Project on

Performance and emission analysis of a C.I. engine using blends of conventional and non-conventional fuels

Project Guide

Dr. P. K. Sahoo

Mr. Shyam Pandey

By

Kriti Pant (R140206027)

Isha Dhyani (R140206024)

Shilpa Pandey (R140206056)

Certificate

This is to certify that the project work entitled "Performance and emission analysis of a C.I. engine using blends of conventional and non-conventional fuels" has been completed by Kriti Pant (R140206027), Isha Dhyani (R140206024) and Shilpa Pandey (R140206056) under our supervision and guidance. Their work is original and genuine to the best of our knowledge.

Pradeepta 14/15/2010

Dr. P.K. Sahoo
Assistant Professor
UPES

Shyam 14/5/10

Mr. Shyam Pandey
Assistant Professor
UPES

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Kriti Pant (R140206027)

Isha Dhyani (R140206024)

Shilpa Pandey (R140206056

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Chapter 1:

INTRODUCTION

Alternative fuels, also known as no conventional or advanced fuel are any material or substances that can be used as fuels, other than conventional fuels. Conventional fuels include fossil fuels (petroleum oil, coal, propane and natural gas), and nuclear materials such as uranium. The steady increase in energy consumption coupled with environmental pollution has promoted research activities in alternative in renewable energy fuels. Many countries in world are developing materials and method s for effectively utilizing the alternative fuel resources available in their region.

Petroleum based fuels have limited reserved concentrated in certain regions of the world. The dramatic increase in the price of the petroleum and the finite nature of fossil fuels, increasing concerns regarding environmental impact, specially related to green house gas emissions , health and safety considerations of forcing the search for new energy sources and alternative ways to power the worlds motor vehicles and stationary engines. The major environmental concerns, according to an IPCC reports, is that "most of the observed increase in globally average temperatures since the mid-20th century is due to the observed increase anthropogenic green house gas concentrations in the atmosphere, they are lightly contributed to global warming.

The majority of the known petroleum reserves are located in the Middle East. There is general concern that worldwide fuel could intensify the unrest that exist in the region leading to further conflict and war therefore ,those countries not having these resources are facing energy/foreign exchange crises, mainly due to the import food petroleum. Hence it is necessary to look for alternative fuel which can be produced from resources available locally within the country. Some well known alternative fuels include biodiesel, bioalcohal (Methanol, ethanol, butanol), chemically stored electricity(batteries and fuel cells),hydrogen, on fossil methane, on fossil natural gas, vegetable oil and other bio mass sources.

In 2007 there were 1.8 million alternative fuel vehicles sold in the united states indicating an increasing popularity of alternative fuels. There is growing perceived economic and political need for the development of the alternative sources. This is due to general environmental, economic , geopolitical concerns of sustainability.

Diesel engines are the most efficient prime movers from the point of view of the protecting global environment and concerns for long term security; it becomes necessary to develop alternative fuels with properties comparable to petroleum based fuels. Unlike the rest of the world, India's demand for diesel fuels is roughly six times that of gasoline, hence seeking alternative to mineral diesel is a natural choice. Non-edible oils are promising fuels for agricultural applications. Vegetable oils have properties comparable to diesel and can be used to run CI engine with little or no modifications. Alcohal fuels have received much attention as a replacement of gasoline use to power automobiles.

Engine Emissions:

The exhaust of automobile is one of the major contributor towards air pollution problem. Recent research and development has made major reductions in engine emissions bur a growing population and a greater number of automobiles means that the problem will exist for many years to come.

Four major emissions produced by internal combustion engines are hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), and solid particulates. Hydrocarbons are fuel molecules which did not get burnt and smaller non equilibrium particles of partially burnt fuels. Carbon monoxide occurs when not enough oxygen is present to fully react all carbon to CO2 or when incomplete air fuel mixing occurs due to the very short engine cycle time. Oxides of nitrogen are created in an engine when high combustion temperatures cause some normally stable N2 to dissociate into monoatomic nitrogen N, which then combines with reacting oxygen. Solid particulates are formed in C.I. engines and are seen as a black smoke in the exhaust of these engines. Other emissions found in the exhaust of engines include aldehydes, sulphur, lead and phosphorous.

C.I. engine operate with overall fuel lean equivalence ratio. C.I. engine have only about one-fifth the HC emission of SI engine. The components in diesel fuel have higher molecular weights on average than those in gasoline blend and this results in higher boiling and condensing temperatures. This allows some HC particles to condense onto the surface of the solid carbon soot that is generated during combustion. In general C.I. engine has about 98% combustion efficiency with only 2% of HC fuel being emissions.

Alcohol as an alternative Fuels:

Some times during the 21st century crude oil and petroleum products will become very scarce and costly to find and produce. At the same time there will likely be an increase in number of automobiles and other IC engines. Although fuel economy of engines is greatly improved from the past and will probably continue to be improved, numbers alone dictate that there will be a great demand for fuel in the coming decades. Gasoline will become scarce and costly. Alternative fuel technology, availability and use must and will become more common in the coming decades.

Although there have always been some IC engine fueled with non-gasoline or diesel oil fuels, there numbers have been relatively small. Because of the cost of petroleum products, some third world countries have for many years using manufactures as their main vehicle fuel. Many pumping stations on natural gas pipelines or natural gas pipeline use pipeline gas to fuel engines driving the pump. This solves an otherwise complicated problem of delivering fuel to pumping stations, many of which are in very isolated regions. Some large displacement engines have been manufactured specially for pipeline work. These consist of bank of cylinder engines and bank of compressive cylinders connected to the same crankshaft and contained in a single engine block similar to a V-style engine.

Another reason of motivating the development of alternative fuels for the IC engine is concerned over the emission problem of gasoline engine. Vast improvements have been made in reducing emissions given off by an automobile engine. If a 30% of improvement is made over a period of years and during the same time the number of automobiles increases by 30%, there is no net gain.

Most alternate fuels are very costly at present. This is often because of the quantity used. Many of these fuels will cost much less if the amount of their usage gets to the same order of magnitude as gasoline. The cost of manufacturing, distribution, and marketing all would be less.

Another problem with alternative fuels is the lack of distribution points (service stations) where the fuel is available to the public. The public will be reluctant to purchase an automobile unless there is a large scale network of service stations available, where fuel for that automobile can be purchased. Some cities are starting to make available a few distribution points for some of these fuels, like propane, natural gas, and methanol. The transfer from one major fuel type to another will be a slow, costly, and sometime painful process.

Alcohol are an attractive alternative fuels because they can be obtained from a number of sources both natural and manufactured.Methanol (methyl alcohol) and ethanol(ethyl alcohol) are two kinds of alcohol that seem most promising and have had the most development as a engine fuel.

The advantages of alcohol as a fuel includes:

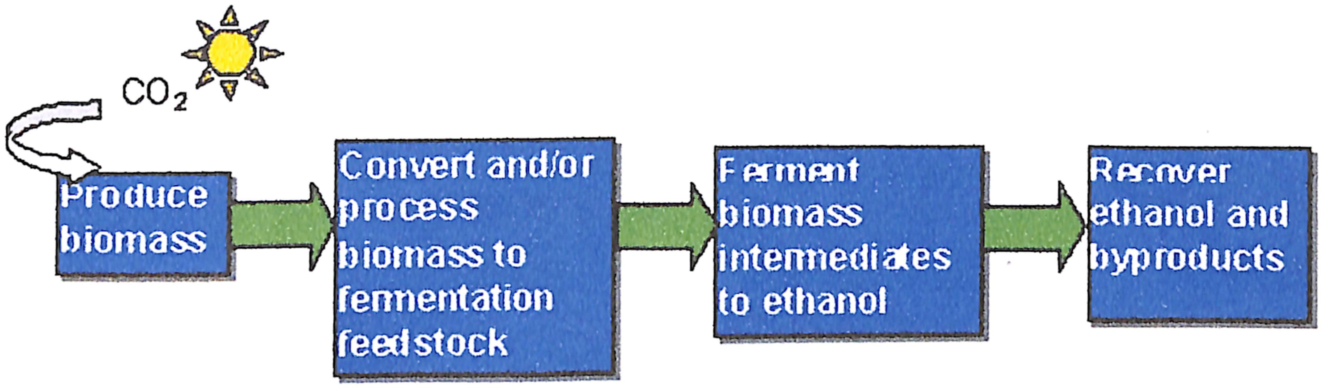
- Can be obtained from a number of sources both natural and manufactured.
- Is a high octane fuel with anti-knock index numbers(octane number on fuel pump) of over 100.High octane number results, atleast in part, from the high flame speed of alcohol.
- Engines using high octane fuels can run more efficiently by using higher compression ratios.
- Generally less overall emissions when compared with gasoline.
- When burned, it forms more moles of exhaust, which gives higher pressure and more power in the expansion stroke.
- Has high evaporative cooling(hfg) which results in a cooler intake process and compression stroke. This raises the volumetric efficiency of the engine and reduces the required work input in the compression stroke.
- Low sulphur content in the fuel.

The disadvantages of alcohol fuels include:

- Low energy content of the fuel. This means that almost twice as much alcohol as gasoline must be burned to give the same energy input to the engine. With equal thermal efficiency and similar engine output usage, twice as much fuel would have to be purchased, and the distance which could be driven with a given fuel tank volume would be cut in half. The same amount of automobile use would require twice as much storage capacity in the distribution system, twice the number of storage facilities, twice the volume of storage at the service station, twice as many trucks and pipelines etc. even with the lower energy content of alcohol, engine power for a given displacement would be about the same. This is because of the lower air-fuel ratio needed by alcohol. Alcohol contains oxygen and thus requires less air for stoichiometric combustion. More fuel can be burnedwith the same amount of air.

- More aldehydes in the exhaust. If as much alcohol fuel was consumed as gasoline, aldehyde emissions would be a serious exhaust pollution problem.
- Alcohol is much more corrosive than gasoline on copper, brass, aluminium, rubber, and many plastics. This puts some restrictions on the design and manufacturing of engines to be used with this fuel. This should also be considered when alcohol fuels are used in engine systems designed to be used with gasoline. Fuel lines and tanks, gaskets,and even metal engine parts can deteriorate with long-term alcohol use (resulting in cracked fuel lines, the need foe special fuel tank, etc). Methanol is very corrosive on metals.
- Poor cold weather starting characteristics due to low vapor pressure and evaporation. Alcohol-fueled engines generally have difficulty starting at temperatures below 10 deg celcius. Often a small amount of gasoline is added to alcohol fuel, which greatly improves cold-weather greatly improves cold-weather starting. The need to do this, however, greatly reduces the attractiveness of any alternative fuel.
- Poor ignition characteristics in general.
- Alcohols have almost inviscible flame which is considered dangerous while handling fuels. A small amount of gasoline or diesel removes this danger.
- Danger of storage tank flammability due to low vapor pressure. Air can leak into storage tanks and create a combustible mixture.
- Vapor lock in fuel delivery system.

Alcohol fuels particularly ethanol can be produced by fermentation of biomass crops, mainly sugarcane, wheat and wood. Usages of alcohols as a fuel for SI engines have some advantages compare to gasoline. Both methanol and ethanol have better antiknock characteristics than gasoline. The engine thermal efficiency can be improved with increasing of compression ratio. Alcohols burns with lower flame temperatures and luminosity owing to decreasing the peak temperature inside the cylinder so that the heat losses and NOx emissions are lower. Both methanol ethanol have high latent heat of vaporization. The latent heat cools the intake air which increases charge density and volumetric efficiency. However the oxygen content of methanol and ethanol reduces their heating value compare to gasoline. As a disadvantages for methanol and ethanol which reduces the vehicle range per liter of fuel tank capacity.



Corn ethanol produces 29% more energy than is used(mostly fossil fuels)in producing it. However the net energy gain is much higher from bio diesel fuels made from soybeans. For soy biodiesel, gain is 93%.Processing plants use improved, energy efficient technology to produce bio fuels. However most of ethanol 25% energy dividend comes from the production of ethanol coproduct, distillers grain use as animal feed. The new research shows the alternative crop such as switch grass, which can grow on marginal land with minimal input of fossil fuel, fertilizer and pesticides, offers the best hope for supplementing the energy future.

Ethanol is a clear colorless liquid. In dilute aqueous solution, it has a somewhat sweet flavor, but in more concentrated solutions it has burning taste. Ethanol (CH3CH2OH) is made up of the group of compounds whose molecules contains a hydroxyl group,-OH, bounded to a carbon atom. Ethanol made from cellousic biomass materials instead of traditional feed stocks (starch crops) is called bioethanol. There has been a strong demand for ethanol as an oxygenate blended with gasoline. In the United states each year approximately 2 billion gallons are added to gasoline to increase octane and improve the emission quality of gasoline. Blends of at least 85%ethanol are considered alternative fuels under the energy policy act of 1992(Epact)in US.E85,a blend of 85%ethanol and 15%gasoline is used in flexible fuels vehicles(FFVs) that are currently offered by most major auto manufacturers. FFVs can run on gasolines, E85 or any combination of two qualify as alternative fuel vehicle under EPAct regulations.

Ethanol has been used as automobile fuel for many years in various regions of the world. Brazil is probably the leading user, where in the early 1990's, 4.5 million vehicles operated on fuels that were 93% ethanol. For number of years gasohol has been available at service stations in the United States, mostly in the Mid-west corn-producing states. Gasohol is a mixture of 90% gasoline and 10% ethanol. The development of systems using mixtures of gasoline and ethanol continues. Two mixture combination that are important are E85 (85% ethanol) and E10(gasohol). E85 is basically an alcohol fuel with 15% gasoline added to eliminate some of the problems of pure alcohol (i.e., cold starting, tank flammability, etc.). E10 reduces the use od gasoline with no modification needed to the automobile engine. Flexible-fuel engines are being tested which can operate on any ratio of ethanol-gasoline and ethanol-diesel.

