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CERTIFICATE

It is to certify that the dissertation entitled **"EXPERIMENTAL STUDIES ON FUMIGATION OF ETHANOL IN A SMALL CAPACITY DIESEL ENGINE"** submitted by Mr. Shyam Sundar Pal, 18/THR/06 in partial fulfillment for the award of the Degree of Master of Engineering in Thermal Engineering, is an authentic record of student's own work carried out by him under my guidance and supervision.

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

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Abstract

Diesel vehicles remain a major cause of street level air pollution in many cities. For new diesel vehicles, increasingly stringent emissions standards have been imposed to reduce the pollutants they emitted. For in-use diesel vehicles, improvements are required to reduce air pollution as well. In some cities, after-treatment devices and clean fuels have been applied. After-treatment devices, including the oxidation catalytic converter and the particulate filter, can lead to reduction of CO, HC and/or particulate emissions. However, after-treatment devices currently in-use are unable to reduce emission of carbon dioxide (CO_2), and have very limited application for reducing nitrogen oxides (NO_x).

Ethanol has been widely investigated for applying in combination with diesel fuel to reduce pollutants, including smoke and NO_x . The present work aims at developing a fumigation system for introduction of ethanol in a small capacity diesel engine and determines its effects on emission. Ethanol is an oxygenated fuel and lead to smooth and efficient combustion. Atomization of ethanol also result in lower combustion temperature .During the present study, gaseous emission has been found to be decreasing with ethanol fumigation. The results from the experiments suggest that ethanol fumigation can be effectively employed in existing C.I. engine to achieve substantial saving of the scarce diesel oil. At the same time, this also results in improved engine performance with lower NO_x and smoke emissions.

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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
^oC	Degree Celsius
cc	Cubic centimeter
CI	Compression Ignition
cm^{-1}	Per Centimeter
CN	Cetane Number
CO	Carbon Monoxide
CO_2	Carbon Dioxide
cSt	Centi Stoke
Cu	Copper
CV	Calorific Value
D100	Neat Diesel
DI	Direct Injection
DF	Diesel fuel
$dQ/d\Theta$	Apparent Net Heat transfer Rate
$dQ_{ch}/d\Theta$	Gross Heat Release Rate
$dQ_{ht}/d\Theta$	Heat Transfer across the cylinder walls, J/ºCA
EOI	End of Injection
EV	Electric Vehicle
ºF	Degree Fahrenheit

F/A	Fuel to Air
FFA	Free Fatty Acid
FIT	Fuel Inlet temperature
FIP	Fuel Injection Pump
FT	Fourier Transform
FTIR	Fourier Transform Infra red
g	Gram
g/cc	Gram per cubic centimeter
HC	Hydrocarbon
H_2O	Water
HP	Horse Power
Hz	Hertz
IC	Internal Combustion
IDI	Indirect Injection
IR	Infra Red
IS	Indian standard
JO	Jatropha oil (Unheated)
KOH	Potassium Hydroxide
KVA	Kilo Volt Ampere
kW	Kilo Watt
kW-h	Kilo Watt Hour
LSD	Low Sulphur Diesel
LPM	Liter per Minute
1M	1 Mole
Min.	Minute
ml	Milliliter
mm	Millimeter
Mt	Million Tonnes
Mtoe	Million Tonne of Oil Equivalent
NO	Nitric Oxide
Nos.	Numbers
NO_2	Nitrogen Di-oxide
NO_x	Oxides of Nitrogen

O_2	Oxygen
ppm	Parts per million
rpm	Revolutions Per Minute
SAE	Society of Automobile Engineering
sfc	Specific Fuel Consumption
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

1.1 ENERGY CRISIS AND NEED FOR ALTERNATE FULES

There is a realization throughout the world that the petroleum resources which are non renewable are limited and are being consumed at an alarming rate. The growing demand for energy and gradual extinction of fossil fuels has lead to an energy crisis. Most of the power for industries and transportation is derived from oil and coal as basic fuels. Special mention is needed for automobiles where almost all of the fuels for combustion engine today are derived from petroleum a nonrenewable source of energy, which is nearing its end at an unprecedented pace. The grave name of the energy problem was sharply brought into focus by the oil crisis of 1973. Since then, several price hikes have taken place, upsetting economy of most of the nation.

Table 1.1: Comparison of Per Capita Energy and Electricity Consumption [1]

Country	CO_2 Emission (metric ton/capita)			Electric Consumption (kWh)				Energy use (kgoe)			
	2001	2002	2003	2001	2002	2003	2004	2001	2002	2003	2004
India	1	1	1	403	417	435	457	503	509	515	531
Japan	9	9	10	7861	7960	7840	8072	4096	4093	4041	4173
China	2	3	3	1069	1184	1389	1585	881	943	1072	1242
Norway	8	13	10	25595	24617	23196	24645	5461	5526	5947	6024
UAE	33	34	33	11479	11634	11436	11331	10290	10697	10513	10142
UK	10	9	9	6102	6153	6198	6206	3942	3853	3898	3906
USA	20	20	20	13030	13126	13255	13351	7916	7936	7843	7920
France	6	6	6	7597	7572	7793	7900	4500	4465	4507	4527
Germany	10	10	10	6853	6740	6898	7029	4293	4184	4205	4218
World (Average)	4	4	4	2390	2441	2517	2601	1677	1693	1731	1790

Most of the internal combustion (IC) engines use petroleum fuels which are limited and expected to be exhausted in about 40 years. Limited energy sources leads to the warning of potential lack of energy in the future. Approximately 1/3 of the petroleum fuels are consumed in the IC engines which have lesser power than 185 kW and exhaust gases emitted from these engines are one of the main reasons of the environmental pollution. In the last years, many studies on the IC engines aiming to reduce exhaust emissions have been carried out by changing operating parameters such as valve timing, injection timing, and atomization rate. At the same time, depletion of fossil fuels and environmental considerations has led to investigations on the renewable fuels such as ethanol, hydrogen, and biodiesel. [2, 3]

1.1.1 ENERGY SCENARIO: INDIAN CONTEXT

India is heavily dependent upon the import of petroleum to cater its need for automobile and other application.110 million tons of oil imported during 2006-07. Worth Rs. 2199.91 billion, with rapid industrialization and very fast increasing number of automobile due to general economic uplift of society, the demand for petroleum is increasing at a very rapid rate. This will lead to greater scarcities and higher prices with consequent adverse effects on the economy of the country.

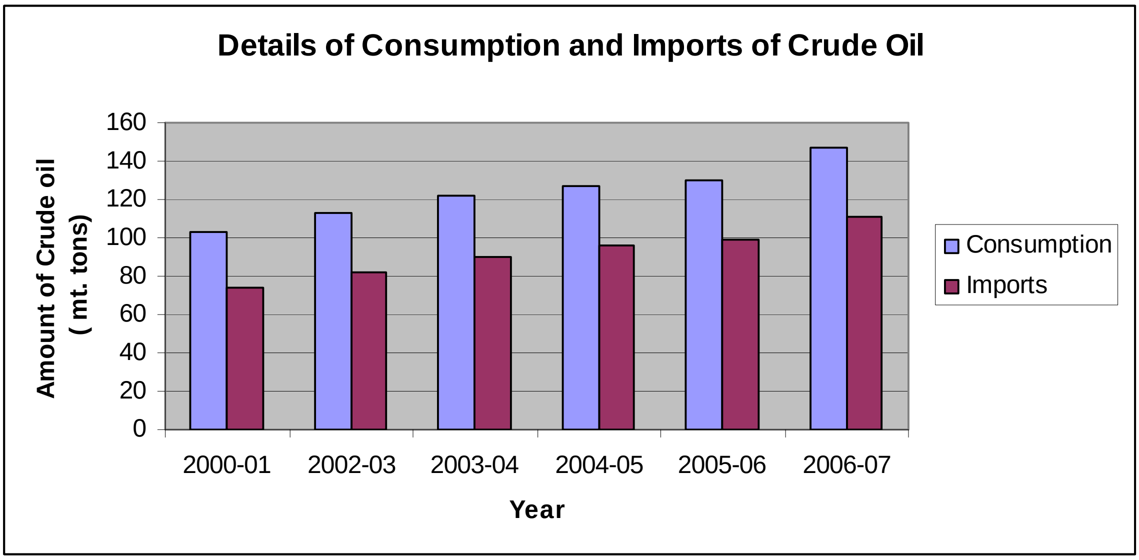

Fig. 1.1: Details of Consumption and Imports of Crude Oil

Added to the problem of fast dwindling resources of petroleum fuels and the economic and political factor associated with their procurement environmental pollution caused by the combustion of these fuels in automobiles and other stationary sources , have focused the attention of researchers in this area to search for the clean burning renewable alternative fuels for automobiles.

1.1.2 COMPRESSION IGNITION ENGINES AND ALTERNATE FUELS

The compression ignition engine is based on the works of Rudolf Diesel, a German scientist, around 1892 and operates on a cycle of events known as diesel cycle. The C.I. engine can be envisioned as a conventional spark ignition engine with spark plugs replaced by fuel injectors and hence it offers the advantage of reliability by the elimination of high voltage electrical equipment. There is no carburettor or associated air throttle there by eliminating the throttling losses and hence it provides idling and part load economy .higher compression ratio used in C.I. engine offer it the high thermodynamic efficiency.

In addition to its popularity for mass transport system, it is getting popular in small automobile engine for passenger cars and light trucks due to its better part load performance and improved emission characteristics. in India ,the number of C.I. engine is so large that bulk of imported petroleum is consumed in the form of diesel fuels .there are more 2 million diesel engine that are single cylinder used for electricity and water pumping.

The possible alternatives energy sources for use in diesel engines are hydrogen, biogas and alcohols. Hydrogen may prove to be a long term possible fuel since many problems associated with its economical production, hazardous nature, storage and handling are yet to be sorted out. Bio-gas required high storage pressure, if it has to be used in automobiles. Leakage from cylinder may cause problem. Hence use of biogas as substitute fuel for automobiles is ruled out till such time as simple and safe storage and handling facilities are developed.

The demand for diesel is five times higher than the demand for petrol in India. But while the ethanol industry is mature, the biodiesel industry is still in its infancy. India's current biodiesel technology of choice is the transesterification of vegetable oil. The government has formulated an ambitious National Biodiesel Mission to meet 20 per cent of the country’s diesel requirements by 2011-2012. Since the demand for edible vegetable oil exceeds supply, the government has decided to use non-edible oil from Jatropha Curcas seeds as biodiesel feedstock. Extensive research has shown that Jatropha offers the following advantages: it requires low water and fertilizer for cultivation, is not grazed by cattle or sheep, is pest resistant, is easy propagated, has a low gestation period, and has a high seed yield and oil content, and produces high protein manure.

The main problem in getting the biodiesel program rolling has been the difficulty in initiating the large-scale cultivation of Jatropha because farmers do not consider Jatropha cultivation rewarding enough. The government needs to sponsor confidence-building measures such as establishing a minimum support price for Jatropha oilseeds and assuring farmers of timely payments.

