseline diesel fuel and JB100. At full load condition BSEC for D100 is 15.70 MJ/KWh while for JB 100 it is 15.05MJ/KWh. BSEC for JB80E20 shows lowest BSEC value (13.79MJ/KWh) in comparison to other test fuels.This is due to the fact that biodiesel and ethanol both are oxygenated fuels and Biodiesel havehigher cetane number, whichimproved the combustion process than diesel. Due to better combustion of fuel blends, requirements for energy is reduced and hence BSEC of blends decreases comparison to base line The results are in similar to the result obtained byAgrawal [31] and Qi et.al.[40].

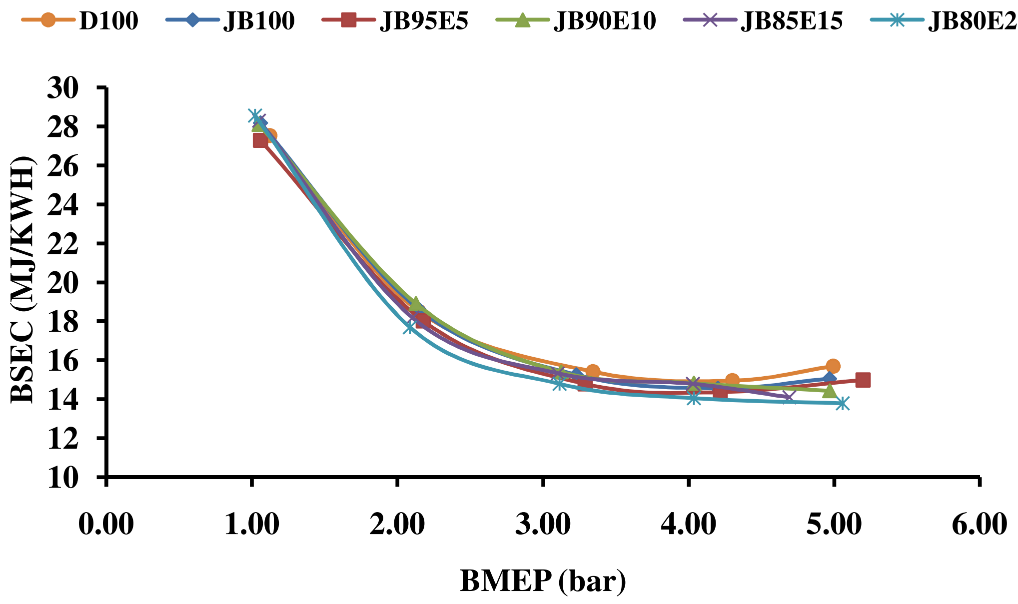

Fig:-4.2BSEC Vs BMEP

4.2.3 EXHAUST TEMPERATURE

The variation of exhaust temperature with brake mean effective pressure of biodiesel-ethanol blendanddiesel fuel are shown in Fig 4.3. It has been observed that the exhaust gas temperature increased withincrease in load in all cases. The highest value of exhaust gas temperature of 430ºC was observed with the JB100, whereas the corresponding value with diesel was found to be 370º C. This is because of better combustion of biodiesel which improved the temperature of combustion.However, the exhaust gas temperature of biodiesels is reduce by addition of ethanol due to higher value of latent heat of evaporation of ethanol.These results are in agreement with the result obtained byAgrawal [31].