Merits of ethanol

- It is not a fossil fuel thus manufacturing it and burning it does not increase the green house effect.
- It reduces dependence on imported fuel.
- Refueling is similar to that of gasoline or diesel
- It can be used in both light and heavy duty vehicles.
- Ethanol is biodegradable without harmful effects on the environment
- It significantly reduces harmful exhaust emissions thereby reduces air pollution
- More energy density compared to gasoline with optimized compression ratio.
- Ethanol's high oxygen content reduces carbon monoxide levels more than any other oxygenate by 25 to 30%.
- Ethanol reduces nitrogen oxide, sulphur dioxide, hydrogen, and CO2 emissions.
- It provides high octane at low cost as an alternative to harmful fuel additives.
- As on octane-enhancer, ethanol can cut emissions of cancer causing benzene and butadiene by more than 50%.

Demerits of ethanol

- The relatively low boiling point and high vapour pressure indicate that vapour lock could be serious problem, particularly at high altitudes on warm summer days.

- The relatively high latent heat of ethanol can cause problems in its mixing with air and transporting through the intake manifold of the engine. Heating the intake manifold may be necessary in cold weather or before the engine reaches the operating temperatures. Without external heat to more completely vaporize the fuel, the engine may be difficult to start and sluggish for a considerable time after starting.
- Although ethanol when used near its stoichiometric ratio produces more power, a larger quantity of fuel is required to produce a specified power output. For example in an automobile, more fuel is required for each mile driven.
- Ethanol has strong affinity for water. Less engine power is produced as the water content of ethanol increases. Further vapor lock fuel mixing and starting problem increases with water.
- Corrosiveness: ethanol is corrosive to certain materials used in engines and thus can dissolve them. It can also cause injury or physical harm if not used properly.

Diesel-Ethanol Emulsion - Merits

- Significant lowering of diesel particulate matter emissions (PM is reduced by 22-75%)
- Possible improvement in cold flow properties imparted by ethanol (Low freezing point of ethanol)
- Possible improvement in fuel lubricity imparted by the emulsifier additives.

Diesel- Ethanol Emulsion- De-Merits

- Lower flash point
    - ✧ Modification in storage and handling system and in vehicle fuel system
- Emulsifier and additive issues
    - ✧ Stability in a range of diesel fuels, over a range of temperatures, needs to be established
    - ✧ Research and development efforts to be expedited

Energy content of some fuels compared with ethanol:

Fuel type	MJ/L	MJ/kg	Research octane number
Dry wood (20% moisture)		~19.5	
Methanol	17.9	19.9	123
Ethanol	23.5	31.1	129
E85 (85% ethanol, 15% gasoline)	25.2	33.2	105
Liquefied natural gas	25.3	~55	
Autogas (LPG) (60% Propane + 40% Butane)	26.8	50.	
Aviation gasoline (high-octane gasoline, not jet fuel)	33.5	46.8	
Gasohol (90% gasoline + 10% ethanol)	33.7	47.1	93/94
Regular Gasoline	34.8	44.4	min. 91
Premium Gasoline			max. 104
Diesel	38.6	45.4	25
Charcoal, extruded	50	23	

Objective of the project:

The main objective of the project undertaken was to test the performance and emission of a CI engine using diesel and its various blends with ethanol in different proportions.

The work included the determination of the feasibility of these blends in running the diesel engine and whether these blends can replace diesel in the near future. Blends of diesel with different proportions of ethanol were prepared in the laboratory. The calorific value and density of these blends were obtained through various tests. These blends were then used to run diesel engines and results were obtained.

Chapter 2:

LITERATURE REVIEW

The global fuel crises in the 1970s triggered awareness amongst many countries of their vulnerability to oil embargoes and shortages. Considerable attention was focused on the development of alternative fuel sources, with particular reference to the alcohols. A blend of 10% dry ethanol and unleaded gasoline (E10) was commercially introduced into the US and continues to be marketed mainly in the Midwestern states. The use of ethanol blended with diesel was a subject of research in the 1980s and it was shown that ethanol–diesel blends were technically acceptable for existing diesel engines. The relatively high cost of ethanol production at that time meant that the fuel could only be considered in cases of fuel shortages. Recently the economics have become much more favorable in the production of ethanol and it is able to compete with standard diesel. Consequently there has been renewed interest in the ethanol–diesel blends with particular emphasis on emissions reductions. An additional factor that makes ethanol attractive as a fuel extender or substitute is that it is a renewable resource. The dwindling fossil fuel sources and the increasing dependency of the USA on imported crude oil have led to a major interest in expanding the use of bioenergy. The recent commitment by the USA government to increase bioenergy three-fold in 10 years has added impetus to the search for viable biofuels. The European Union (EU) have also adopted a proposal for a directive on the promotion of the use of biofuels with measures ensuring that biofuels account for at least 2% of the market for gasoline and diesel sold as transport fuel by the end of 2005, increasing in stages to a minimum of 5.75% by the end of 2010. In the last two decades of the 20th century, major advances in engine technology have occurred, leading to greater fuel economy in vehicles. The reduction of emissions from engines has become a major factor in the development of new engines and manufacturers are focusing considerable energy and resources in order to meet emissions standards specified by the US Environmental Protection Agency (EPA) and by the EU. As a result the use of non-conventional fuels as a means of meeting these requirements has generated much attention.

About 2.1 billion gallons of fuel ethanol was used in the United States in 2002, mainly in the form of gasoline blends containing up to 10% ethanol (E10). Ethanol use has the potential to increase in the U.S. blended gasoline market because methyl tertiary butyl ether (MTBE), formerly the most popular oxygenate blendstock, may be phased out owing to concerns about MTBE contamination of the water supply. Ethanol would remain the only viable near-term option as an oxygenate in reformulated gasoline production and to meet a potential federal renewable fuels standard (RFS) for transportation fuels. Ethanol may also be blended with additives (co-solvents) into diesel fuels for applications in which oxygenation may improve diesel engine emission performance.

Numerous studies have been conducted to evaluate the fuel-cycle energy and greenhouse gas (GHG) emission effects of ethanol-gasoline blends relative to those of gasoline for applications in spark- ignition engine vehicles (see Wang et al. 1997; Wang et al. 1999; Levelton Engineering et al. 1999; Shapouri et al. 2002; Graboski 2002). Those studies did not address the energy and emission effects of ethanol-diesel (E-diesel or ED) blends relative to those of petroleum diesel fuel in diesel engine vehicles. The energy and emission effects of E-diesel could be very different from those of ethanol-gasoline blends because (1) the energy use and emissions generated during diesel production (so-called "upstream" effects) are different from those generated during gasoline production; and (2) the energy and emission performance of E-diesel and petroleum diesel fuel in diesel compression-ignition engines differs from that of ethanol-gasoline blends in spark-ignition (Otto-cycle-type) engine vehicles.

The Illinois Department of Commerce and Economic Opportunity (DCEO) commissioned Argonne National Laboratory to conduct a full fuel-cycle analysis of the energy and emission effects of E-diesel blends relative to those of petroleum diesel when used in the types of diesel engines that will likely be targeted first in the marketplace. This report documents the results of our study. The draft report was delivered to DCEO in January 2003. This final report incorporates revisions by the sponsor and by Argonne.

Study Scope

In the past several years, test bench experiments and fleet demonstrations using E-diesel in diesel engines have been conducted in the United States and in other countries. Although both diesel passenger cars and diesel heavy trucks were tested with E-diesel, application of E-diesel in the United States will very likely be concentrated in subsets of the heavy vehicle fleet. So the present study does not encompass E-diesel use in diesel passenger cars, but focuses on urban transit buses and farming tractors, which are likely to be among the earliest commercial E-diesel applications. In past and current U.S. demonstration programs, buses and farming tractors operate on E-diesel blends. Besides the petroleum displacement advantage, use of E-diesel in urban buses is intended primarily to help reduce emissions of fine particulate matter (PM) and oxides of nitrogen (NOx); PM has been identified as an important direct health threat and NOx as an important precursor of tropospheric ozone. The application of E-diesel in farming tractors is viewed by the agricultural community as a means to use an agriculture-based fuel for farming activities.

At this point, experiments have involved ethanol blended into diesel at proportions between 7.5% and 15% by volume (ED7.5 to ED15). In order to avoid phase separation, fuel additives are used in ED blends. Several vendors currently produce and supply proprietary additives for ethanol and diesel blending. For ED blends ranging from 7.5% to 15%, the treat rate of additives ranges from about 0.75% to 1.5% by volume. In general, these rates are significantly lower than in earlier ED blends. We have included estimates of the energy use and emissions associated with additive production and distribution in our fuel-cycle analysis.

Use of additives

Pure Energy Corporation (PEC) of New York was the first manufacturer to develop an additive package that allowed ethanol to be splash-blended with diesel fuel using a 2–5% dosage with 15% anhydrous ethanol and proportionately less for 10% blends (Marek and Evanoff, 2001). A small amount of commercially available cetane improver (<0.33% by volume) also was added to restore the cetane value of the blend. The second additive manufacturer was AAE Technologies of the United Kingdom, who have been testing 7.7% and 10% ethanol–diesel blends containing 1% and 1.25% AAE proprietary additive in different states in the USA (Marek and Evanoff, 2001). The third manufacturer was GE Betz, a division of General Electric, Inc., who has developed a proprietary additive derived purely from petroleum products, compared to the previous two, which are produced from renewable resources. This additive has been used in a number of tests, especially with 10% ethanol–diesel blends (Hansen et al., 2001; Marek and Evanoff, 2001). The percentage of additive required is affected by the lower limit of temperature to which the blend must be stable (Letcher, 1980). Accordingly ethanol–diesel blends require less additive in summer conditions as compared to winter. PEC specified 5% additive for stability at temperatures well below)18 _C, making it suitable for winter fuel formulation. Marek and Evanoff (2001) stated that an added benefit was that the fuel remained a liquid at these temperatures, allowing it to be pumped through the fuel injection system, as opposed to No. 2 diesel fuel, which tended to gel. In the summer, the additive requirement dropped to 2.35% with spring and fall concentrations being 3.85% by volume (Marek and Evanoff, 2001).

The use of ethanol in gasoline engines in the early 1980s resulted in numerous materials compatibility studies, many of which are also applicable to the effect of ethanol–diesel blends in diesel engines and particularly in the fuel injection system. The quality of the ethanol has a strong influence on its corrosive effects (Hardenberg and Schaefer, 1981). In addressing the problems of ethanol corrosion associated with gasoline blends, Brink et al. (1986) divided ethanol corrosion into three categories: general corrosion, dry corrosion and wet corrosion. General corrosion was caused by ionic impurities, mainly chloride ions and acetic acid. Dry corrosion was attributed to the ethanol molecule and its polarity. de la Harpe (1988) reviewed reports of dry corrosion of metals by ethanol and found that magnesium, lead and aluminum were susceptible to chemical attack by dry ethanol. Wet corrosion is caused by azeotropic water, which oxidizes most metals (Brink et al., 1986).

Decreasing Cetane Value

With the inverse relationship of octane number and cetane number, ethanol exhibits a low cetane rating. Hence, increasing concentrations of ethanol in diesel lower the cetane number proportionately. Hardenberg and Ehnert (1981) stated that using cetane numbers to describe the ignition characteristics of ethanol–diesel blends was unreliable, because of discrepancies in the determination of cetane numbers below 30. However, they estimated that the cetane number of ethanol was between 5 and 15. Lower cetane numbers mean longer ignition delays, allowing more time for fuel to vaporize before combustion starts. Initial burn rates are higher causing more heat release at constant volume, which is a more efficient conversion process of heat to work. Nevertheless, it is preferable to add an ignition improver to raise the cetane number of ethanol–diesel blends so that they fall within an acceptable range equivalent to that expected of No. 2 diesel fuel(cetane 40).

Studies on engine performance and durability

Comparisons of engine performance between ethanol– diesel blends and standard diesel in unmodified engines generally show reductions in power that are approximately the same as the reductions in energy content of the blends relative to diesel fuel. Increased leakage in the fuel injection pump with the lower viscosity fuels also contributes to reduced power in the load control range of the engine. Meiring et al. (1983b) reported a 5% drop in maximum fuel delivery when evaluating a 30% ethanol–diesel blend in a tractor engine fitted with a rotary distributor pump. They adjusted the maximum fuel delivery setting on the pump to partially restore the power lost from reduced energy content and fuel pump leakage. In recent studies, Hansen et al. (2000) measured a 7– 10% decrease in power at rated speed with a 15% dry ethanol, 2.35% PEC additive and 82.65% No. 2 diesel fuel blend run in a Cummins 5.9 L engine. Kass et al. (2001) checked the torque output from the same model engine with two blends containing 10% and 15% dry ethanol, respectively, and 2% GE Betz additive, and reported an approximate 8% reduction for both fuel blends.