Alcohols seem to be the most attractive alternate fuels from the point of view of availability, storage and handling. Two alcohols commonly considered for automotive application are methanol and ethanol. Methanol has certain disadvantage such as its low calorific value and toxic effects.

1.1.3 ETHANOL AS SUPPLEMENTARY FUEL IN C.I. ENGINES

Since 19th century, ethanol has been used as a fuel for compression ignition (CI) engines. Ethanol can be fermented and distilled from biomasses. The current manufacturing cost of ethanol and biodiesel in India is about Rs. 21/litre, roughly the same as petrol and diesel. This puts ethanol in a favorable position for meeting India's energy needs, especially as the cost of petroleum is expected to continue its upward trend. In addition to providing energy security and a decreased dependence on oil imports, ethanol offer several significant benefits such as reduced emission of pollutants and greenhouse gases and increased employment in the agricultural sector. Therefore, it can be considered as a renewable fuel.

As a fuel for CI engines, ethanol has some advantages over diesel fuel, such as the reductions of soot, carbon monoxide (CO) and unburned hydrocarbon (HC) emissions. Although having these advantages, due to limitation in technology, economic and regional considerations, ethanol still cannot be used extensively. However, ethanol blended diesel fuels can be practically used in CI engines [4, 5].

Ethanol (C2H5OH) is a pure substance. However, diesel fuel is composed of C3–C25 HCs, and has wider transitional properties. Ethanol contains an oxygen atom so that it can be viewed as a partially oxidized HC. Ethanol is completely miscible with water. This may cause the blended fuel to contain water, and further results in the corrosion problems on the mechanical components, particularly for components made from aluminum, brass, and copper. To diminish this problem on the fuel delivery system, such materials stated above should be avoided. Ethanol can react with most rubber and create jam in the fuel pipe. Therefore, it is advised to use fluorocarbon rubber as a replacement for rubber. The auto-ignition temperature of ethanol is higher than that of diesel fuel, which makes it safer for transportation and storage. On the other hand, ethanol has a much lower flash point than that of diesel fuel, a disadvantage with respect to safety [6, 7].

Alcohol, especially ethanol or ethyl alcohol, has been recognized as a quality motor fuel, as the design of the first automobile (the original Ford Model-T) for the spark-ignition engine because of its high anti-knock value designated by the `octane Number' and better performance in terms of power and efficiency. It is only recently (since the 1970s) that interest was shown in the use of ethanol and methanol as diesel fuels. Ethanol is very difficult to burn by compression-ignition, because of their low ignition quality, usually designated by a low cetane number. A high-octane fuel (a virtue for a petrol engine), necessarily has a low cetane value (a curse for the diesel engine). The main research in diesel-alcohol technology was to find ways and means to force alcohol to ignite by compression in the diesel engine.

It is interesting that India was the earliest to recognize the merits of burning ethanol in diesel engines. The bi-fuel system developed by the Prof H. A. Havemann and his colleagues at the Indian Institute of Science (IISc) Bangalore, in the early 1950s, was the subject of the earliest original published work in technical literature regarding alcohol diesels.

It is apparent from the increasing popularity of light-duty diesel engines that alternative fuels such as alcohols must be applicable to diesel combustion if they are to contribute significantly as substitutes for petroleum-based fuels. However, in the past, little attention has been given to the utilization of Ethanol fuels in compression ignition engines this is due to the difficulties encountered while attempting to use ethanol in diesel engines.

The main difficulties are:

1. More Ethanol fuel than diesel fuel is required by mass and volume.
2. Large percentages of Ethanol do not mix with diesel fuel; hence use of diesel- Ethanol blends is not feasible. Also, the blends were not stable and separate in the presence of trace amounts of water [8].
3. Ethanol have extremely low cetane numbers, whereas the diesel engine is known to prefer high cetane number fuels (45-55) which auto-ignite easily and give small ignition delay [9].
4. Diesel fuels serve as lubricants for diesel engine. Alcohol fuels do not have the same Lubricating qualities [10, 8].
5. The poor auto-ignition capability of Ethanol is responsible for severe knock due to rapid burning of vaporized alcohol [11, 8] and combustion quenching caused by high latent heat of vaporization and subsequent charge cooling [8].

Although replacing diesel fuel entirely by alcohols is very difficult, an increased interest has emerged for the use of alcohols, and particularly lower alcohols (methanol and ethanol) with different amounts and different techniques in diesel engines as a dual fuel operation during recent years.

1.1.4 ETHANOL SOURCES

In India ethanol is produced by the fermentation of molasses – a by-product of sugar manufacture. The cost of ethanol production can be decreased by using improved agricultural practices to increase sugarcane yield and deploying energy-efficient ethanol dehydration methods like pressure-swing adsorption and membrane separation. Restrictive government policies need to be reformed to loosen constraints on ethanol production.

India is now the world's largest sugar consumer and this has put added pressure on the ethanol industry. As agricultural research has amply demonstrated, sweet sorghum and tropical sugar beet are cost-effective feedstock crops that may substitute for sugarcane. Furthermore, exciting new biotechnology involving enzymatic saccharification and fermentation has made it possible to use readily available cellulosic material like wood and crop residue for ethanol production. Also, trade in ethanol can play an important part in helping meet India's ethanol requirements. India's trade policies do not have to be protectionist, but should rather be aimed at spurring domestic growth.

Molasses: a byproduct of sugar industry.

Sugarcane: Major source of ethanol production in India.

Sugar beet: Sugar beet cultivation and its processing to ethanol is not very popular in the country.

Starch (grain, corn etc): Corn oil is edible and its use in India for production of ethanol is not considered.

1.1.5 ETHANOL CAPACITY IN INDIA

India is the fourth largest ethanol producer after Brazil, the United States and China, its average annual ethanol output amounting to 1,900 million litres with a distillation capacity of 2,900 million litres per year. For a 5 per cent ethanol blend in petrol nationally, the ethanol required would be 640 million litres of ethanol in 2006-2007 and 810 million litres in 2011-2012. Current capacity can potentially satisfy this demand.

- Second largest producer of sugarcane in the world - 315.5 million tonnes per annum.
- Fourth largest producer of ethanol.
- Annual production of 2.3 billion litres in 2006-07.
- Capacity utilization of 65%.

Table 1.2: Production Capacity of Ethanol in India

Year	Ethanol Production M lt	Potable Use M Lt	Industry Use M lt	Other use M lt	Surplus M lt
1999-00	1654.0	622.7	518.9	57.6	455.8
2001-02	1775.2	647.8	539.8	59.9	527.7
2003-04	1969.2	693.7	578.0	70.0	627.5
2006-07	2300.4	765.2	631.4	81.0	822.8

- Gasoline demand expected to increase from 7.9 MT to 16.4 MT in 2016-17
- Current availability of molasses is adequate to meet this requirement after addressing the needs of chemical industry and potable sectors

1.1.6 Economics of Ethanol Production from Molasses

The cost of molasses in India varies widely across different states; in past years it has been as low as Rs. 50/ton and as high as Rs. 2,000/ton. A sizeable part of the cost is central excise duty, sales tax, transportation cost, etc., and the statutory controlled sugarcane and sugar prices. The international price of molasses, which was $50/ton in 2004, has doubled to $100/ton. Assuming a molasses price of Rs 3,000/ton and a yield of 220 litres of ethanol per ton, the feedstock cost would be Rs. 13.64/litre ethanol. A detailed cost breakdown of a 9 million litre/year ethanol production plant is given in table 1.3.

Table 1.3: Economics of Ethanol Production from Molasses

		Stand alone	Integrated with sugar
Cost of molasses	Per ton	Rs. 3,000	Rs. 3,000
Transportation cost	Per	Rs. 150 ($3.33)	0
Total		Rs. 3,150	Rs. 3,000
		Stand alone	Integrated
Recovery of ethanol	litres	220	220
		Rs./litre	Rs./litre
Molasses cost after milling		14.32	13.64
Steam cost @ Rice Husk Rs. 500/ton		0.25	0
Power cost @ Rs. 4.50/KwH		0.59	0
Chemical cost		0.2	0.2
Labour cost		0.25	0.25
Repair and maintenance		0.15	0.15
Total direct cost		15.76	14.24
Finance and other costs			
Indirect costs, including overheads		0.56	0.28
Interest @12 per cent for borrowed Rs.72 million (Debt/equity ratio=1 .5)		0.96	0.96
Interest @12 per cent for working one month of molasses and ethanol		0.2	0,2
Depreciation @ 10 per cent for Rs. 120 Million		1.33	1.33
Total finance and other costs		3.05	2.77
Total costs		Rs. 18.81	Rs. 17.01

1.2 PROPERTIES OF ETHANOL

Ethanol is isomeric with di-methyl-ether (DME) and both ethanol and DME can be expressed by the chemical formula C2H6O. The oxygen atom in ethanol possibly induces three hydrogen bonds. Although, they may have the same physical formula, the thermodynamic behavior of ethanol differs significantly from that of DME on account of the stronger molecular association via hydrogen bonds in ethanol. The physical properties of alcohols in comparison to CNG, DME and petroleum fuels are given in table 2.1.

Table1.4: Comparison of Various Primary Alcohols with Gasoline and Diesel [12, 13, 14, 15]

	Methane	Methanol	Dimethyl ether	Ethanol	Gasoline	Diesel
Formula	CH_4	CH_3OH	CH_3OCH3	CH_3CH_2OH	C_7H_{16}	$C_{14}H_{30}$
Molecular weight (g/mol)	16.04	32.04	46.07	46.07	100.2	198.4
Density (g/cm^3)	0.00072	0.792	0.661	0.785	0.737	0.856
Normal boiling point (^{1}C)	–162	64	–24.9	78	38–204	125–400
LHV (kJ/cm^3)	0.0346[a]	15.82	18.92	21.09	32.05	35.66
LHV (kJ/g)	47.79	19.99	28.62	26.87	43.47	41.66
Carbon Content (wt%)	74	37.5	52.2	52.2	85.5	87
Sulfur content	~ 7 – 2 5	0	0	0	~ 2 0 0	~ 2 5 0

Values per cm3 of vapor at standard temperature and pressure. Density at P ¼ 1 atm and T¼ ~25 1C.

Alcohol fuels, methanol and ethanol have similar physical properties and emission characteristics as that of petroleum fuels (Table 1.4). Alcohol's production is cheaper, simple and eco-friendly. This way, alcohol would be a lot cheaper than gasoline fuel.

Alcohol can be produced locally, cutting down on fuel transportation costs. Alcohol can be used directly in an engine or it can be blended with gasoline or diesel fuels.