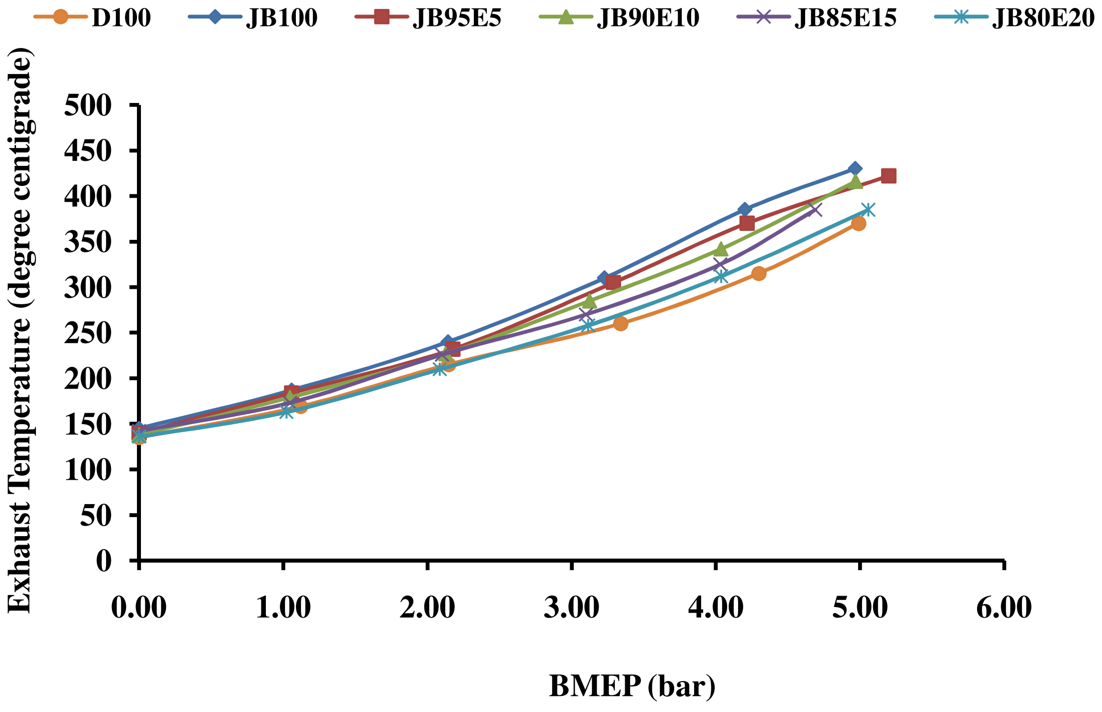

Fig:-4.3 Exhaust Temperature Vs BMEP

4.2.3 CO EMISSIONS

CI engine operate on lean mixture and at high stoichiometric fuel air ratio. Therefore CO emission is insignificant than Gasoline engine but they are further reduced by use of biofuels. The fig.4.4shows the variation of carbon monoxide (CO) with respect to BMEP for various test fuels. The CO emission for all the test fuels is found lower in comparison to baseline diesel fuel. The CO emissions are found to be increasing with increase in load since the air-fuel ratio decreases with increase in load such in internal combustion engines. The engine emits less CO using biodiesel-ethanol blends as compared to that of diesel fuel under all loading conditions. With increasing ethanol percentage in biodiesel, CO emission level decreases as amount of oxygen content in blends helps in better combustion and proper oxidation.The higher cetane number of blend as compared to that of mineral diesel is also one of the reasons of better combustion. At part load condition the variation in the emission level of different blends are insignificant but at full load condition baseline diesel fuel shows highest CO emission level (0.2% v/v). However, for JB100 and JB80E20 CO emission level are 0.18% and 0.11 % respectively. The results obtained are accordance with Zhu et.al. [18]