In-field studies of a tractor and combine running on 10% dry ethanol, 1.3% GE Betz additive and 88.7% No. 2 diesel fuel yielded increases in fuel consumed of 4–5% compared to the same model tractor and combine operating on No. 2 diesel fuel, which was approximately equivalent to the reduction in energy content (Hansen et al., 2001). The operators of these vehicles indicated that they did not notice any significant differences when operating their machines in the field. As would be expected, the specific fuel consumption (SFC) in kg/kW h increases with increasing concentrations of ethanol in the blend because of the reduced energy content. However, specific energy consumption (SEC) in MJ/kW h is approximately the same as for diesel fuel or has been shown to be slightly better. Moses et al. (1980) stated that the improvements in SEC were small but consistent for the ethanol–diesel blends tested and they were assumed to be the result of an improvement in the thermal cycle efficiency. Hansen et al. (2001) reported similar trends for a combine harvester operating under field conditions on 10% ethanol, in which the combine on the blend ran consistently with a 2–3% higher brake thermal efficiency.

A limited range of durability tests have been conducted on ethanol–diesel blends both in the laboratory and in the field. In early studies, tests with blends containing approximately 10% and 15% dry ethanol indicated no abnormal wear in engines correctly adjusted for injection timing (Hansen et al., 1982; Hashimoto et al., 1982; Meiring et al., 1983a). Some engines included in these tests were more sensitive to a lowering of the cetane number and accordingly an increased ignition delay causing piston erosion from severe localized temperatures and pressures. However, a small retardation of injection timing was recommended so as to reduce rates of pressure rise. In the durability tests conducted by Meiring et al. (1983b) no abnormal deterioration of the engine or fuel injection system was detected after 1000 h of operation on a blend containing 30% dry ethanol, small amounts of octyl nitrate ignition improver and ethyl acetate phase separation inhibitor, and the remainder diesel fuel. 282 A.C. Hansen et al. / Bioresource Technology 96 (2005) 277–285 Recent over-the-road tests by Archer Daniels Midland (ADM), Bloomington, IL, US on two trucks operating on 15% ethanol blend of E diesel have resulted in an accumulation of over 400,000 km on each vehicle with no abnormal deterioration in condition (Marek and Evanoff, 2001). The Chicago Transit Authority (CTA) in the US monitored the condition and overall performance of a fleet of 30 buses, of which 15 were operated on the 15% ethanol blend and 15 were the control and were run on No. 1 diesel. After 434,500 km accumulated by the 15 buses running on the blend, no abnormal maintenance or fuel-related problems were encountered (Marek and Evanoff, 2001). Hansen et al. (2001) conducted a farm demonstration project with two John Deere 9400 tractors manufactured by Deere & Company, East Moline, IL, US, two Caterpillar Challenger 95E tractors manufactured by Caterpillar, Inc., Peoria, IL, US and two John Deere 9650 combines also manufactured by Deere and Company, US, one of each vehicle type running on a 10% ethanol blend of ''E diesel'' using the GE Betz additive, and the other on No. 2 diesel. One of the objectives was to monitor the durability of the vehicles. The John Deere tractors operated for two Spring seasons and one Fall season accumulating approximately 700 h with no abnormal deterioration in engine condition, based on oil analyses. The Caterpillar tractors and combines completed two seasons with approximately 380 and 600 h accumulated, respectively, again with no abnormal wear patterns according to oil analysis. A laboratory-based 500 h durability test was performed by Hansen et al. (2000) on a Cummins ISB 235 engine running on a 15% dry ethanol, 2.35% PEC additive and 82.65% diesel fuel. The engine operated at rated speed and maximum load in order to maximize the fuel throughput in the fuel injection system. With the exception of the fuel injection system, no abnormal deterioration in engine condition was detected based on detailed engine component measurements and examination. Calibration checks of both the injection pump and injectors showed that they were within normal tolerances. However, one resin-sealed sensor in the injection pump failed because of possible chemical interaction with the fuel and the injectors exhibited heavy wear from the needle valve action. Further tests are required to verify these results. Long-term durability tests of at least 1000 h are necessary to provide confirmation that ethanol–diesel blends do not adversely affect engine wear compared to the norms established for diesel fuel usage.

The rapidly increasing use of ethanol as a fuel additive for gasoline provides an opportunity to expand its further use as an oxygenate for diesel fuel, with the beneficial effects of reducing US dependence on imported petroleum, and substituting diesel fuel with a renewable resource that will expand markets for agricultural commodities used to produce ethanol. The more stringent emissions regulations and government proclamations to increase biofuel usage should increase the urgency to address the remaining barriers to the adoption of ethanol–diesel blends as a commercial fuel.

The properties of ethanol–diesel blends have a significant effect on safety, engine performance and durability, and emissions. A set of specifications that define key fuel characteristics pertaining to ethanol–diesel blends and additives should be established in collaboration with fuel and additive manufacturers and with engine manufacturers before these blends can be commercialized. An increase in fuel consumption approximately equivalent to the reduction in energy content of the fuel can be expected when using ethanol–diesel blends. With ethanol percentages of 10% or less, operators have reported no noticeable differences in performance compared to running on diesel fuel.

Long-term durability tests in a range of engines with different fuel injection system configurations will help to confirm that diesel oxygenated with diesel does not adversely affect engine wear compared to diesel fuel. Such tests should be performed in collaboration with engine manufacturers.

It is accepted that the addition of ethanol to diesel fuel will have a beneficial effect in reducing the PM emissions at least. The amount of improvement varies from engine to engine and also within the working range of the engine itself. While there is considerable value in being able to use the fuel directly in an unmodified engine, small adjustments to fuel injection characteristics may result in further gains in reducing emissions. It is being found that a 20% blend of rape methyl ester (RME) biodiesel degraded the cold-startability of diesel by 4[degree]C. Adding a cold-flow improver additive supposedly depressed the CFPP to -21[degree]C, but in fact the real starting temperature of the additized biodiesel was only -15[degree]C, the study showed.

"Normal laboratory analyses overestimates the cold performance of RME blend," the study found. "The RME blend had a strong response on CFPP with the additive," but "again the laboratory tests overestimated the cold performance of RME blend." Likewise, the standard cetane test engine grossly over-estimated cetane improver addition to biodiesel blend, by some 12-15 cetane units.

Ethanol emulsion without RME additive failed to deliver proper performance in either a Volvo bus engine or the cetane engine. On a light-duty Audi TDI car, the ethanol fuels produced "extremely high HC emissions" compared to ordinary diesel fuels, but didn't reduce NOx as in the heavy-duty tests.

Chapter 3:
METHODOLOGY

Selection of test fuel

The fuels selected for the performance, emission and combustion tests to be performed on C.I. engine are:

- Diesel
- E5 (blend of 5% ethanol and 95% diesel)
- E10 (blend of 10% ethanol and 90% diesel)
- E15 (blend of 15% ethanol and 85% diesel)
- E20 (blend of 20% ethanol and 80% diesel)

These fuels were used to run C.I. engine alternatively at different load conditions and results were obtained.

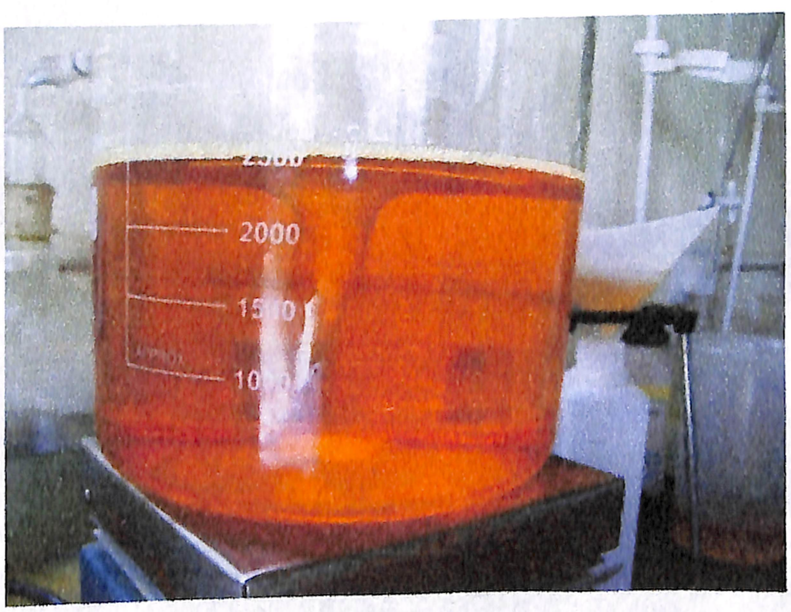
Preparation of blends:

The blends for the tests were prepared in the laboratory. A total quantity of 2.5*l* was prepared. The required quantity of ethanol and diesel were measured and taken in a container. As diesel and ethanol are immiscible, phase separation results at normal room temperature. Diesel settles down and ethanol rises to the top. To prevent this phase separation, an emulsifier is added to the solution. The emulsifier helps in mixing of diesel and ethanol and a clear solution of the required blend is obtained. The amount of emulsifier required for proper blending of ethanol and diesel was determined by optimization.

blend	% of ethanol	total quantity of fuel (*l*)	quantity of ethanol (*l*)	quantity of diesel (*l*)	% of emulsifier	quantity of emulsifier (*l*)	
E5	5% of total fuel	2.5	0.125	2.3625	0.5% of total fuel	0.0125	Optimized as per manufacturer's recommendation
E10	10% of total fuel		0.25	2.225	1% of total fuel	0.025	
E15	15% of total fuel		0.375	2.05	3% of total fuel	0.075	

Table 1

Optimization of blends



Preparation of blend

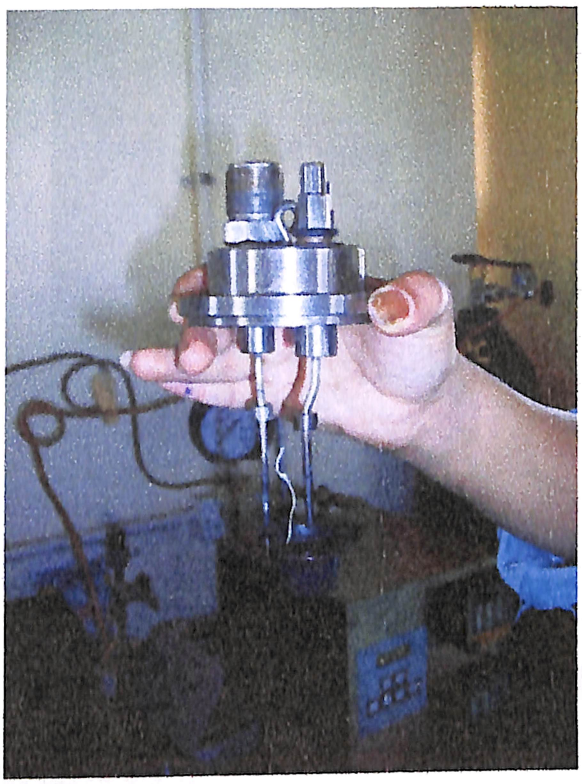
Physio-chemical analysis

The physio-chemical analysis of fuel includes the determination of fuel properties by various methods.

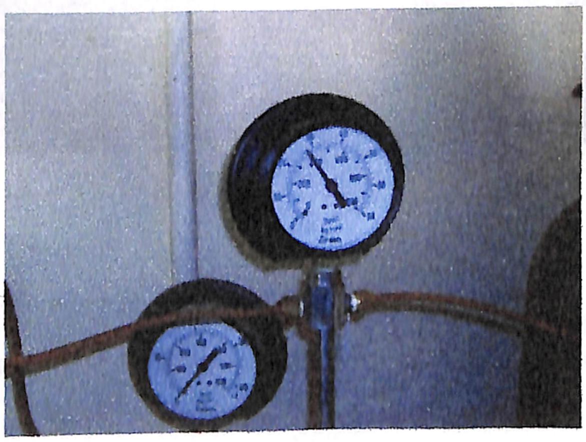
- **Calorific value:** The calorific value of the fuel is measured with bomb calorimeter. A bomb calorimeter is a type of constant-volume calorimeter used in measuring the heat of combustion of a particular reaction, bomb calorimeters have to withstand the large pressure within the calorimeter as the reaction is being measured. Electrical energy is used to ignite the fuel; as the fuel is burning, it will heat up the surrounding air, which expands and escapes through a tube that leads the air out of the calorimeter. When the air is escaping through the copper tube it will also heat up the water outside the tube. The temperature of the water allows for calculating calorie content of the fuel. In order to calculate the calorific value of the sample first a known mass of benzoic acid is ignited and then the fuel sample is ignited.

Bomb calorimeter in the laboratory

1 gm of benzoic acid is weighed and its tablet was made to carry out the process. The tablet was kept inside the bomb. The two electrodes were connected using a wire. A thread of 10 cm was tied to the wire so that it touched the tablet.

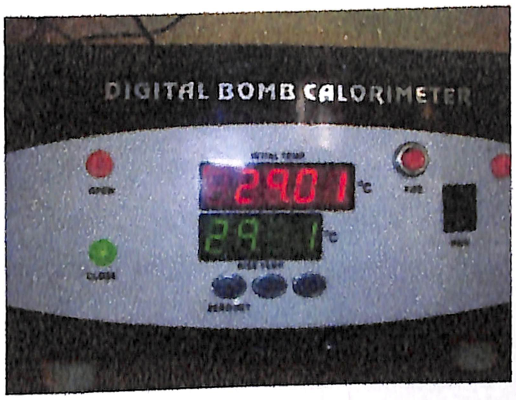


The bomb was closed and oxygen was filled inside the bomb at a pressure of 31 kg/cm^2.