Table 1.5 Properties of the Fuels used in the Tests

Properties	Ethanol	Diesel
Formula	C_2H_5OH	$C_{12}H_{26}$—$C_{14}H_{30}$
Molecular weight	46.07	170–198
Boiling temperature (°C)	78.3	190–280
Density (kg/m^3, at 20°C)	811.5	820–845
Flash point (°C)	13	52
Auto ignition temperature (°C)	425	300–340
Lower heating value (kJ/kg)	27	43
Cetane number	>15	50>
Vapor pressure (kPa, at 38 °C)	17	0.34
Stoichiometric air–fuel ratio	8.96	14.7
Latent heat of vaporization (kJ/kg)	921.1	620

Ethanol fuels can be successfully used as IC engine fuels either directly or by preparing biodiesel [16]. Transesterification process utilizes methanol or ethanol and vegetable oils as the process inputs. This route of utilizing alcohol as a diesel engine fuel is definitely a superior route as the toxic emissions (aldehydes) are drastically reduced. The problem of corrosion of various engine parts utilizing alcohol as fuel is also solved by way of transesterification. Alcohols have been attracting attention worldwide. Consumer wants a cleaner fuel that can lower the risk of harm to environment and health. Governments aim to reduce reliance on imported energy and promote domestic renewable energy programs, which could utilize domestic resources and create new economic activities.

Though biofuels remain relatively small in use compared to more traditional energy forms, the scenario is changing rapidly. When factors are coupled with vast agri-resources, new technologies that reduce cost, emphasize on environment and pollution abatement and a strong will from both the government and private entrepreneurs; the markets for biofuels are slowly but surely gaining momentum. The fuel ‘‘ethanolisation’’ of the world alcohol industry is set to continue. If all recently announced ethanol projects are implemented, total fuel ethanol production worldwide could grow to 31 billion litres by 2006 against approximately 20 billion litres in 2001. Government actions on Ethanol in India are mentioned in the table 1.5

Table 1.6: Government Actions on Ethanol [17]

Year	Agency/ Body	Actions
1979	Ministry of Petroleum, Chemicals & Fertilisers	Constituted an interdepartmental committee to look at the opportunities for blending of alcohol with petrol
	IIP, Dehradun	Trials were conducted on ethanol-petrol mix at three locations
2001	MoPNG	Launched pilot projects to test the feasibility of blending petrol with 5% ethanol.
2002	MoPNG	Allow the sale of 5% ethanol blending
2003	GOI	E5 made mandatory in 9 states and 4 UTs AP, Gujarat, UP, TN, Karnataka, Mah, Punjab, Haryana, Goa, UT - Damman and Diu, Dadra and Nagar Haveli, Chandigarh, Pondicherry.

1.2.1 MARKETS FOR BIOFUELS AS TRANSPORTATION FUEL

- During Mar 2003 to Sep 2004, 0.37 billion litres of ethanol purchased by the oil industry as part of the 5% ethanol blending program
- During 2003-04, sugar cane production went down due to drought and ethanol producers were unable to meet demand of oil companies
- During 2003-07, ethanol prices increased from INR 15.50/lt to INR 25.10/lt.

CHAPTER 2

LITERATURE SURVEY

2.1 METHOD OF INTRODUCING ALCOHOL IN DIESEL ENGINE

2.1.1 Alcohol-Diesel Dual Fuel Operation

There are several techniques involving alcohol-diesel dual fuel operation. The ignition of alcohol in dual fuel operation is ensured by the high self-ignition diesel fuel. The most common methods for achieving dual fuel operation are-

1. Alcohol fumigation - the addition of alcohols to the intake air charge, displacing up to 50% of diesel fuel demand.
2. Dual injection - separate injection systems for each fuel, displacing up to 90% of diesel fuel demand.
3. Alcohol-diesel fuel blend - mixture of the fuels just prior to injection, displacing up to 25% of diesel fuel demand.
4. Alcohol-diesel fuel emulsion - using an emulsifier to mix the fuels to prevent separation, displacing up to 25% diesel fuel demand.

2.1.2 Advantage of Fumigation

The techniques we are concerned with in this study (the simplest) are alcohol fumigation and alcohol-diesel blends. Fumigation is a method by which alcohol is introduced into the engine by carbureting, vaporizing or injecting the alcohol into the intake air stream. This requires the addition of a carburettor, vaporizer or injector, along with a separate fuel tank, lines and controls.

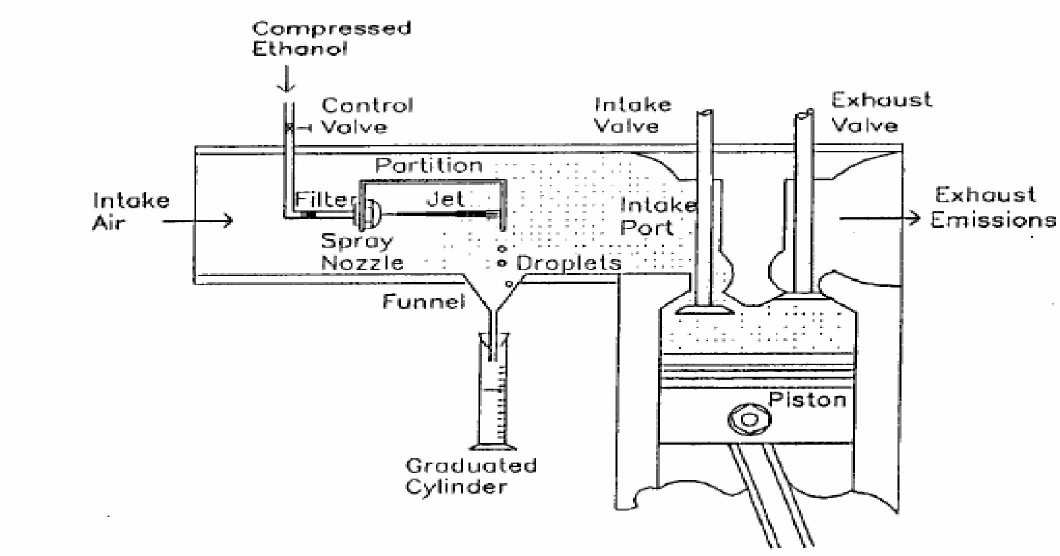

Fig.2.1 Schematic Diagram of Ethanol Fumigation System

Fumigation has some following advantages:

1. It requires a minimum of modification to the engine, since alcohol injector is placed at the intake air manifold. Also, flow control of the fuel can be managed by a simplified device and fuel supply system.

2. The alcohol fuel system is separate from the diesel system. This flexibility enables diesel engines, equipped with the fumigation system, to be operated with diesel fuel only. The engine can switch from dual fuel to diesel fuel operation and vice-versa by disconnection and connection of the alcohol source to the injector.

3. If an engine is limited in power output due to smoke emissions, fumigated ethanol could increase the power output because alcohol tends to reduce smoke. This is because of good mixing of the injected charge with alcohol.

4. Fumigation can substitute alcohol for diesel fuel. Up to 50% of the fuel energy can be derived from alcohol by fumigation [18].

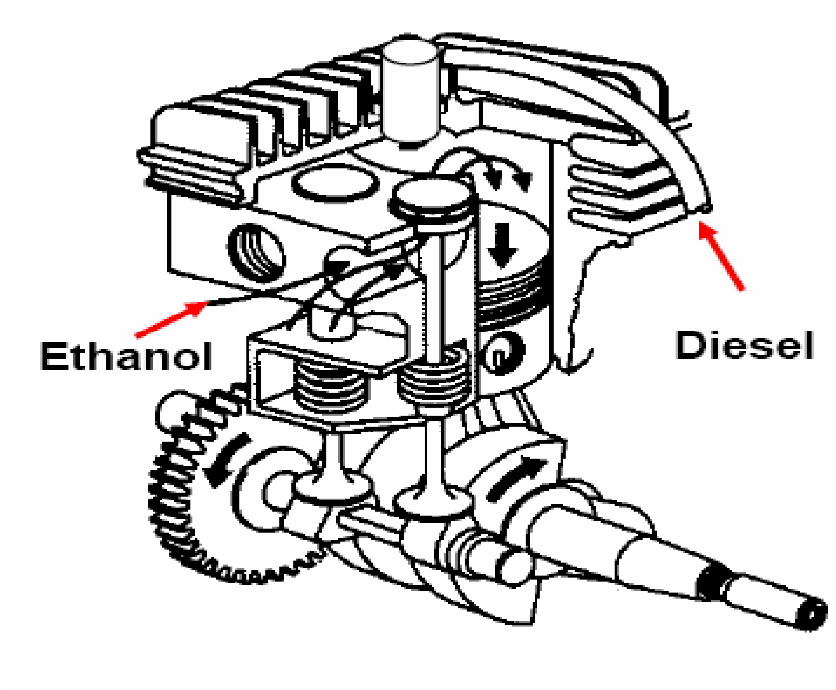

Fig.2.2 Ethanol Fumigation in Diesel Engine

The easiest method by which alcohols can be used in diesel engines is in the form of blends. For lower alcohols, this approach is limited to ethanol because methanol is not soluble or has very limited solubility in the diesel fuel [18].

An advantage of ethanol-diesel fuel solutions is that few major component changes are required for their use. Small adjustments to the injection timing and fuel delivery may be necessary to restore full power. The adjustments depend on the ethanol concentration and the combustion effects of ethanol [18, 19]. In this study, no modification on the engine was made for blends, since the amounts used were within the permitted range.

2.2 The Effect of Alcohol Fumigation on Diesel Engine Performance and Emissions: A Literature Survey

A Literature Survey has been done from 1956 to 2008.

Abu M. et al. The effects of ethanol fumigation (i.e. the addition of ethanol to the intake air manifold) and ethanol-diesel fuel blends on the performance and emissions of a single cylinder diesel engine have heen investigated experimentally and compared. An attempt was made to determine the optimum percentage of ethanol that gives lower emissions and better performance at the same time. This was done by using a simple fumigation technique. The results show that both the fumigation and blends methods have the same behaviour in affecting performance and emissions, but the improvement in using the fumigation method was better than when using blends. The optimum percentage for ethanol fumigation is 20%. This percentage produces an increase of 7.5% in brake thermal efficiency, 55% in CO emissions, 36% in HC emissions and reduction of 51% in soot mass concentration. The optimum percentage for ethanol diesel fuel blends is 15%. This produces an increase of 3.6% in brake thermal efficiency, 43.3% in CO emissions, 34% in HC and a reduction of 32% in soot mass concentration.

Alperstein et al. [21] studied the effect of fumigation in diesel engines. It was reported that fumigation can be imagined to help diesel combustion in two ways: better air utilization due to premixing and more complete combustion due to chemical effect of fumigation

Weidman et al. [22] used a standard Volkswagen 4-cylinder, swirl-chamber diesel Engine to test the performance of alcohol-diesel fuel blends. The alcohols involved were Ethanol and methanol. Their object was to report on the development of an engine/fuel Concept designed for alcohol-diesel fuel blends. They reported that HC and CO emissions were increased and NOx emissions decreased compared to diesel fuel. Also, alcohol-diesel fuel blends emit more aldehydes and less polycyclic aromatic hydrocarbons (PAH)

Czerwinski [23] tested a 4-cylinder, heavy duty, direct injection diesel engine in which 30% ethanol and 15% rape oil mixtures were used. He found that the addition of 30% ethanol to the diesel fuel causes longer ignition delay. The combustion temperatures were lower. At full load, all emissions were lower. At lower loads and speeds, CO and HC emissions were increased. It was possible to obtain emissions similar to diesel fuel, but with reduced power output up to 12.5%.