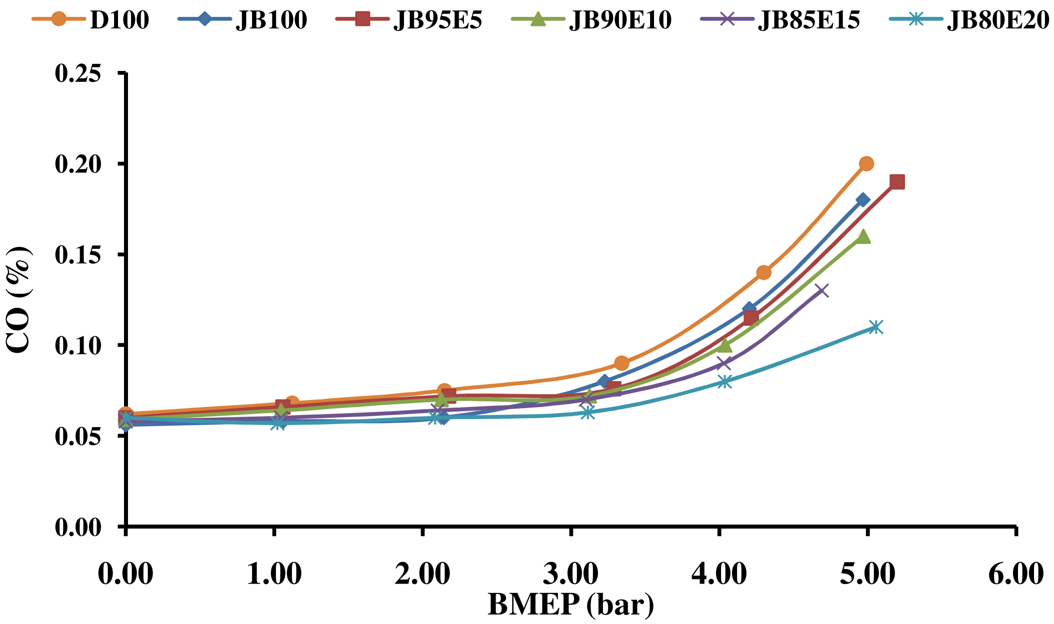

Fig:-4.4 CO(%) Vs BMEP

4.2.4 CO_2 EMISSION

Fig.4.5 shows the variation of carbon dioxide (CO_2) with respect to BMEP for various test fuels. It is found that CO_2 emission gradually increases with increase of load for all the test fuels. Neat biodiesel and blends of ethanol emit more CO_2than diesel.The increase of CO_2 emission levels may be due to theCO decreases, which continues the oxidation process because of thehigh oxygen level of the biofuels, ensuring a more complete combustion. Thesurplus oxygen present in burn gas makes the CO oxidationpossible in the exhaust manifold also. The results obtain are in accordance with Barbas et.al [27].The increased in CO2 emission level should not beconsidered as a negative consequence, because it is captivated in the photosynthesis cycle of the plants used for biofuels and ethanol production and it is a sign of more complete combustion and increase of BTE.

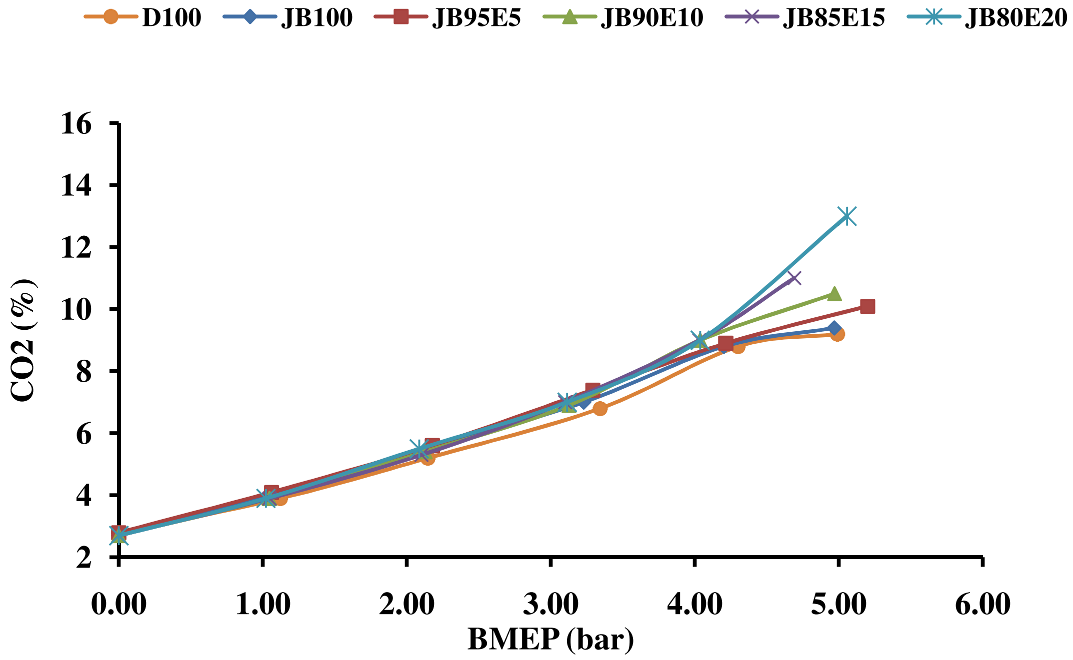

Fig:-4.5 CO_2 Emission Vs BMEP

4.2.5 UNBURNT HYDROCARBON

UnburntHydrocarbons (UBHC) known as organic emissions are the result of incomplete combustion of HC fuel and is a useful measure of combustion inefficiency.

Fig.4.6 shows the variation of UBHC emission in exhaust gas(ppm) with respect to BMEP for various test fuels. It has been observed that HC emissions gradually increase with increase of engine load.Moreover the HC emissions of the biodiesel and ethanol biodiesel blends are lower than baseline data of diesel.This may be due to the fact that low cetane rating and high self ignition temperature ofethanol deteriorates combustion process. Another reason for HC emission is quenching effect due to higher value of latent heat of evaporation. At part load condition the variation in HC emission is insignificant to that of mineral diesel but at full HC emission for D100 is 58 ppm while JB 100 shoes lowest HC emission of the level of 42 ppm.The results obtained are accordance with Zhu et.al. [18] and Sahoo et al. [35].