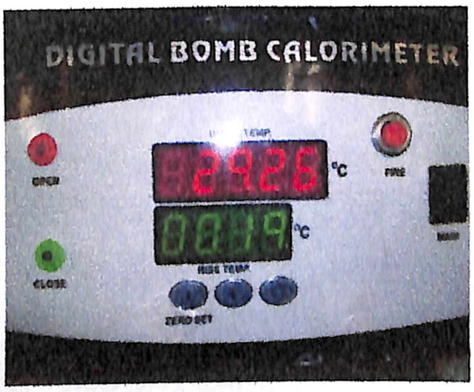


The bomb was kept inside the container and distilled water was filled up to the surface of the bomb. The setup was closed completely.

When the temperature inside and the temperature rise become constant, zero was set and the setup was fired.



Before firing



After firing

The maximum rise in temperature was noted down.

The same process was repeated for each fuel sample except that the bomb contained liquid fuel.

Calorific value was calculated by following process:

T1= temperature rise of benzoic acid

T2= temperature rise of fuel sample

M= Mass of fuel

w= weight of bezoic acid

W= Water equivalent (calories degree celsius)

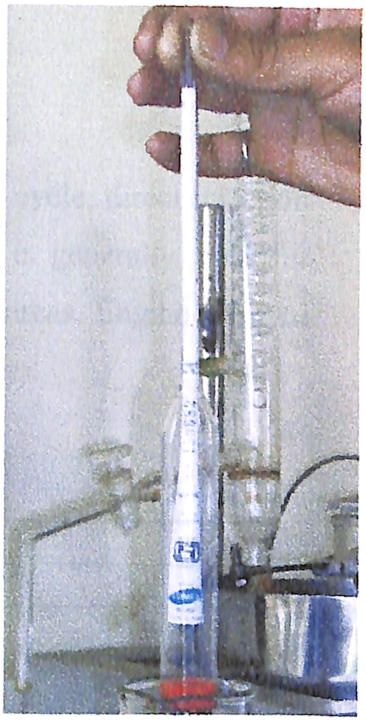
CVt= calorific value of thread

CVw= calorific value of wire

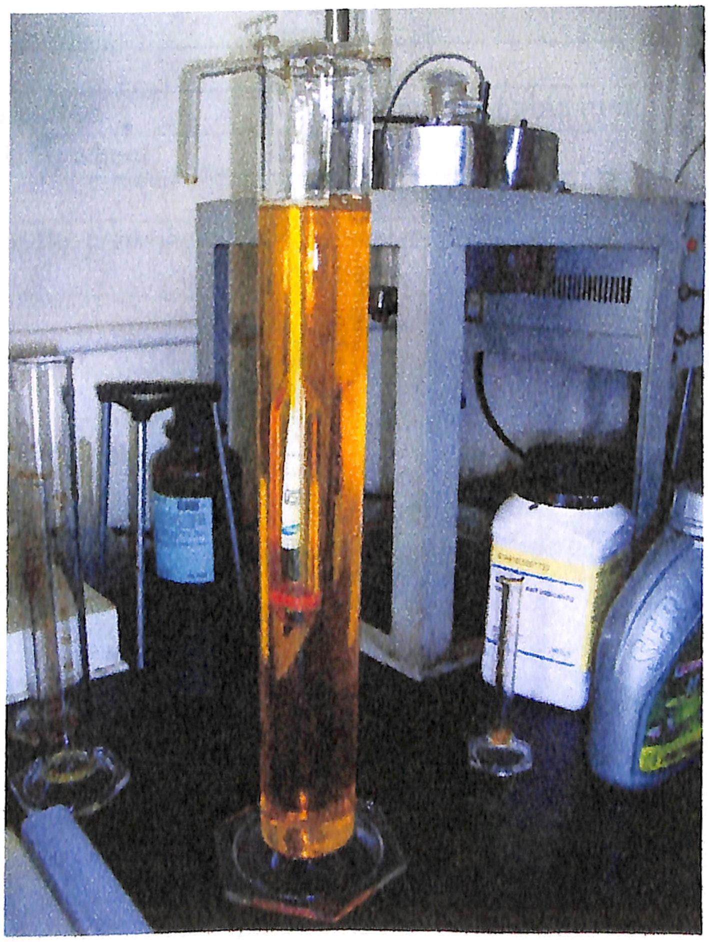
CV(of fuel in J/gm)= [4.18{(T2XW) – (CVt+CVw)}] / M

W= [(6319 X w)+ 21 +9.32] / T1

- **Fuel density**: Fuel density is measured with the help of a hydrometer. A hydrometer is a device used to measure the specific gravity (or relative density) of liquids; that is, the ratio of the density of the liquid to the density of water. It is usually made of glass and consists of a cylindrical stem and a bulb weighted with mercury or lead shot to make it float upright.



The liquid to be tested was poured into a tall jar, and the hydrometer was gently lowered into the liquid until it floated freely. The point at which the surface of the liquid touched the stem of the hydrometer was noted. Hydrometers usually contain a paper scale inside the stem, so that the specific gravity can be read directly.



Experimental setup

a. **Engine:**

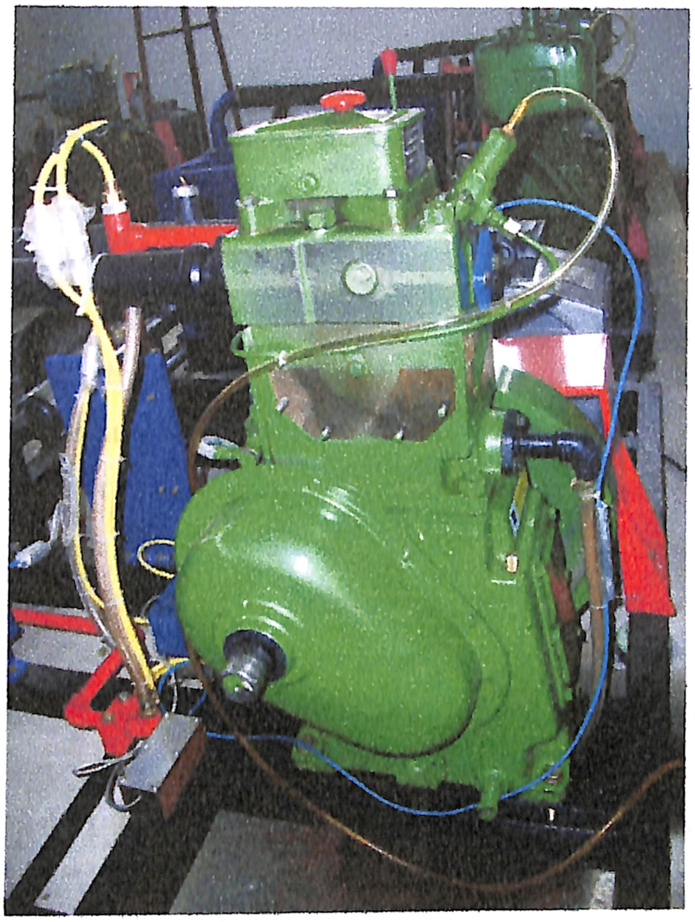
A Kirlosker made single cylinder, water-cooled, vertical, 4 stroke cycle, direct injection diesel engines was used for performing the tests. This engine is generally used for decentralized power generation and irrigation pump sets in rural areas. Engine selected for study are the best selling in India and used by most of the farmers.

The specifications of the engine are given in the table:

Model AV1 (Kirloskar Make)

No. of cylinders	One
Bore X stroke	80 X 110 mm
cubic capacity	0.553 lit
Compression Ratio	16.5 : 1
Rated output as per BS5514/ISO 3046/IS 10001	3.7 kW (5.0 hp) at 1500 rpm
SFC at rated hp/1500 rpm	245 g/kWh (180g
Lub Oil Consumption	1.0% of SFC max.
Lub Oil Sump Capacity	3.3 lit
Fuel Tank Capacity	6.5 lit
Fuel Tank refilling time period	Every 6 hours engine running at rated output
Engine Weight (dry) w/o flywheel	114 kg
Weight of flywheel	33 kg- Standard
Rotation while looking at the flywheel	Clockwise Optional- Anticlockwise
Power take-off	Flywheel end Optional- Gear end half or full speed
Starting	Hand start with cranking handle

Table 2

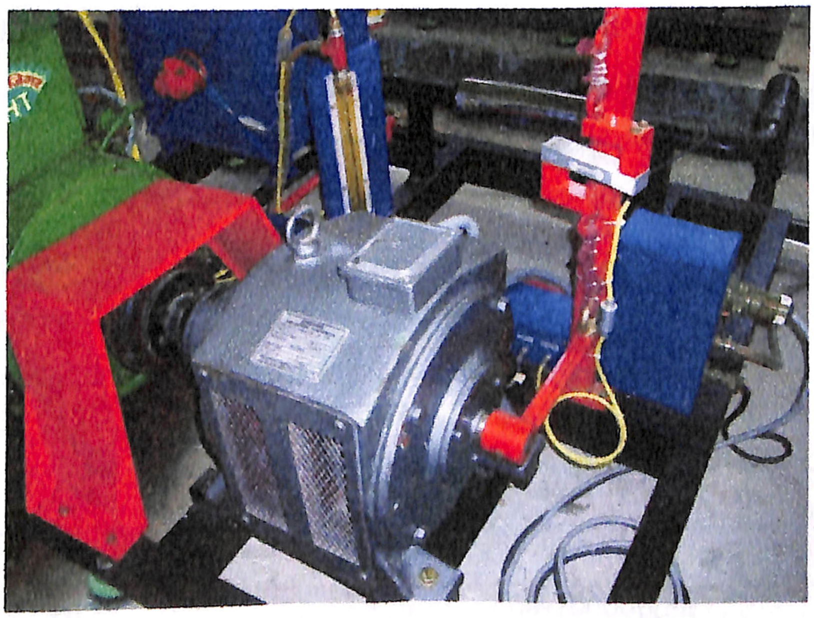


b. **Dynamometer:**

The test engine was coupled to a Powermag eddy current dynamometer. "POWERMAG" is a simple eddy current adjustable dynamometer which is a totally new concept in dynamic load system for accurate testing appliations of all type of electric motors, engines and other rotating machinery's. The need for a dynamic load system which allows flexibility of appliations in an economical way has been felt for a long time in technical education institutes, research and development, quality control in industry, and "POWERMAG" eddy current adjustable dynamometer provides the ideal solution for such applications.

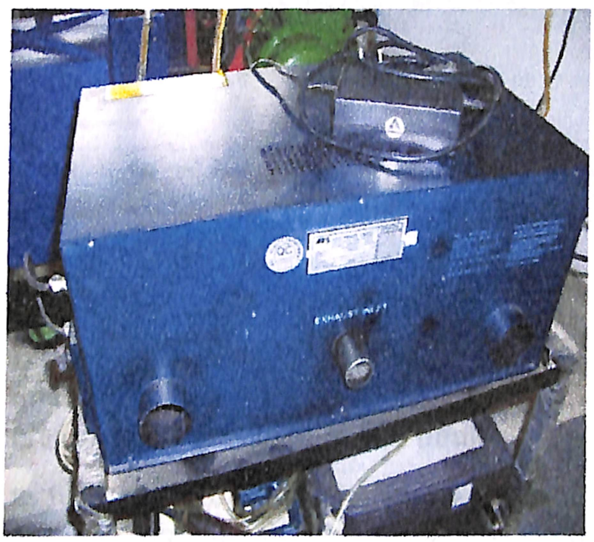
Operating principle:

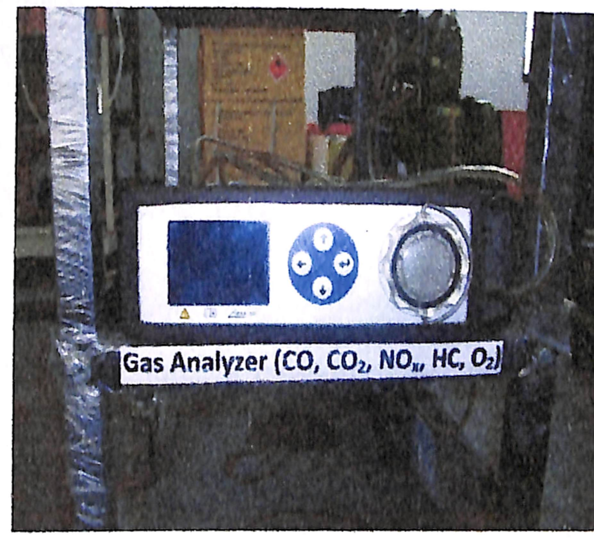
The primary elements of POWERMAG adjustable dynamometer are an eddy current clutch,a separate solid state controller.POWERMAG eddy current adjustable dynamometer absorb power, torque and speed characteristics with a unique hysteresis braking system which provides frictionless torque loading (0% to 100% constant / variable torque load) independent of shaft speed. The eddy current adjustable dynamometer provides torque by the use of two basic components - a reticulated pole structure with output shaft which connected to the spring balance weighing gear load and a specialty steel rotor drum with input shaft assembly fitted together but not in physical contact. The engine under test suitably arranged on a common bed plate could drive the input. Until the pole structure is energized, the rotor drum can spin freely on its shaft bearings. When a magnetizing force from the field coil is applied to the pole structure, the air gap becomes a flux field and the rotor is magnetically restrained, providing a braking action between pole structure and rotor drum. A solid state electronic controller is used to excite the field coil. Torque is proportional to coil current. An integral tachogenerator is mounted on the input rotor shaft, to give voltage and frequency proportional to speed, which is used for speed indication (RPM), so that simultaneously torque and speed of the motor can be read under 0% to 100% load test. POWERMAG eddy current adjustable dynamometer test stands of all kinds, when equipped with them carry out various dynamic characteristic tests and operating mode tests of all type of electric motors, engines and other rotating machinery's.



c. **<u>Exhaust gas analyzer and smoke meter:</u>**

The engine exhaust emissions such as carbon monoxide, carbon dioxide, nitrogen oxides, and unburned hydrocarbon were measured with a five gas analyzer (AVL DiGas– 4000 model) and a smoke-meter (AVL 437 model). The sensor of the analyzer was exposed to the exhaust gas and the observations were recorded. The measured emissions were analyzed and interpreted graphically.