Chandler et al. [24] A project was established by the state of Ohio to demonstrate the use of ethanol flexible-fuel vehicles (FFV) in their fleet operations. Ten FFVs and three gasoline vehicles operated five state agencies were included in the study. During the two-year project a large amount of data was collected, including information on vehicle maintenance and fuelling, cost of operation and fleet management comments. Emissions testing of two ethanol FFVs and two standard gasoline vehicles were also included in the project. The results indicate that the ethanol FFVs are operating well and meeting the requirements of the state agency operators.

Broukhiyan et al. [25] applied ethanol fumigation to a 5.7 I, V-8, light duty, indirect injection diesel engine by using a pressurized nitrogen cylinder with secondary air supply in amounts up to 50% of the total fuel energy. Their research was undertaken to study the effect of ethanol fumigation on the performance (efficiency), combustion knock characteristics and exhaust emissions. For all conditions except the 1/4 rack setting (light load) condition, modest thermal efficiency gains were observed upon fumigation. However, engine roughness or the occurrence of severe knock limited the maximum amount of ethanol that could be fumigated. Brake specific NOx concentrations were found to decrease for all conditions tested. While decreasing the mass of particulate emitted, ethanol fumigation enhanced the biological activity of that particulate.

2.2.1 Main Finding of Literature Review

- Most of the research work on ethanol has been done on blend with diesel. A small quantum of research work has been done on fumigation.
- Fumigation has proved to as viable solution alternative diesel fuel.
- No detail about which type of carburettor is used.
- Effect of changing injection pressure of diesel on fumigation not being discovered.

2.3 COMPARISON BETWEEN BLENDS AND FUMIGATION

The blended fuels compared least favorably with fumigation at all speeds and approach the diesel fuel in some cases. This could be due to the following reasons:

1-The physical properties of diesel fuel are changed when ethanol is added in solution (blend).The addition of ethanol causes the viscosity of diesel fuel to decrease. Also, the addition of ethanol in solutions with diesel fuel causes the cetane rating to drop and the heating values to be lower.

2- Evaporation of ethanol in the intake air (fumigation case) lowers the intake mixture Temperature and increases its density. Thus, as more air is made available in the cylinder, greater amounts of power can be generated if the right proportion of fuel is added.

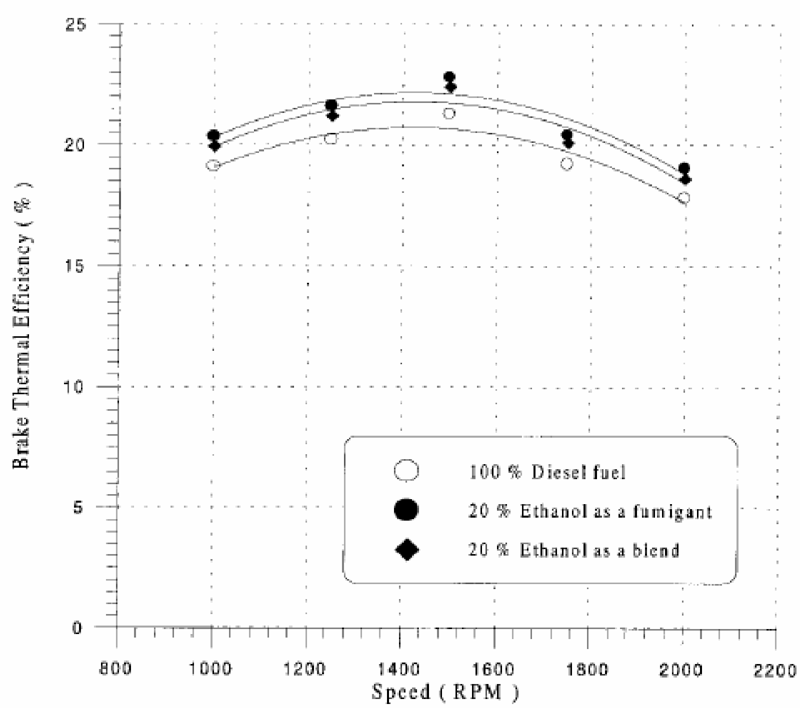

Fig.2.3 Brake Thermal Efficiency versus Speed for Ethanol Fumigation and For Fuel Blends

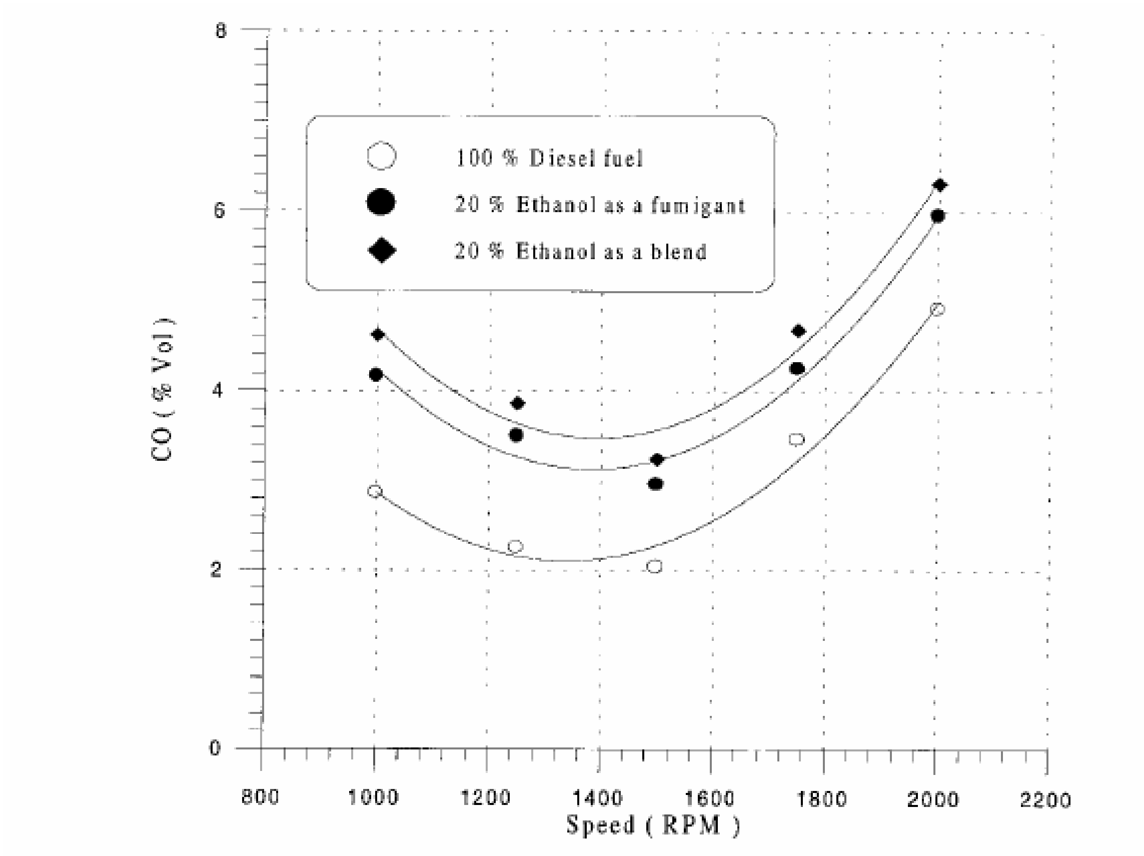

Fig.2.4 CO Emissions vs. Speed for Ethanol Fumigation and for Fuel Blends

The maximum increase in CO and HC emissions was at 20% ethanol for both the fumigation and blends methods. Also, the CO and HC emissions were always higher when using the blended fuels than when the engine operated with fumigation.

For 20% ethanol fumigation, the increase in CO emissions was in the range of 21-55% at the speed range used, and for 20% ethanol as a blend with diesel fuel, the increase in CO emissions was in the range of 28-71.5% at the same speed range used. The increase in the CO levels with increasing ethanol substitution is a result of incomplete Combustion of the ethanol-air mixture. Factors causing combustion deterioration (such as high latent heats of vaporization) could be responsible for the increased CO production.

Combustion temperatures may have had a significant effect. A thickened quench layer created by the cooling effect of vaporizing alcohol could have played a major role in the increased CO production. Another reason for the increasing CO production is the increase in ignition delay. This could lead to lower temperatures throughout the cycle. This results in combustion of a proportion of the fuel in the expansion stroke, which lowers temperatures and reduces the CO oxidation reaction rate. The produced emissions of CO from fumigation were less than for blends. Combustion Temperatures for fumigation may be higher than for blends, better air utilization due to the presence of a homogeneous ethanol charge and lower effect of previous reasons when applying. Ethanol fumigation may have lowered the CO emissions for fumigation compared with blends. Also, the minimum increase in CO emissions was at the higher speeds because of more turbulence in the cylinder (effective mixing) and relatively high combustion temperatures compared with the lower speeds.