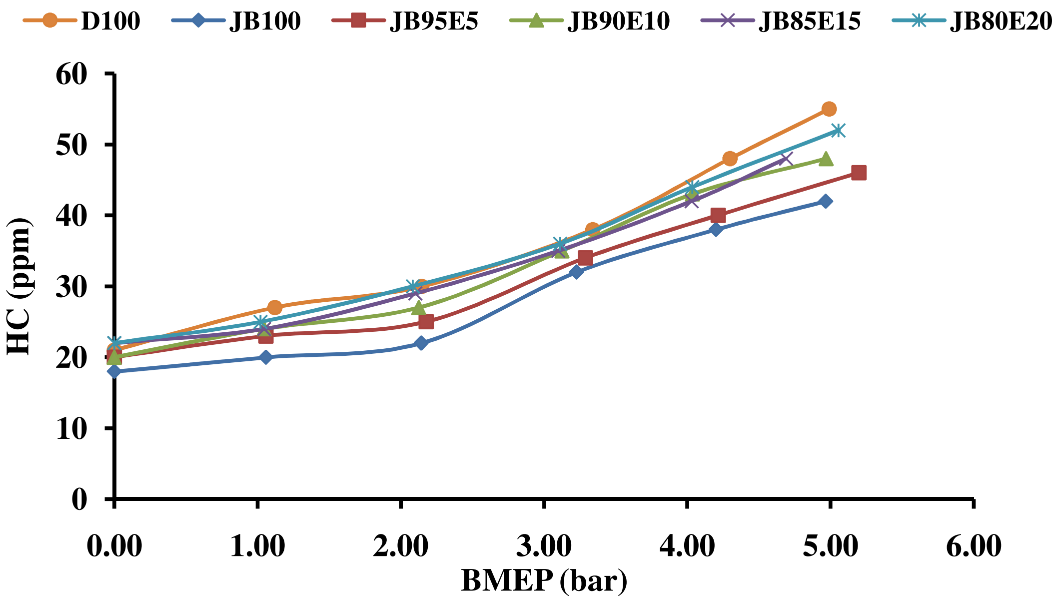

Fig:-4.6 HC(ppm) Vs BMEP

4.2.6 NOx EMISSIONS

The nitric oxide (NO) and nitrogen dioxide (NO2) are grouped together as NOx emission, nitric oxide is the predominant oxide of nitrogen produced in side in the cylinder .At lower temperature the nitrogen is inert but at temperature higher than 1100°C nitrogen reacts with oxygen and form NOx. [45] It is seen in fig 4.7 the variation of Nitrogen oxide (NOx) ppm with respect to BMEP for various test fuels. It has been observed thatNOx emission isincrease with increase in engine load for all tested fuel.The neat biodiesel has been emitted highest NOx than all blends. It is obvious that with biodiesel have high oxygen contain and better combustion property result in higher combustion temperature. However NOx is further reducingby addition of ethanol in biodiesel. The higher value of latent heat of evaporation and lower calorific value of ethanol decrease the combustion temperature. The cooling effect of the alcohol should be dominant factor on NOx emission at low load but at high engine load the cooling effect of the alcohol is less influential leading to small difference in the NOx emissions between the fuels.However, for JB100, JB95E5, JB90E10, JB85E15, JB80E20 and D100 have emitted NOX 2547,2447,2400,2350.2200 and 2012 respectively.The results agreement withAgrawal [31] andSahooet. al. [35].