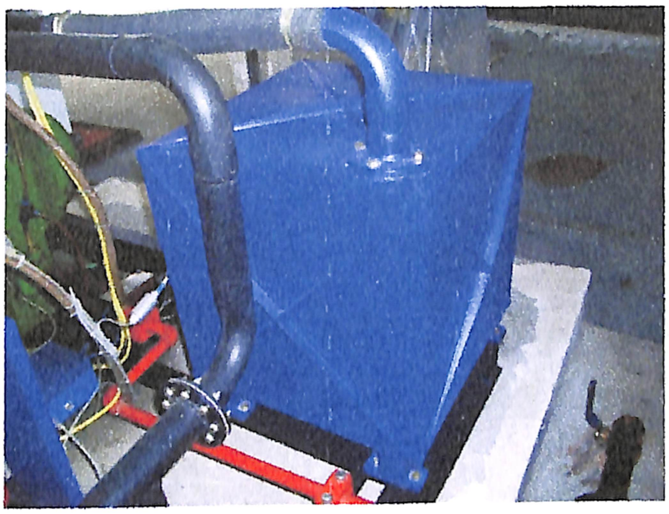


AVL 437 smokemeter are designed for automatic measurement of the soot content in the exhaust gas of particulate emitting internal combustion engines. It is a proven and recommended instrument for measuring diesel particulates based on the classical filter paper method. Although primarily designed for applications on engine test beds, the AVL 437 smokemeter can also be used in a chassis dynamometer. It has 0-100% opacity and 0-99.99 absorption.

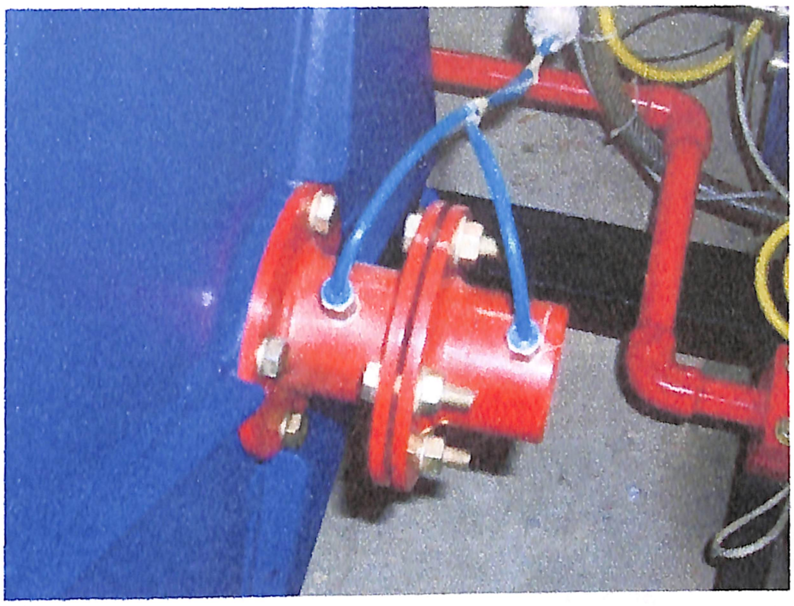
AVL Digas analyzer-40000 is used to measure the amount of CO2, HC, CO, NOx in the exhaust from the engine. The measuring range of these particulates is:

Measured Quality	Measuring range
CO	0-10% vol
CO2	0-20% vol
HC	0-20000ppm
NOx	0-5000ppm

d. **Air surge tank:** It is used to supply air to the engine through an orifice meter.



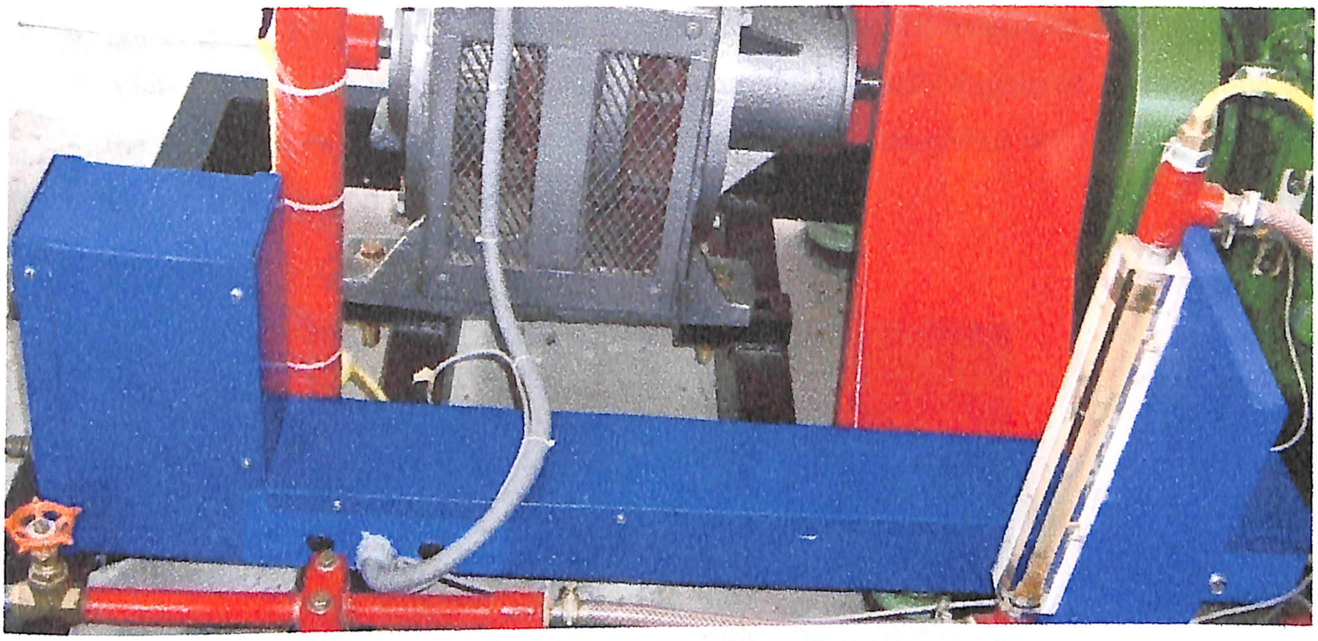
e. **Pressure sensors:** They detect the pressure of air at the inlet. A pressure sensor measures pressure typically of gases or liquids, it usually acts as a transducer and generates a signal as function of the pressure imposed. Pressure sensors are used for control and monitoring in thousands of everyday applications. Pressure sensors are also be used to indirectly measure variables such as fluid/gas flow, speed, water level and altitude, they are alternatively be called pressure transducers, pressure transmitters, pressure indicators, piezometers. There is also a category of pressure sensor that is designed to measure in a dynamic mode for capturing very high speed changes in pressure. For example: application for this type of sensor would be in the measuring of combustion pressure in an engine cylinder or a gas turbine.



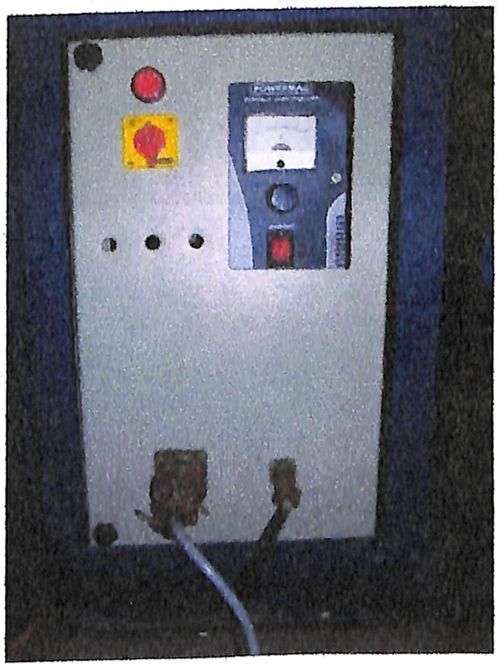
f. **Thermocouple:** It is used to measure the temperature of the exhaust gas, the coolant water, the air entering and leaving the fuel filter and the lubrication temperature.

Thermocouple is a junction between two different metals that produces a voltage related to a temperature difference; it is a widely used type of temperature sensor for measurement and control and can also be used to convert heat into electric power. They are inexpensive and interchangeable, are supplied, fitted with standard connectors, and can measure wide range of temperatures. The main limitation is accuracy thermocouples are widely used in science and industry, applications include temperature measurement for gas turbine exhaust, diesel engine and other industrial processes.

g. **Junction Box:** the main function of a junction box is to collect data from all the sensors. It contains I.C. circuits which collect these data and send it to the computerized data acquisition system.



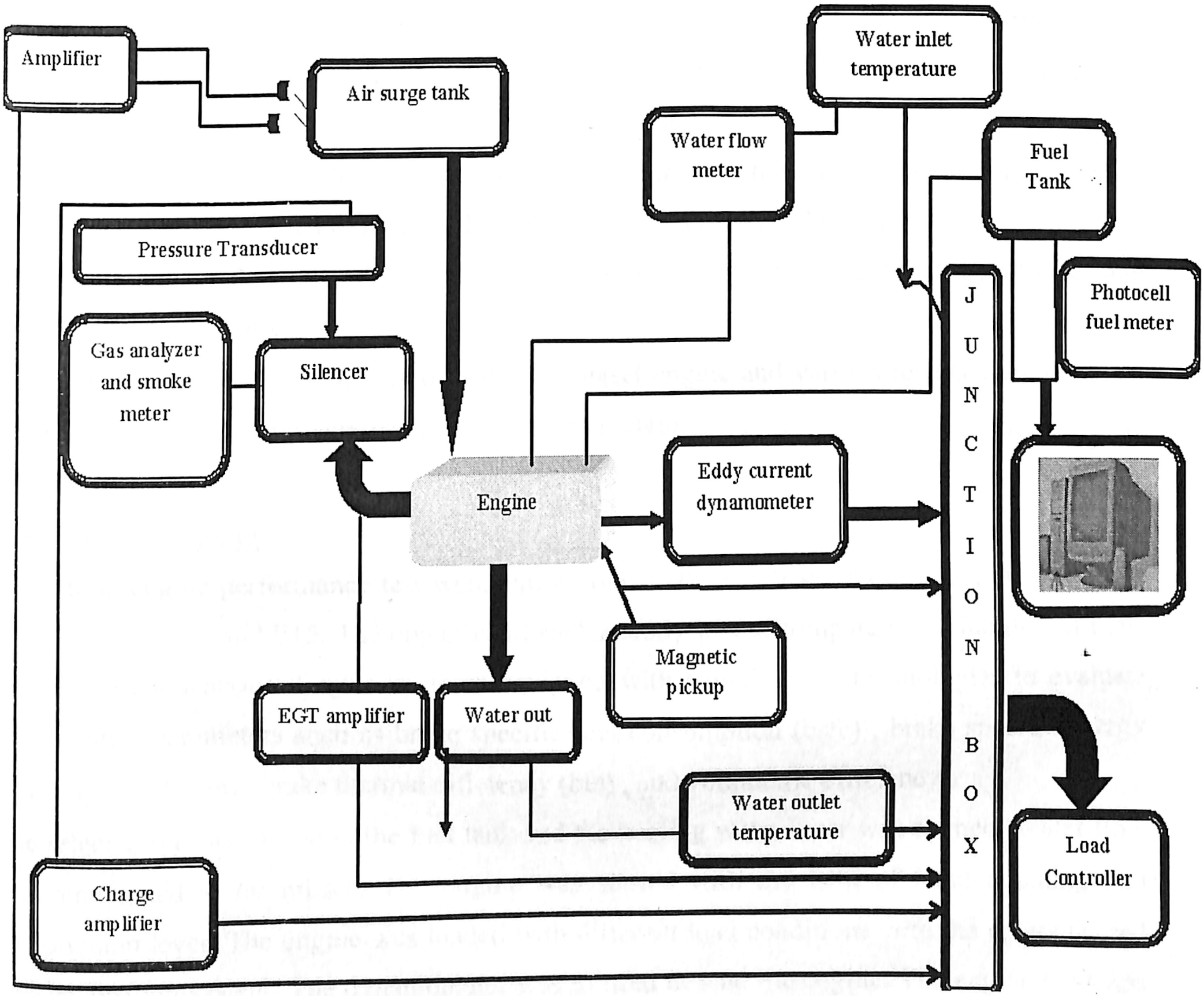
h. Load controller: It is used to change the loading conditions of the engine.



i. **Amplifiers:** Amplifier is a device that usually increases the amplitude of a signal. The relationship of the input to the output of an amplifier usually expressed as a function of the input frequency, is called the transfer function of the amplifier and the magnitude of the transfer function is termed the gain.

j. **<u>Computerized data acquisition:</u>** it receives all the data collected through various sensors. The calorific value and the density of the fuel are fed to the computer. The engine is then loaded and the required performance data is generated by the computer.