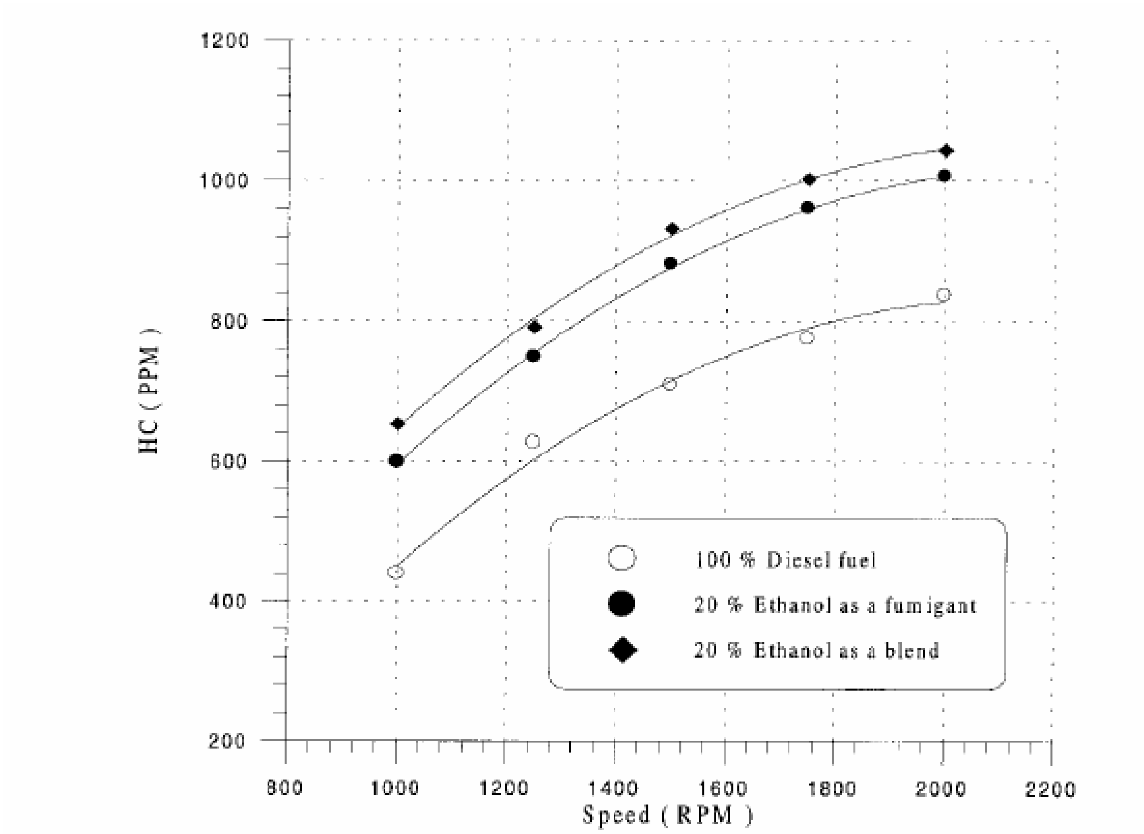

Fig.2.5 HC emissions vs. Speed for Ethanol Fumigation and for Fuel Blends

Fig. 5.2 shows the effect of ethanol substitution on HC emissions. For 20% ethanol fumigation, the increases in HC emissions were between 20 and 36%, and for 20% ethanol as a blend with diesel fuel, the increases were between 25 and 49% over the entire speed range. IT is noticed that there is a resemblance in the results concerning CO and HC emissions production. The HC emissions tend to increase because of the quench layer of unburned fumigated Ethanol present during fumigation. There is no quench layer with diesel fuel injection alone because the combustion is droplet-diffusion-controlled and completely surrounded by air. Also, the high latent heat of vaporization can produce slow vaporization and mixing of fuel and air. These factors result in high HC levels.

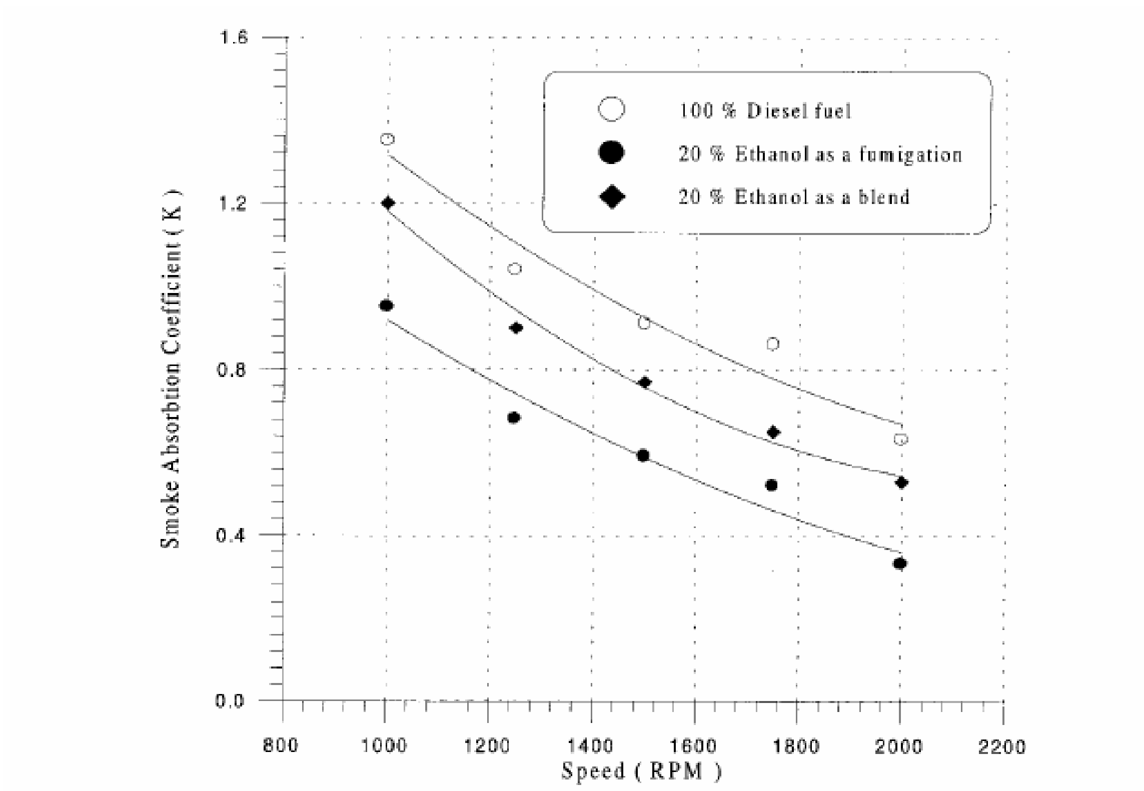

Fig.2.6 Engine Smoke vs. Speed for Ethanol Fumigation and for Fuel Blends

Fig. 5.3 shows the effect of ethanol substitution on engine smoke. The smoke measurements were plotted as a smoke absorption coefficient. This is a number which gives an indication about the exhaust emissions density. There is a decrease in smoke coefficient of 30±48% for 20% ethanol as a fumigant, decreases of 11-25% for 20% ethanol as a blend with diesel fuel and a decrease of 18.5-33.3% for 15% Ethanol as blend. This decrease was the maximum over the entire speed range used. It appears that the optimum percentages of ethanol for smoke reduction are 20 and 15% for the fumigation and blends methods, respectively.

The recognized drastic reduction in smoke coefficient, as more amount of ethanol was used, is attributed to several reasons. Here, the charge cooling increases ignition delay and, thus, enhances the mixing of diesel fuel with the ethanol-air mixture which, in turn, makes for better air utilization and less smoke. Also, diesel fuel has a high tendency to soot formation due to its low H/C ratio and the nature of its combustion process. Using ethanol, either as a blend or as a fumigant in a diesel engine, increases the hydrogen content in the mixture and eventually reduces the engine smoke and leads to a soot free combustion of ethanol under normal diesel engine operating conditions.

The soot mass concentrations for ethanol fumigation, diesel fuel blends and diesel fuel operations are shown in Fig. 5.4. From this figure, it can be seen that there is a matching between smoke and soot measurements, and both methods confirm each other. Soot concentration represents the mass fraction of soot in the exhaust. It is given in milligrams of soot per kilogram of exhaust.

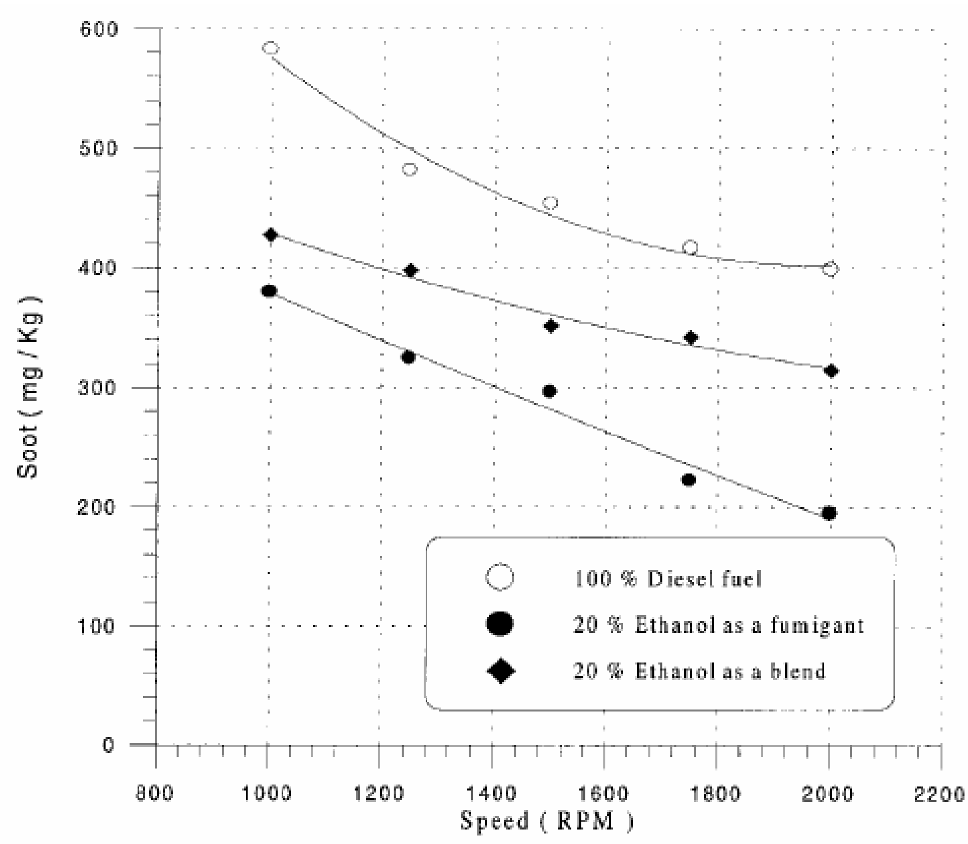

Fig. 2.7 Soot Emissions vs. Speed for Ethanol Fumigation and for Fuel Blends

From Fig. 5.4, the maximum decrease (over the entire speed range) in soot concentrations was 33-51% for 20% ethanol fumigation, 10-22% for 20% ethanol blends and 15-32.5% for 15% ethanol-diesel fuel blends. Soot formation, when applying ethanol in both methods, shows a strong dependence on the amounts of ethanol used. The decrease in soot formation rate could be attributed to the same reasons responsible for the smoke decrease.

From the results discussed previously, it is apparent that using ethanol in diesel engines causes increased HC and CO emissions and reduces particulate or smoke. The emissions of CO and HC can be a strong limiting factor in the proportion of ethanol that can be used. Though these emissions are increased, it should be kept in mind that in many cases, they are quite low to start with and small increases may be entirely acceptable. Also, ethanol fumigation of diesel engines holds the promise of reducing smoke from the current generation of diesel engines to which this simple method is being applied.

CHAPTER 3

SYSTEM DEVELOPMENT AND EXPERIMENTAL SET UP

3.1 ENGINE SELECTION

There is no difference of opinion that India is going to face a severe fuel crisis in future because fuel consumption has increased in all the vital sectors specially transportation and agricultural sector. As diesel engines plays an indispensable role in transportation and agriculture sector and as such diesel consumption will increase multifold in time to come. The diesel engine continues to dominate the agriculture sector in our country in comparison to spark ignition engine and have always been preferred widely because of power developed, specific fuel consumption and durability. A through description of combustion mechanism in diesel engine is beyond the scope of this study. However, it would be worthwhile to inform that the fuel is burnt in diesel engine by self ignition at higher temperature and pressure conditions of the order of 600°C and 40 bar, respectively. Diesel as a fuel is injected into the combustion chamber at the end of compression stroke and after certain ignition delay; it burns to give the motive power.