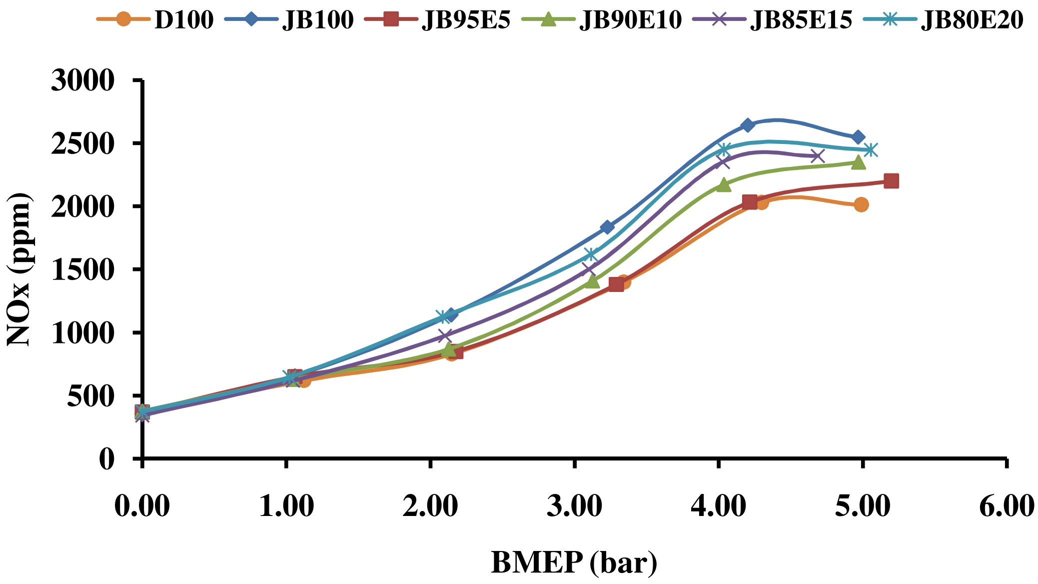

Fig:- 4.7 NOx (ppm) Vs BMEP

4.2.7 SMOKE OPACITY/PM EMISSIONS

Fig.4.8 shows the variation of percentage of smokevariation with respect to BMEP for various test fuels. It has beenobservedthat smoke opacity increases with engine load because of fuel consumption gradually increase with increase of load. At high load more fuel is burnt in diffusion mode. This leads to increase in the smoke opacity. The PM decreases when the engine is fuelled with biodiesel and blend ofbiodiesel and ethanol compared with diesel. By increasing the percentage of ethanol in biodiesel blend, have resulted in reduction in smoke at all load condition. The blended fuel contains more oxygen than biodiesel which leads to improve the combustion process and reduce PM emissions.

Blending biodiesel with ethanol could reduce the viscosity and density of the blend which leads to better atomization and hence lower PM emissions. The results obtained are accordance with Zhu et.al. [18] Agrawal [31] andsolakis(2006).

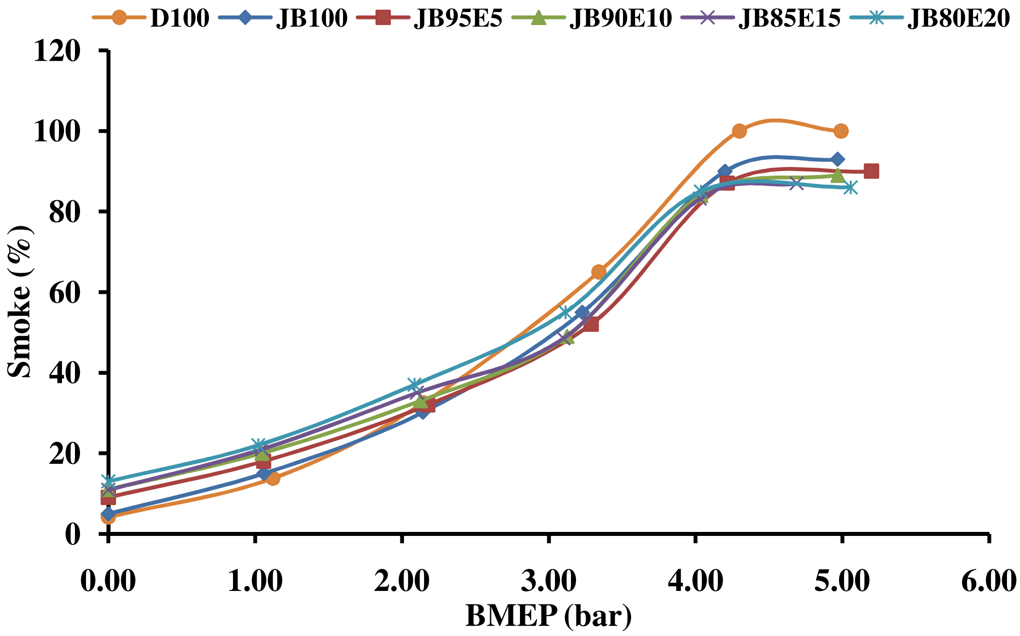

Fig:- 4.7 Smoke Vs BMEP

CHAPTER 5

CONCLUSION AND SCOPE FORFUTURE WORK

In the present study, the experiments was conducted using blends of Jatropha methyl ester and ethanol. Subsequently performance, and emission studies were carried out .