Test Setup


Amplifier
Air surge tank
Water inlet temperature
Water flow meter
Fuel Tank
Pressure Transducer
Photocell fuel meter
Gas analyzer and smoke meter
Silencer
JUNCTION BOX
Engine
Eddy current dynamometer
Magnetic pickup
EGT amplifier
Water out
Water outlet temperature
Load Controller
Charge amplifier

Engine test procedure

In order achieve the objective of our project, we reviewed the available literature to determine the current status of understanding on the subject, and identify important issues related to this experiment. The literature review also helped in identifying the specific activities to be carries out. To analyze the suitability of the fuel blends, it was necessary to identify the properties of the fuel as well as various performance and emission parameters of the engine. The following methodology was adopted for experimental investigations:

The first step of the procedure was to prepare the blends in the laboratory. The quantities of ethanol and emulsifier used to prepare these blends are discussed in Table 1.

Secondly the calorific value and density of diesel were determined using bomb calorimeter and hydrometer respectively.

The prepared blends were then used to run the diesel engine and various results were obtained and recorded by the computerized data acquisition system.

Performance Testing:

Short-term engine performance test were carried out on the small sized diesel engine with neat diesel oil, E5, E10 and E15. The objective of such a study was to compare the suitability of fuels for engine applications. Engine systems equipped with experimental technologies to evaluate performance parameters such as brake specific fuel consumption (bsfc) , brake specific energy consumption (bmep) , brake thermal efficiency (bte) , and volumetric efficiency.

The selected fuel was filled in the fuel tank and the cooling water lever was opened. Water flow was maintained at 60 ml/sec. The engine was started with the help of hand cranking and compression lever. The engine was loaded with different load conditions with the computerized data acquisition system. The dynamometer was to used to load the engine. The engine load was varied from 0% to 100% in approximation of 20%. In order to evaluate the performance of engine data like calorific value, density of fuel, and cooling water flow were fed to the computer. The various engine parameters were recorded by the computer during the whole cycle of operations.

The result obtained from performance tests were analyzed and interpreted graphically.

Emission Test:

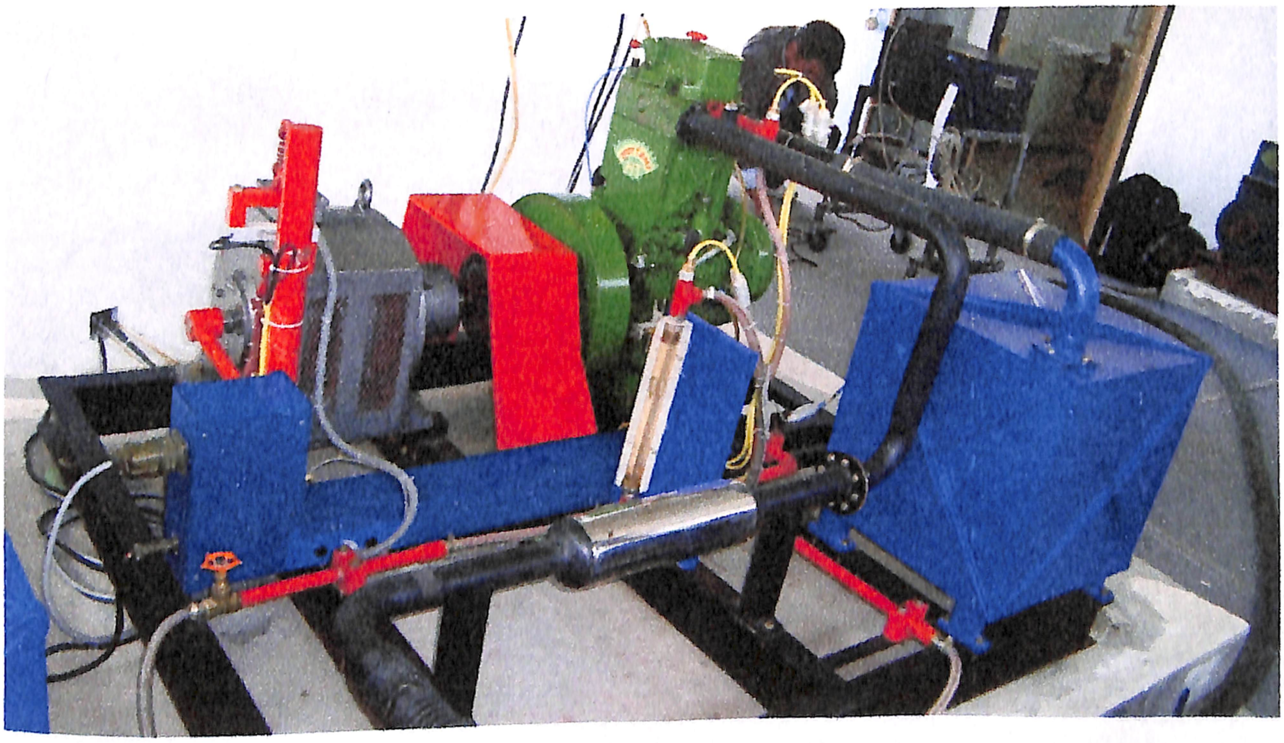
In order to perform the emission tests for carbon monoxide, carbon dioxide, unburnt hydrocarbons, nitrogen oxides and smoke, a five gas analyzer (AVL DiGas- 4000 model) and a smoke-meter (AVL 437 model) were used.

In order to measure the exhaust from the engine following process was carried out.

The smoke-meter and Gas analyzer were switched on. The amount of smoke in the exhaust was measured first. Engine was loaded at 100% load. The engine exhaust to the atmosphere was closed and was connected to the smoke-meter. The smoke-meter was set to zero and the exhaust gas from the engine was fed to it. The observations were recorded. In order to measure other emissions from the engine gas analyzer was used. The sensor of the gas analyzer was exposed to the exhaust gas. Once the readings increase no more and start decreasing, they were recorded.

The engine load was varied from 100% to 0% in approximation of 20%. Same process was repeated for each load.

The result obtained were analyzed and interpreted graphically.



Chapter 4:
RESULTS AND DISCUSSIONS

The results obtained from the experimental analysis of diesel and ethanol-diesel blends are analyzed and interpreted graphically in this section. It includes the results obtained from the physio-chemical analysis of mineral diesel, E5, E10 and E15, performance and emission analysis of these blends under various loading conditions of 20%, 40%, 60% and 100%.

Fuel properties:

The physio-chemical analysis of mineral diesel, E5, E10 and E15 was done in the laboratory. This included the determination of calorific value using bomb calorimeter and the determination of fuel density using hydrometer. The results obtained are given in the table below.

Properties\Fuel	**Diesel**	**E5**	**E10**	**E15**
Calorific value (J/gm)	48832.88	43471.4239	41870.17	39492.59
Density (g/cc^3)	0.817	0.815	0.811	0.809

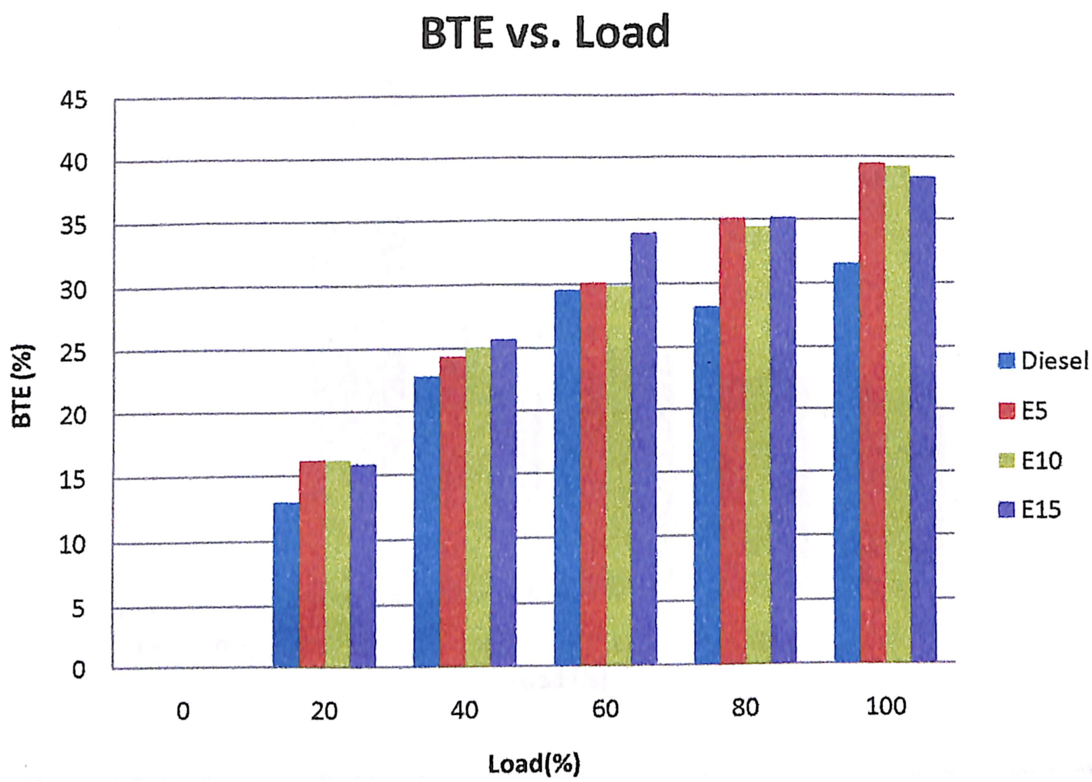
Table 3: The densities and calorific value of various samples

From the table it is clear that the calorific value and the density of mineral diesel are greater than ethanol- diesel blends. The calorific value of diesel was found to be 48832.88 J/gm while that of E5, E10 and E15 were 43471.4239 J/gm, 41870.17 J/gm and 39492.59 J/gm respectively. This decrease is due to the low energy content of ethanol as it contains more oxygen than diesel. Higher energy oxygen content helps in complete combustion of the fuel. The calorific value keeps on decreasing as the amount of ethanol increases.

The value of density also shows a decreasing trend. The density of diesel was found to be $0.817 g/cc^3$. The densities of E5, E10 and E15 were $0.815\ g/cc^3$, $0.811 g/\ cc^3$ and $0.809\ g/\ cc^3$. The density of ethanol is lower than that of diesel. Therefore addition of ethanol to diesel decreases the density of fuel. However it can be seen that there is not much variation in the densities of diesel, E5 and E10.

Performance studies:

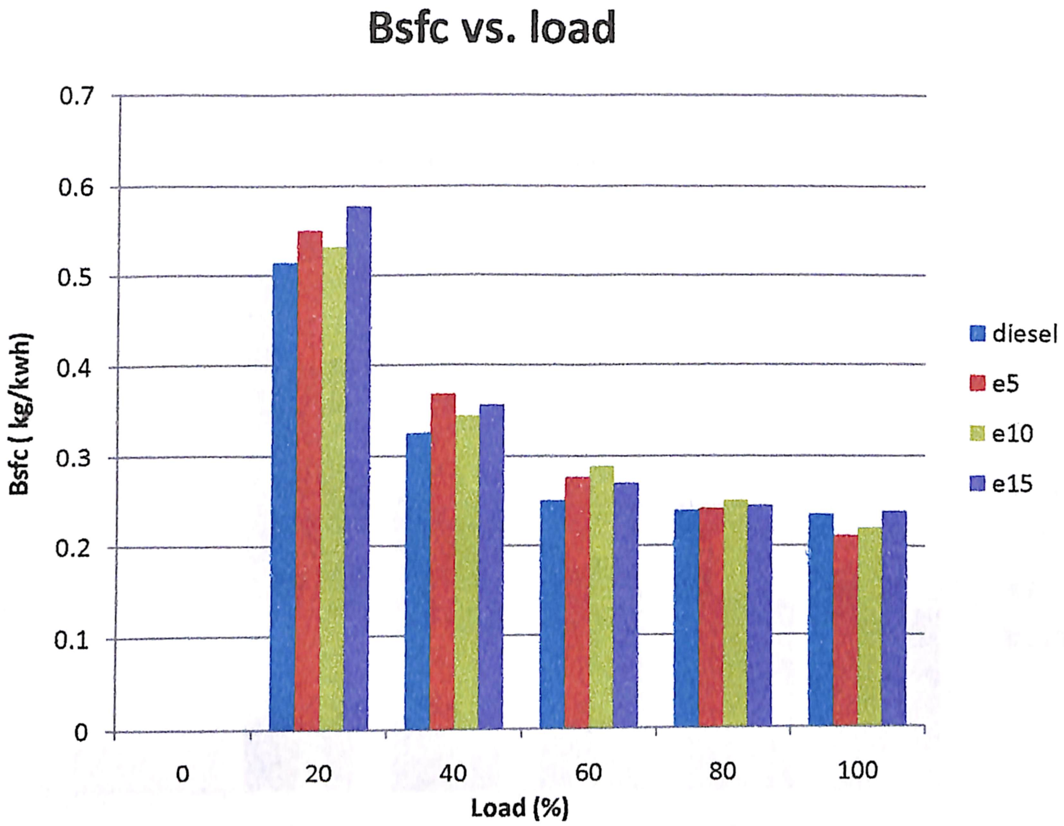
Tests were performed on the diesel engine using diesel and its blends with ethanol i.e. E5, E10 and E15 under various load conditions of 20%, 40%, 60% and 100%. The speed of the engine was 1500 rpm. The results obtained are interpreted and presented below graphically:



Fuel\load (%)	0	20	40	60	80	100
Diesel	0	12.90812	22.725	29.52242	28.13172	31.4735
E5	0	16.17018	24.26547	30.06103	35.02546	39.42338
E10	0	16.1504	25.00312	29.81464	34.37169	39.18514
E15	0	15.7942	25.62146	33.91246	35.08254	38.33065

Table 4

It can be seen from the above graph that the trend for Brake Thermal Efficiency (BTE) improved for ethanol blends. BTE, for all the fuels increases as the load increases. BTE for E5, E10 and E15 was higher than diesel. The values for BTE for these fuels are given in the table. It can be seen that the value of BTE for E5, E10 and E15 was higher at full loads. This increase in BTE may be due to the complete combustion of fuel. The oxygen content of ethanol is greater than that of diesel, also the viscosity of blended fuel is lower than that of diesel which leads to better burning of the fuel.