In India, almost all irrigation pump sets, tractors, mechanized farm machinery and heavy transportation vehicle are powered by direct injection diesel engines. Considering the wide application of a small capacity diesel engine which has got great dominance in Indian agriculture sector, a similar engine has been selected for the present study. The controlling parameters could be changed with suitable arrangement provided in the engines. The direct injection (DI) diesel engine used for this study is manufactured by M/s Vimal Engines Limited. It is widely used in India in agriculture, many small and medium scale industries and in residences for emergency power generation. It is a single cylinder, naturally aspirated, four stroke, vertical, air-cooled engine. It has a provision of loading electrically since it is coupled with single phase alternator through flexible coupling. The engine can be hand started using decompression lever and is provided with centrifugal speed governor. The engine was started on diesel engine and then it was switched on to the straight vegetable mode where it again run on part load for more than half hour then the actual data was taken from no load to full load.

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.

The detailed technical specifications of the engine are given in table 6.1.

Table 3.1: Specifications of the Diesel Engine

Make	**Vimal**
Model	**DAF 8**
Rated Brake Power (bhp/kW)	10/ 7.5
Rated Speed (rpm)	1500
Number of Cylinder	One
Bore X Stroke (mm)	102 x 110
Compression Ratio	17.5:1
Cooling System	Water 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

3.1 VARIOUS PARAMETERS TO BE OBSERVED

3.1.1 Air Measurement

Plate 3.1: Air Box **Plate 3.2: U-Tube manometer**

It is a box of dimension in mm 630*405*175 made by M.S. used to measure mass flow rate of air. Orifice size of box is 35 mm. For using with carburettor and inlet manifold simultaneously. It is fitted with two outlets. One is connected to carburettor and other is connected to main engine inlet.

3.1.2 CV Carburetor

Plate 3.3 : Carburetor Arrangement **Plate3.4 : CV Carburetor**

It is 125cc bike cv (constant velocity) carburettor made likuni japan .

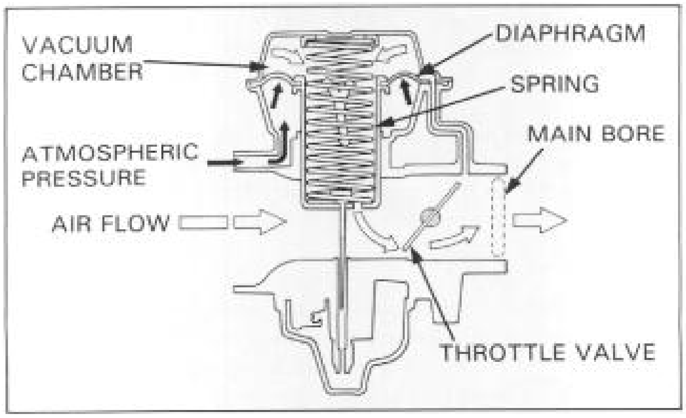

Fig 3.1 Working of CV carburettor

On conventional carburetors the throttle cable is connected directly to the throttle slide. When you twist the throttle, this lifts the slide and immediately increases the size of the carburetor opening letting in more air/fuel mix and increasing the speed of the motor. On CV carburetors, the throttle cable actuates a butterfly valve, as the throttle is opened, the air pressure difference between the sealed chamber above the vacuum slide and inside the carburetor venturi forces the slide (located in front of the butterfly valve) up and down. The downside to the CV carb is a lack of immediate throttle response. Twisting the throttle gives relatively leisurely acceleration compared to a conventional carburetor. One of the advantages is that the carburetor adapts nicely to altitude changes and good gas mileage.

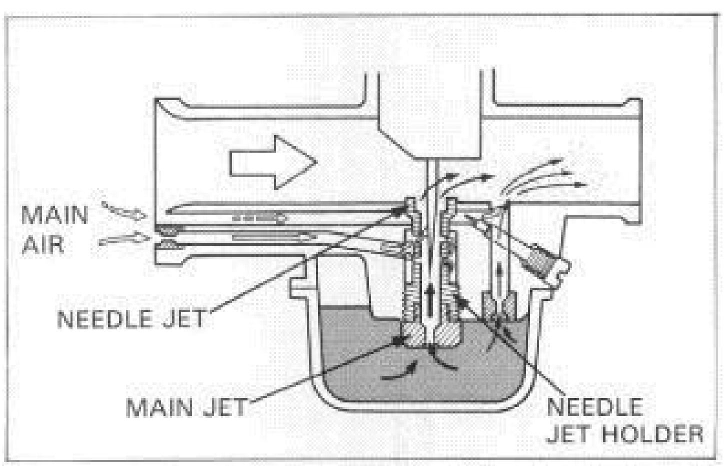

Fig.3.2 Fuel Flow

In the float chamber, the main jet controls the amount of fuel sent to a tube called the needle jet. The needle jet opens into the main bore of the carburetor and allows the fuel into the intake manifold by means of the negative pressure formed by the intake air rushing through the venturi. This is the very same principle witnessed by blowing across the top of a soda straw and drawing up the liquid.

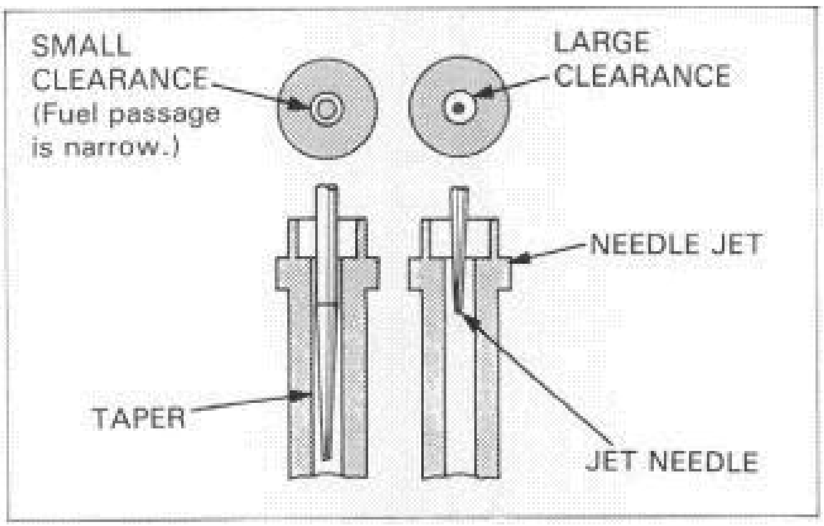

FIG3.3 Opening and Closing of Throttle

The piston carries the 'jet needle' that fits into the needle jet. The jet needle is straight for about 1/3 of its length; the rest is tapered. At idle and low speeds, the piston is nearly all the way down, pushing the needle into the needle jet most of the way. In this position, the straight, large-diameter part of the needle (the root) fills up most of the space inside the needle jet tube, restricting the fuel flow to a narrow annular space around the needle. As the piston rises with increased engine speed, the needle is withdrawn from the jet. Because the needle is tapered, the annular space through which the fuel can travel increases, allowing more fuel to match the increased airflow.

3.1.3 Fuel Consumption Measurement

Plate 3.5: Fuel Consumption Measuring Unit

Fuel measurement is done by two burate of 50ml size. One for ethanol and other is for diesel. These are made of glass. One side of burate is connected to stop valve other is connected to carburettor and engine fuel filter. Fuel measurement is done with the help of stop watch time for 10 ml droop is noted.

3.1.4 RPM Measurement

Plate 3.6: RPM Measurement

An ‘NPN-NO’make RPM Sensor is used to measure the RPM of the engine and proximetric switch which sense one RPM and convert it in to pulse then this pulse transmitted to r.p.m.indicator which gives reading in digital form. It can measure any value from 0-9999 r.p.m.

3.1.5 Fuel Supply System

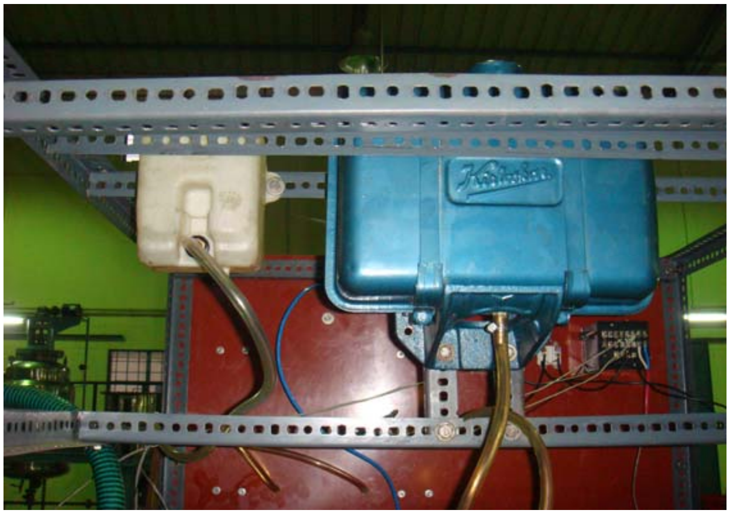

Plate 3.7: Tank Arrangement

Arrangement has been made for two fuel supply tank one is for ethanol and other is for diesel. Diesel fuel capacity is 10 litres and ethanol tank capacity is 2 litres. Both tanks are connected to burette.

3.1.6 Temperature Measurement

Plate 3.8: Temperature Measurement

Temperature measurement is done by a J-Type Thermocouple and a Creative temperature Indicator which can indicate the temperature in the range of 0-600°C.

T_1: Exhaust Gas temperature

T_2: Inlet Air Temperature

T_3: Temperature after Atomization

3.1.7 Emission Measurement:

Plate 3.9: Smoke Meter and Di Gas Analyzer

Emission measurement is done by AVL DIGAS analyzer which able to measure CO_2, CO, NO_X**,** Un-burnt Hydro carbon, Smoke opacity, Smoke Absorbity and Exhaust temperature.

3.1.8 Throttle Control System

Plate 3.10: Throttle Arrangement

Shown above a throttle control system which is made for controlling of throttle valve. With full closing and full opening of throttle it is possible to vary ethanol mixing from 3 to 48 percent.