Based on the experimental results, the following major conclusions were drawn:

1. Full load brake thermal efficiency was found to increase with increase in ethanol percentage in the biodiesel as a result of higher cetane rating of biodiesel. Full load BTE of all the ethanol blended fuels were found higher than diesel baseline, However, JB80E20 exhibites an impressive 20% increase overbaseline data of diesel.
2. BSEC for JB80E20 was lower followed by JB85E15, JB90E10, JB95E5, JB100, D100. The main reason for lower BSEC for biodiesel ethnol blend were amount of oxygen present in the both fuel as well as proper atomization of the test fuels.
3. Due to higher density of biodiesel andbetter BTE, JB100 shows highest exhaust temperature compare to baseline diesel fuel, rest of the blends are having exhaust temperature range between D100 and JB100.
4. Emission of carbon-monooxide was found to reduce with increase in the biodiesel-ethanol percentage. At part load condition the variationis insignificant but after 60 % loading condition significant increase in CO emission was observed for all the test fuels. JB80E20 exihibit lowest CO emission whereas, for baseline diesel fuel CO emission is highest.
5. Carbondioxide emission for biodiesel-ethanol blended fuel was found to be higher in comparision to mineral diesel fuel,due to better combustion and reduction of carbon monooxide.

6. It hadobserved that HC emissions increasegraduallywith increase in load.HC emissions of the biodiesel-ethanol blends were lower than baseline data of diesel.This may be due to the lower self ignition temperature as well as lower cetane rating and higher value of latent heat of evaporationof ethanol which leads to the quenching effect.
7. NO_x emission was highest for JB100 while for mineral diesel it is lowest. This was due to the enriched oxygen present in the biodiesel- ethanol blends and higher combustion temperature of blends. At full load condition NO_x for JB 100 is 26% higher than that of neat diesel followed by JB80E20, JB85E15, JB90E10 and JB95E5.
8. Vartition in smoke opacity was comparable for all the test fuels in comparision to baseline diesel fuel at lower loding condition. However, at peak load baseline diesel fuel shows highest smoke followed by JB100, JB95E5, JB90E10, JB85E15 and JB80E20.

5.1 FUTURE SCOPE

On the basis of experience gained during the present experimental studies, the followingdiections are indicated for further investigation and development.

1. Utilization of blends of biodiesel-alcohol-diesel is suggusted for improvement in combustion characteristics
2. In the present investigation, an unmodified diesel engine was used havig compression ratio 17.5:1. It is recommended that further work may be carried at variable compression ratios and injection angles with combustion analysis.
3. In the present study ,ethanol blending in biodiesel was limited up to 20%.It is suggested that higher percentage of ethanol blendig may be explored .

There is urgent need to carry out long term endurance test to access the sutability of Jatropha methy ester and ethanol blend on engine hardware.

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APPENDIX -I

Technical Specifications of.AVL Di-Gas 4000 Light

Measurement principle:	CO,HC, CO_2	Infrared Measurement
	O_2	Electromechanical
	NO	Chemioluminiscence
OperatingTemperature		5-45°C
Operatingvoltage		230VAC±10%/110VAC
Power Consumption		90VA
Dimensions(WxHxD)		355x216x370 mm

Measurement RangesofAVL Di-Gas 4000 Light

Measured items	Measurement Range	Resolution
CO	0– 10 %Vol.	0.01%Vol.
CO_2	0– 20 %Vol.	0.1%vol.
HC	0– 20.000 ppm Vol.	1ppm
NOx	0– 5.000 ppm Vol.	1ppm
O_2	0– 25 %Vol.	0.01%Vol.
λ-Calculation	0– 9.999	0.001
Engine Speed	250– 9990 rpm/min	10rpm/min
OilTemperature	0-150 °C	1°C
Ignition AngleTDC	-60 – 100 °c.a.	0.1°c.a.
Ignition Angle	0– 60 °c.a.	0.1°c.a.

APPENDIX –II

Technical Specifications ofAVL 437 SmokemeterSpecifications

AccuracyandReproducibility	±1% full scale reading
MeasuringRange	0-100%capacityin % 0-∞ absorption m-1
Measurement Chamber	Effectivelength 0.430 m± 0.005
HeatingTime	220Vin approx20 min
Light Source	Halogen bulb 12V/5W
Color Temperature	3000K ± 150K
Detector	Seleniumphotocelldiameter45mmMax Sensitivity inlight, in frequency range 550to570nm.Below430nmto680nm sensitivityislessthat4%relatedtothe maximumsensitivity.
Maximum smoke temperature:	250^{o}C
Atentrance	