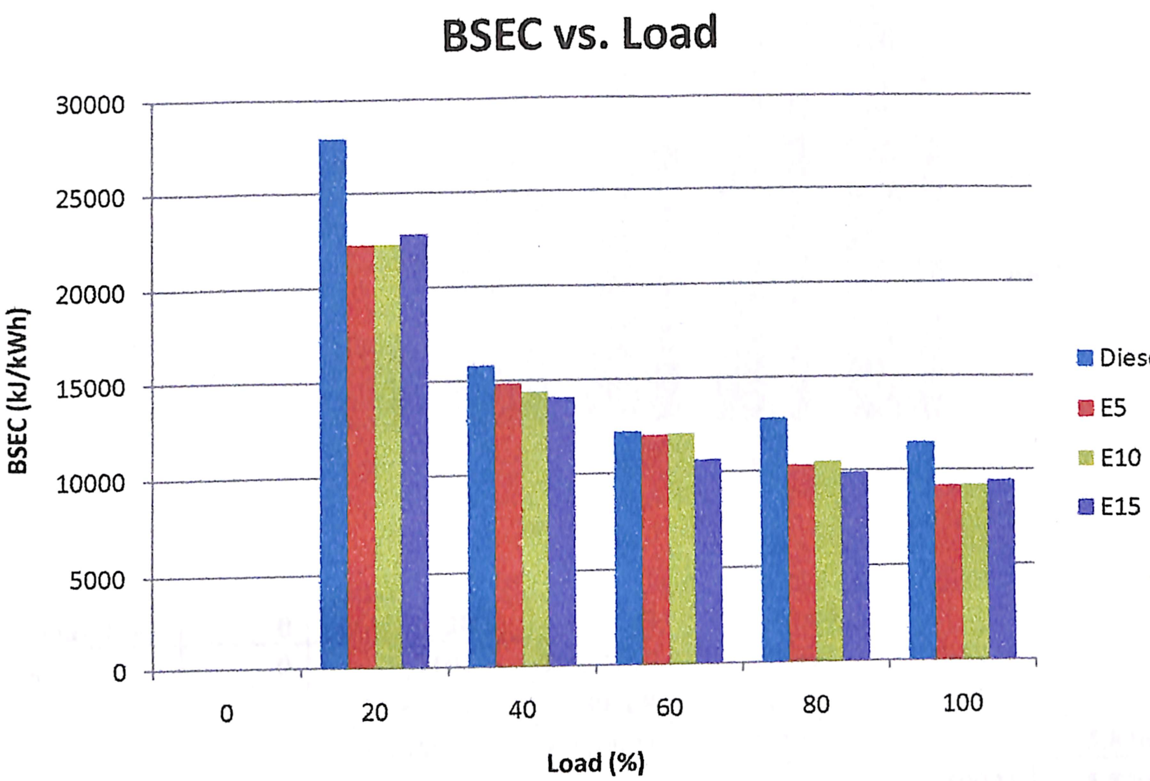
Fuel\load (%)	0	20	40	60	80	100
Diesel	0	0.513921	0.324404	0.249711	0.238275	0.234231
E5	0	0.55032	0.367348	0.275483	0.240652	0.210061
E10	0	0.532371	0.343877	0.288382	0.250148	0.21942
E15	0	0.577151	0.355781	0.268799	0.244285	0.237816

Table 5

Brake specific fuel consumption (BSFC) curves were analyzed to determine the fuel consumption in the engine. It was observed, and can be seen in the graph, that the BSFC is higher for low loads. The fuel consumption decreases at higher loads and is maximum for full load.

It was observed that the trend for BSFC increased slightly for blended fuels. This may be due to the low calorific value of ethanol blended fuels. However BSFC may not be a very reliable parameter for the comparison of fuel blends as the calorific value and density follow different trends.

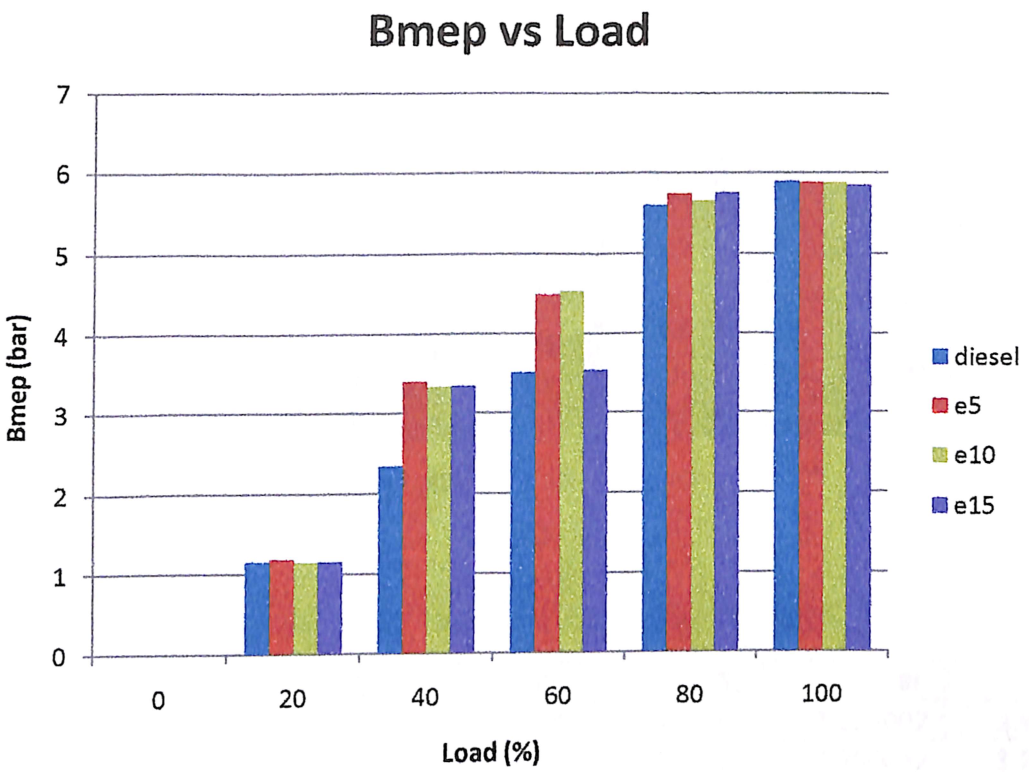
BSEC curves were therefore used for the comparison of diesel and its blends with ethanol, as it is more reliable parameter.



Fuel\load (%)	0	20	40	60	80	100
Diesel	0	27889.42	15789.63	12194.12	12796.94	11438.19
E5	0	22263.21	14835.9	11975.64	10278.24	9131.636
E10	0	22290.46	14398.21	12074.6	10473.74	9187.156
E15	0	22793.17	14050.72	10615.57	9870.75	9391.963

Table 6

It can be observed that the brake specific energy consumption for diesel is higher than the blended fuel. This is due to high calorific value of diesel. BSEC for diesel was higher at low loads but remained almost the same or slightly more than blends at higher loads.

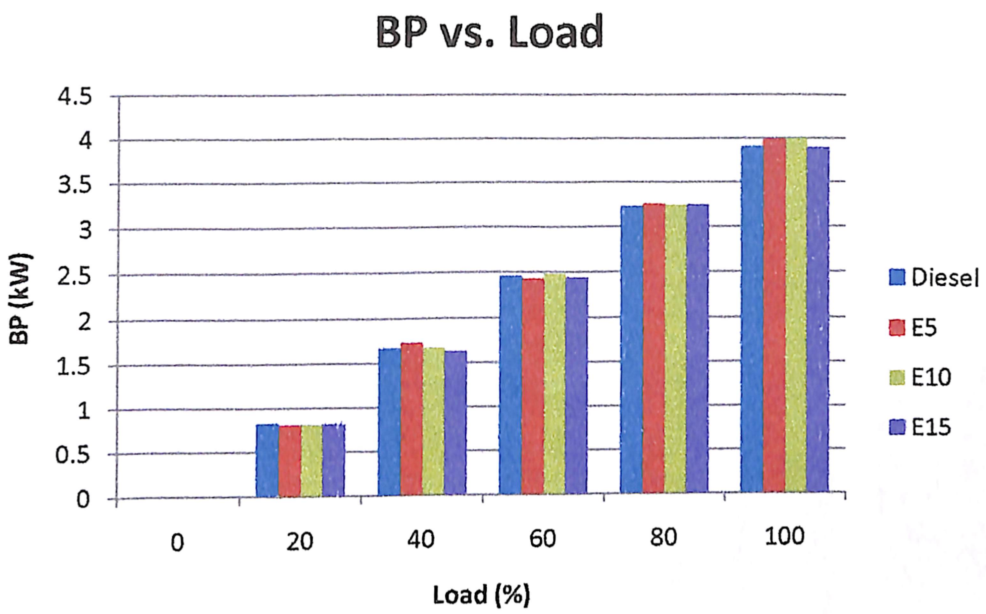


Fuel\load (%)	0	20	40	60	80	100
Diesel	0	1.157107	2.337159	3.504894	5.585833	5.885647
E5	0	1.185791	3.39068	4.484193	5.735112	5.872033
E10	0	1.155554	3.330973	4.532976	5.650025	5.876981
E15	0	1.156021	3.333802	3.533641	5.750021	5.840297

Table 7

Brake Effective Mean Pressure i.e. BMEP for ethanol-diesel blend was observed to be slightly higher than that of pure diesel. This may be due to the presence of more oxygen molecules which help in complete combustion and hence higher pressure inside the cylinder.

The brake power obtained from the blended fuel is less than that obtained from pure diesel. This may be due to the decreased energy content of blended fuel.

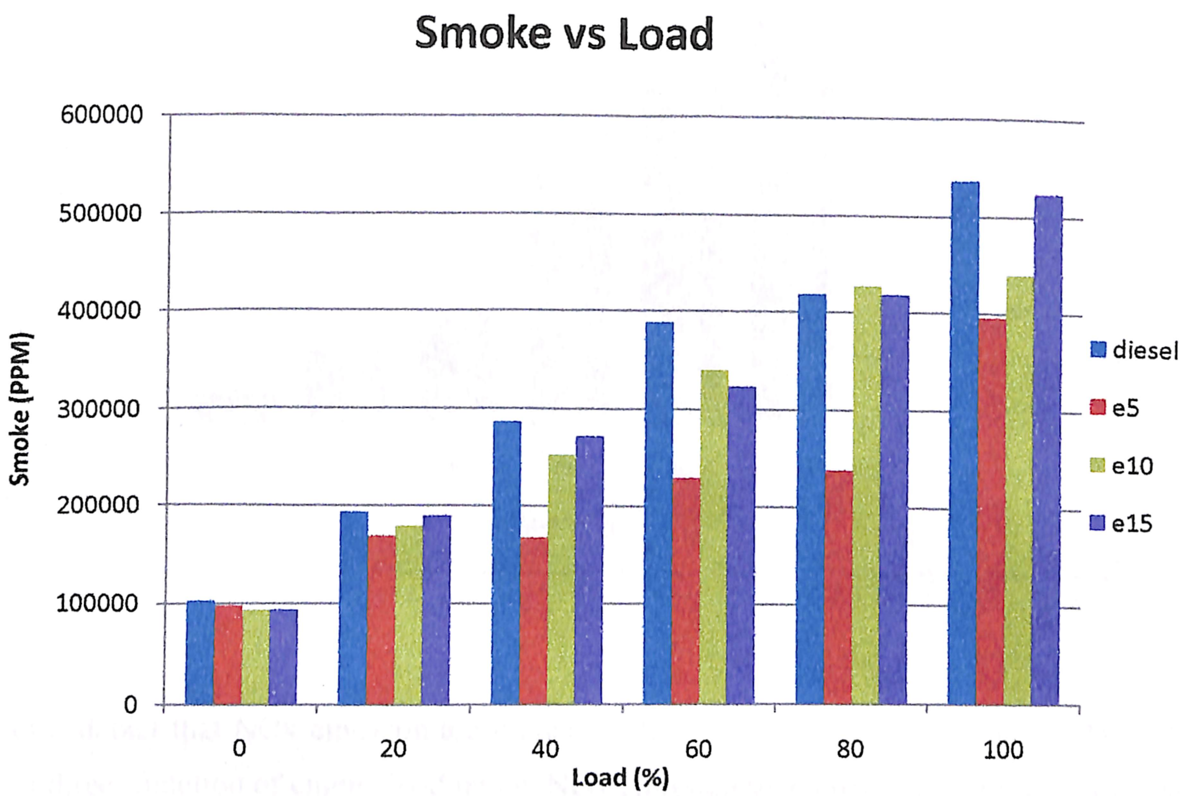


Fuel\load (%)	0	20	40	60	80	100
Diesel	0	0.824819	1.65994	2.457992	3.223092	3.901722
E5	0	0.806147	1.721134	2.422777	3.250442	3.987791
E10	0	0.812326	1.665884	2.480649	3.238428	3.99585
E15	0	0.812169	1.622362	2.436607	3.244008	3.89121