Plate 3.11: Photograph of the Experimental Test Rig

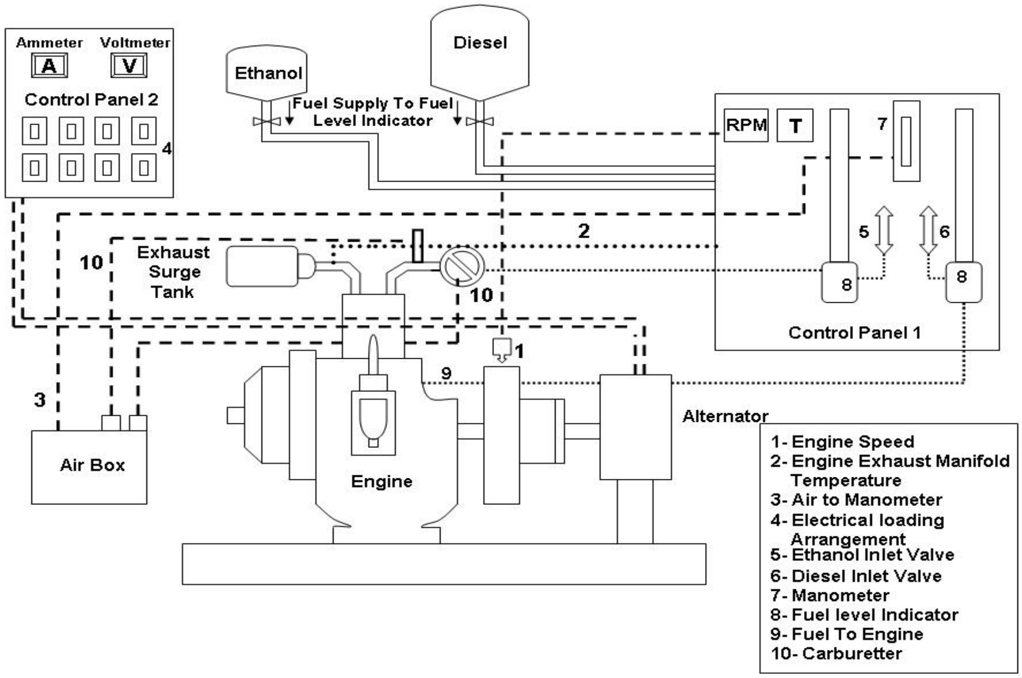

Fig 3.4 Schematic Block diagram of the Experimental Test Rig

3.2 Selection of Testing Parameters

The selection of operating parameters was very important for the accurate monitoring of engine performance and due care was taken to select these parameters. The parameters to be observed are given below.

1. Power produced by the engines
2. Engine speed (Rev/min)
3. Fuel consumption
4. Temperature
5. Speed of the engine

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. Fuel consumption rate

5. AVL 437 smoke meter
6. 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.

3.2.1 Experimental Procedure:

The speed governor adjusted the diesel injection in an attempt to keep the engine speed constant. The engine was started on diesel fuel and 30 minute time is given for steady condition .The quantity of ethanol is controlled by a butterfly valve fitted in CV carburetor. Keeping the butterfly valve fixed in position load on generator was varied and due to this variation diesel quantity is increased by governor to make speed constant. Because diesel combustion quantity varied with load and ethanol mixed in inlet air remain constant with load so percentage of mixed ethanol varied. In a particular load emission measurement is taken out and reading is noted. First reading is taken at no load then 20% 45% 70% 100% of load reading is noted down. There is a series of precaution that are to be taken care off while performing the diesel engine test run. Readings were taken when the engine come into steady state .Digital rpm sensor and indicator were used though it was constant speed diesel engine, in order to check the variation in speed from no load to full load and its effect on various other parameters. The load was varied by changing the power out put from the alternator side which was connected to the load bank. Digital ammeter, voltmeter were used for performing the test.

Thermocouples were used to measure the temperature at the salient point of the diesel engine at running conditions. The output of the thermocouple was fed to the digital temperature indicator with variable junction to indicate the temperature readings. Through special arrangements the thermocouple were mounted on the engine assembly. Optimization of the diesel engine hardware is necessary to avoid leakage of energy in order to obtain the results with best of accuracy

CHAPTER 4

RESULT AND DISCUSSION

4.1 OBSERVATION AND EVALUTION OF PERFORMANCE CHARACTRICS

The chapter presents the results obtained from experimental data and these results are thoroughly discussed in subsequent sections. The present study was done on a small capacity diesel engine which was converted to run on a dual fuel mode operation. The main objective of the study was to evaluate the performance and emission characteristics of diesel engine with fumigation of ethanol in diesel engine.

4.1.1 Ethanol vs. Diesel fuel Consumption

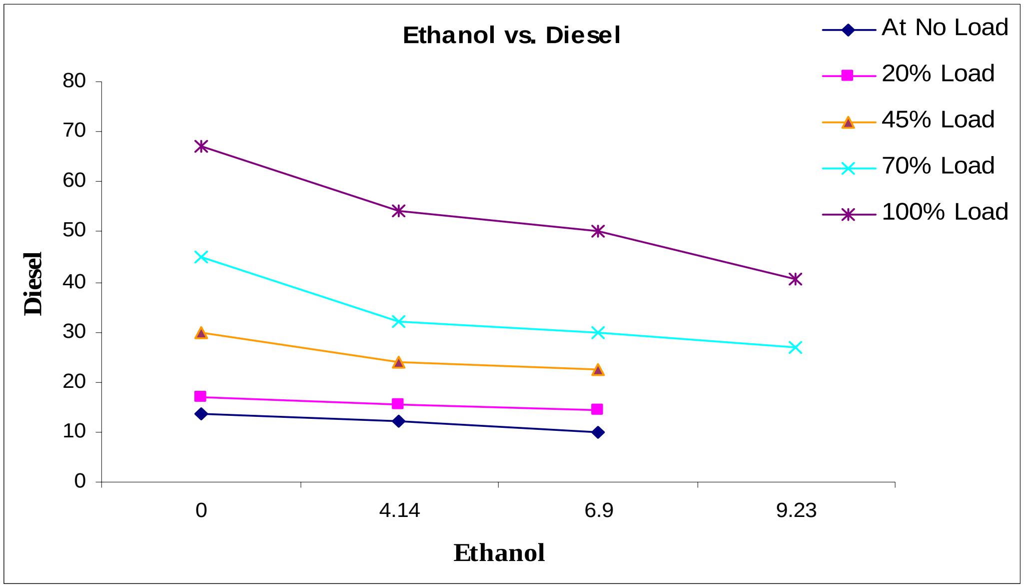

Fig.4.1 Ethanol vs. Diesel fuel Consumption

Fig. 4.1 shows consumption of ethanol and diesel at different load in ml/minute. It is clear that at same load when percentage of ethanol is increase, diesel consumption decrease and pattern of decrease in diesel consumption is higher at higher load. This is because all energy is supplied by diesel when ethanol substitution is zero. However, with ethanol substitution, some portion of energy is supplied by combustion of ethanol and as substitution of ethanol increase, the diesel quantity decreases. A maximum substitution of 48% of ethanol was accomplished with the currently developed fumigation system with out any difficulty. The load is kept constant and ethanol concentration is varied for plotting this graph.

4.1.2 CO Emissions

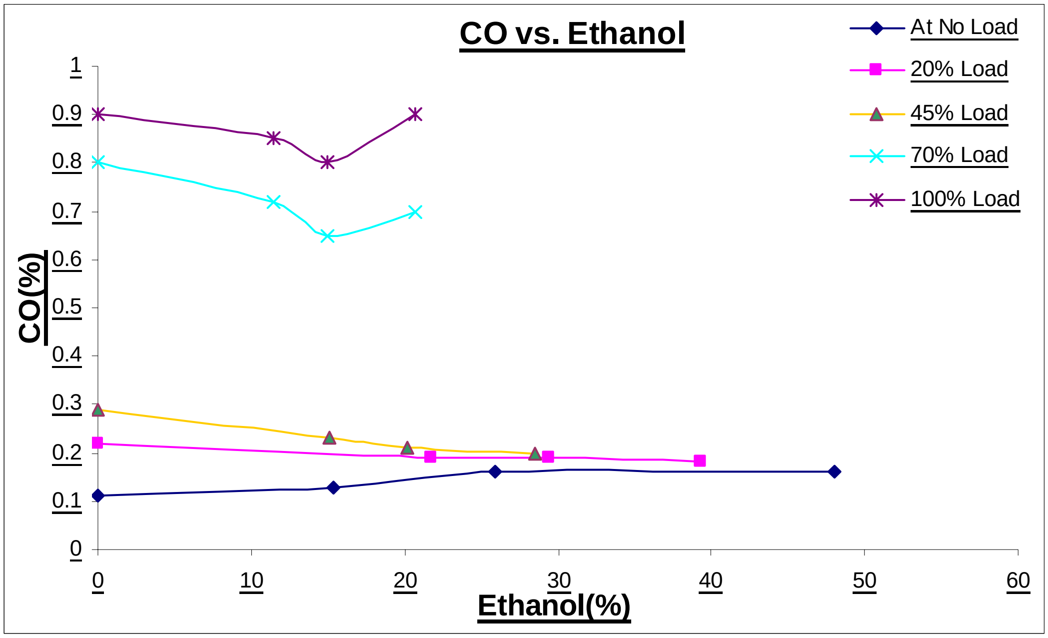

Fig.4.2 CO Vs Ethanol

CO emission is toxic and must be controlled. It is an intermediate product in combustion of a hydrocarbon fuel and its emission results from incomplete combustion. Emission of CO is therefore greatly dependent on the air–fuel ratio relative to the stoichiometric proportions. Rich combustion invariably produces CO, and emissions increase nearly linearly with the deviation from the stoichiometry [16]. CO emission reduced steadily when the engine load increased in the engine. When the engine load increases at constant speed, combustion temperatures boost. Therefore CO emissions start to decrease [26].Fig. 4.2 shows CO emission of diesel engine at different load and at different ethanol mixing. As evident from the graph that at no load CO% increase up to 30% of ethanol fumigation. However, at 20% and 45% of load, CO% decreases up to 20% of ethanol fumigation. At 70% and full load, CO percentage decrease till 15% ethanol fumigation and then increase. This is because CO formation is increased when there is not sufficient quantity of oxygen when combustion take place .At 15% substitution of ethanol, proper combustion take place. So it found at full load and at 15% ethanol fumigation, CO emission is minimum.