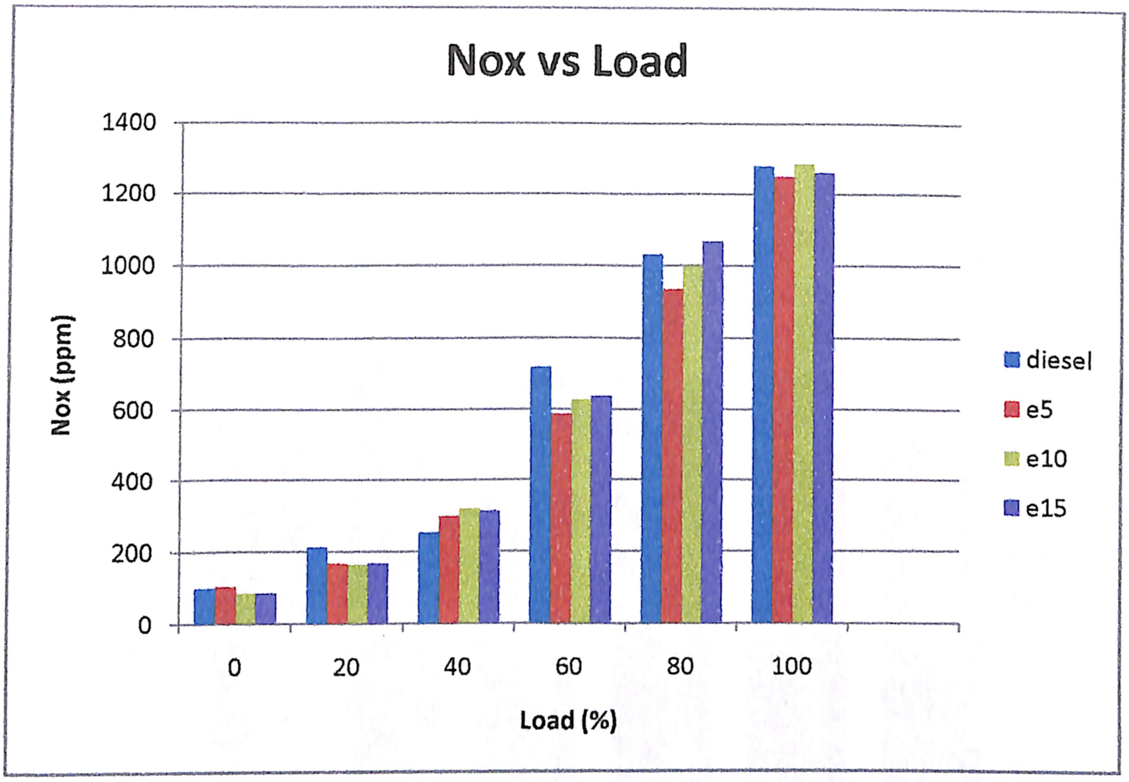
Table 8

Emission studies:

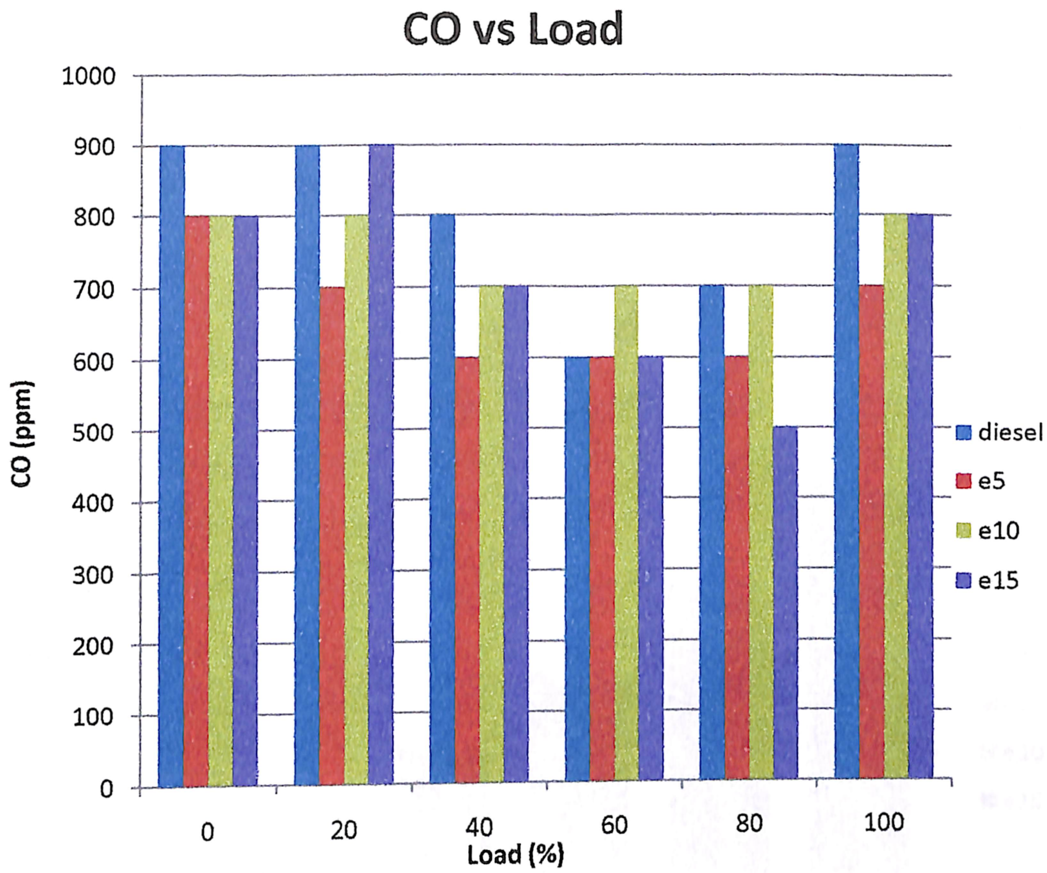
The results obtained from the emission test were analyzed and interpreted graphically.



It is observed that smoke was considerably reduced for all the blends as compared to pure diesel. This was due to the complete and stable combustion of blends. Smoke from E15 was higher than those from E5 and E10. It was least foe E5. E10 also showed lower opacity and thus can be considered for long term use in diesel engines.

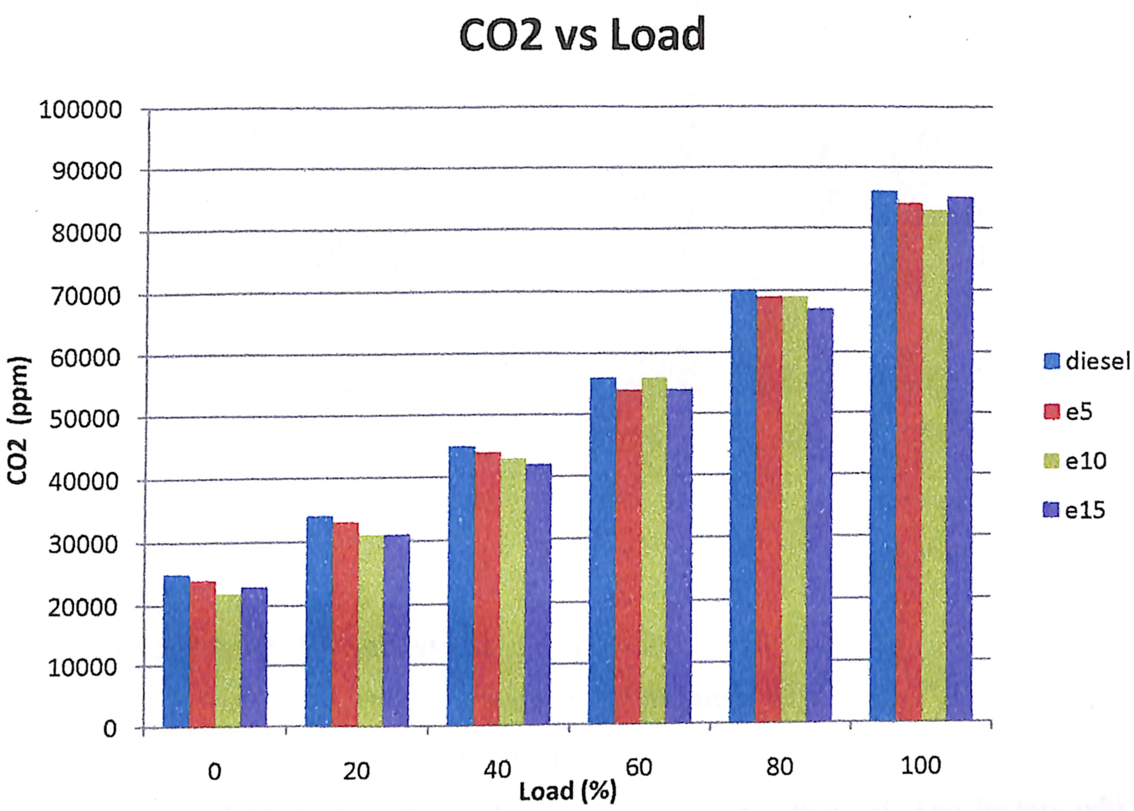


The studies depict that NOx emission are higher for the blended fuels. It is also observed that NOx is a direct function of engine loading i.e. NOx emission increases with the increasing load. This may be due to the rise in temperature of combustion chamber and NOx is a temperature dependent phenomenon. It was also observed that NOx emissions for blends were lower for 100% load. It may be due to lower combustion temperatures in the combustion chamber. NOx was also lower in case of 80% and 60% load. It may be due to less residence time and temperatures in case of blended fuels.

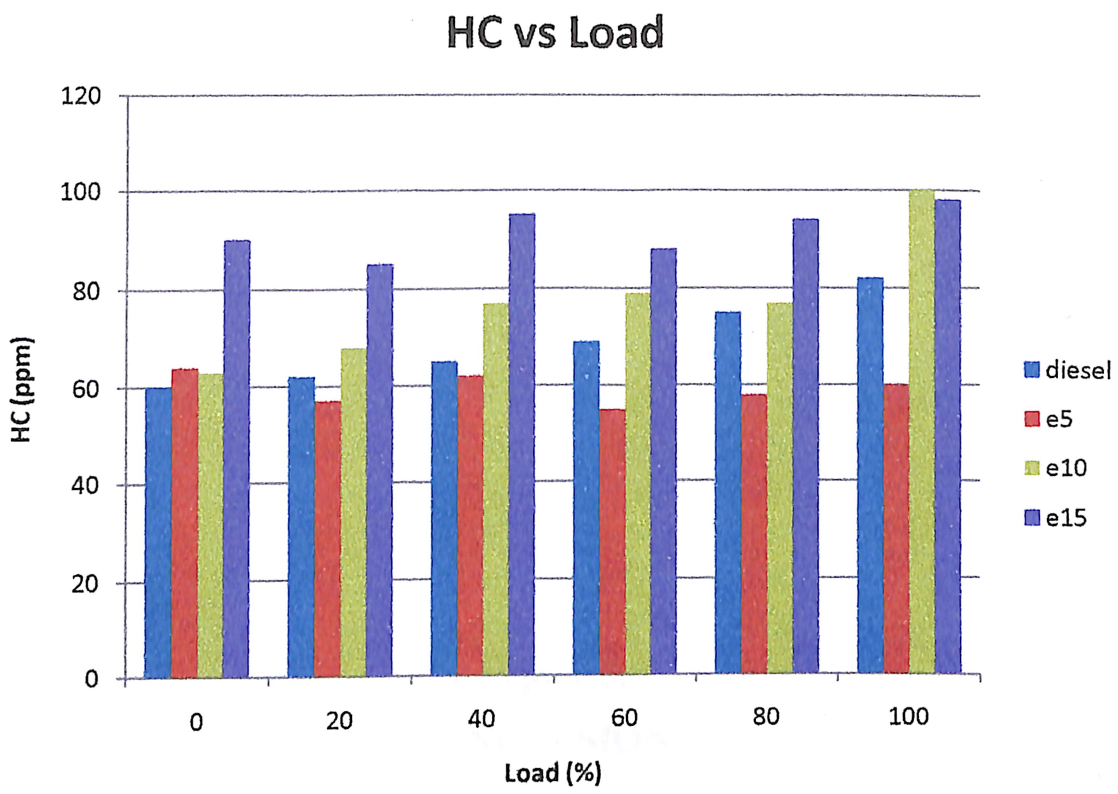


The carbon monoxide emission for E5, E10 and E15 were lower for the entire range of load as shown in the graph. Lower carbon monoxide emissions were due to the complete combustion of fuel.

The results also show a decrease in greenhouse gas emission such as CO_2 as shown in the graph below



All the blends showed satisfactory results in case of Co2 emissions.



The graph shows higher HC emissions for blended fuels. This may be due to the poor atomization of the blended fuels. However HC emissions were found to be lower for E5. Therefore it can be a good replacement for diesel.

It was observed that there were some differences in the data obtained. The factors which may influence emission data include engine fuel metering technology, exhaust control technology, maintenance history, test procedure and test conditions.

Chapter 5:
CONCLUSION

Based on the performance and emission test performed on the C.I. engine it can be concluded that E5 is best suited for the existing C.I. engine without any major hardware modifications. The thermal efficiency, BSEC, BMEP and BP for E5 were satisfactorily higher than diesel. BSFC for E5 was slightly higher than diesel but under the prescribed limits. Smoke, CO, CO2 and HC levels of E5 were considerably lower than that of diesel. NOx level were also found within the standard limits.

Other than E5, E10 was also found to give satisfactory results with increasing performance and lower emissions.

Chapter 6:
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