4.1.3 CO_2 Emissions

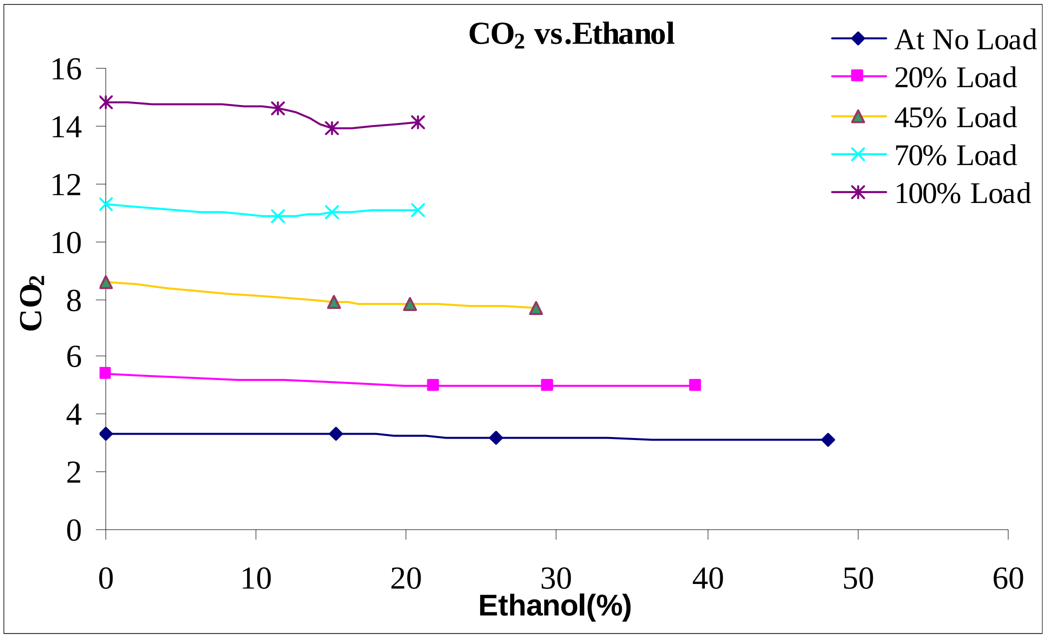

Fig.4.3 CO_2 Vs Ethanol

CO_2 occurs naturally in the atmosphere and is a normal product of combustion. Ideally, combustion of a hydrocarbon fuel should produce only CO_2 and water (H_2O). Fig. 4.3 shows CO_2 emission of fumigated diesel engine at different load and at different ethanol substitution conditions. As clear from graph that at no load CO_2% remains almost constant but at 20% and 45%of load, CO_2 percentage decreases as ethanol substitution is increased. At 70% of load, CO_2 percentage decrease up to 12% fumigation of ethanol and at full load CO_2% decrease up to 15% and then increase. At 15% ethanol fumigation, the combustion is smooth. Therefore, it can be seen that CO_2 emission is minimum at 15% ethanol substitution at full load.

4.1.4 O_2 Emissions

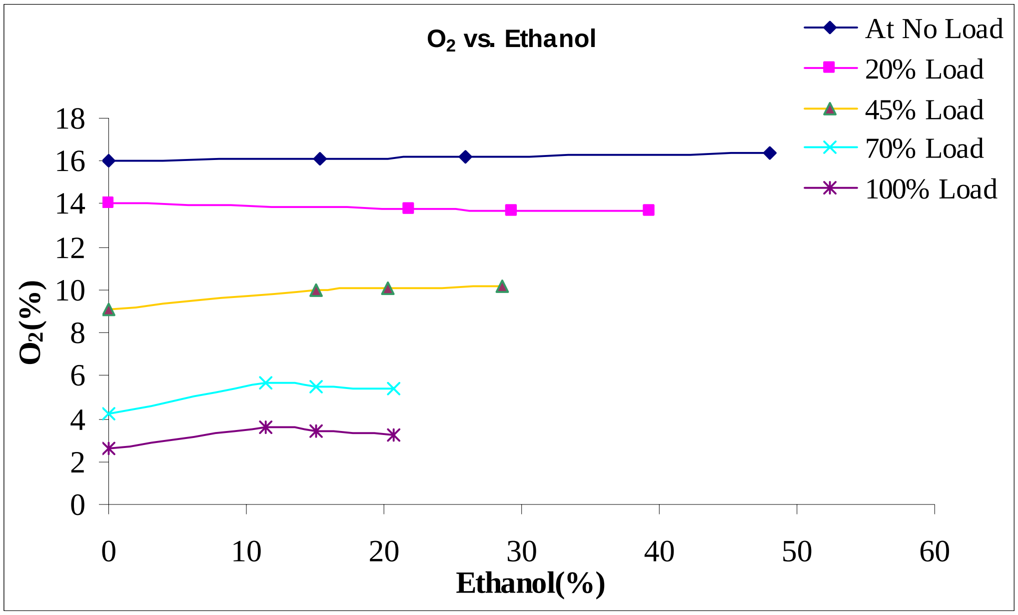

Fig.4.4 O_2 Vs Ethanol

Fig. 4.4 shows O_2 emission of diesel engine at different load and at different ethanol mixing. As evident from the graph that as load increase, O_2 percentage slightly increases. At no and 20% load O_2% remains almost constant but at 45% of load O_2% increases up to 15% of substitution of ethanol then remain almost constant. At 70% and at full load O_2% increase up to 12% ethanol fumigation then starts decreasing. Ethanol is an oxygine component. It releases oxygen on combustion, and which also verified from above graph as ethanol fumigation increases O_2% is also increase.

So it found at 12% ethanol substitution on full load O_2 emission is maximum.

4.1.5: NO_x Emissions

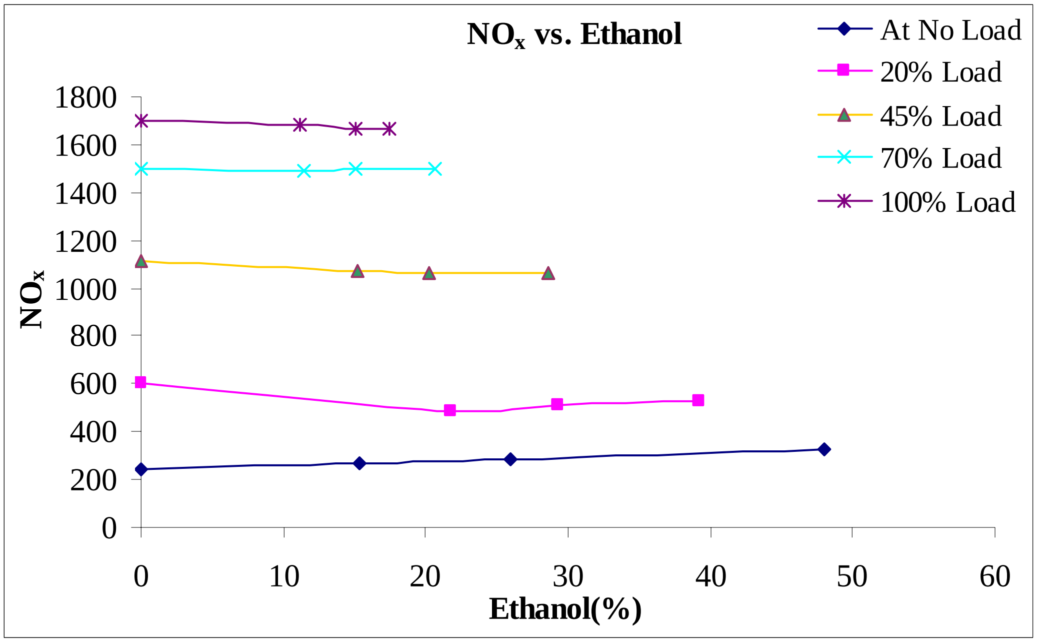

Fig.4.5 NO_x Vs Ethanol

The most troublesome emissions from CI engines are NO_x. The oxides of nitrogen in the exhaust emissions contain nitric oxide (NO) and nitrogen dioxide (NO2). The formation of NO_x is highly dependent on in-cylinder pressure which decreases the peak temperature the oxygen concentration, and residence time for the reaction to take place [4, 28].The NO_x emissions in ppm are shown in.Fig.4.5. The NO_x emissions increased with the engine load, due to a combustion temperature increases with load. This proves that the most important factor for the emissions of NO_x is the combustion temperature in the engine cylinder. It has been found that at no load NOx continue to increase as we increase percentage of ethanol fumigation. At 20% load NO_x emission is minimum on 22% fumigation of ethanol but at 45% load, NO_x emission decreases up to 20% of ethanol substitution then starts increasing. At 70% load and at full load NO_x emission decrease up to 16% ethanol fumigation then starts increasing. Lower loads are able to tolerate only small energy substitution thru ethanol because of low compression temperature and pressures at low loads. Ethanol fumigation thru carburetor result decrease in temperature due to atomization. NO_x emission directly depends on combustion temperature so NO_x emission decreases on increasing of ethanol substitution.

So it found at 16% ethanol substitution on full load NO_x emission is minimum.

4.1.6: Un-burnt Hydro carbon Emissions

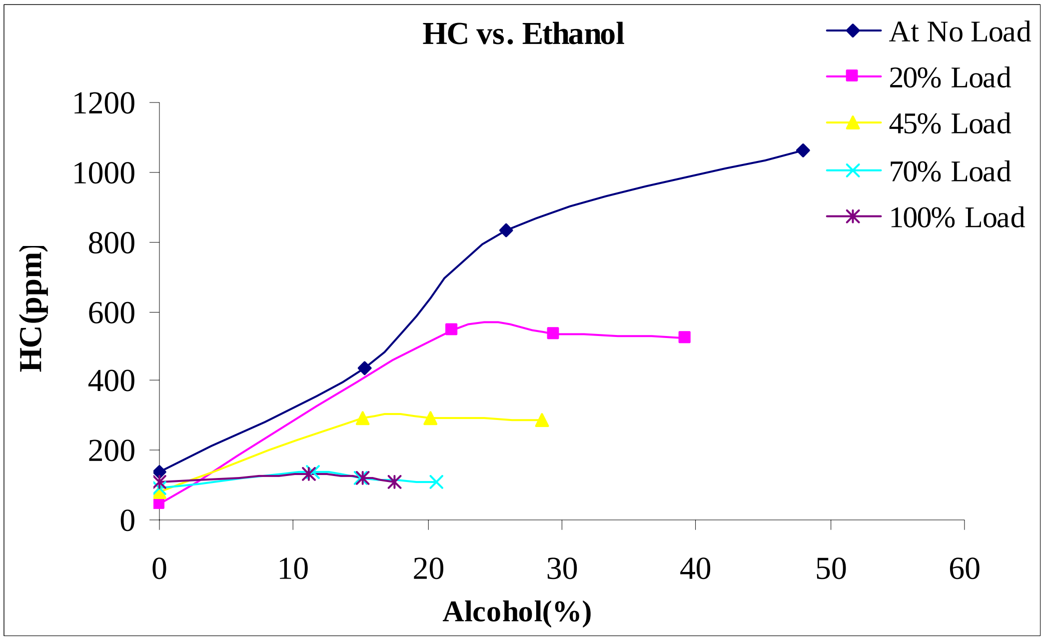

Fig.4.6 UBHC Vs Ethanol

Unburned HC emissions consist of fuel that is incompletely burned. The term HC means organic compounds in the gaseous state; solid HCs are part of the particulate matter. Typically, unburned HCs are a serious problem at light loads in CI engines. At light loads the fuel is less apt to impinge on surfaces; but, because of poor fuel distribution, large amounts of excess air and low exhaust temperature, lean fuel–air mixture regions may survive to escape into the exhaust [29, 30].

The unburnt hydrocarbon (HC) emissions are presented in Fig. 4.6 the HC emissions of both the fuels are lower in partial engine load, but increased at higher engine load. This is due to relatively less oxygen available for the reaction when more fuel is injected into the engine cylinder at higher engine load. It is found in experiment that at 70% and full load unburned HC slowly increases up to 11% ethanol substitution then starts decreasing till

18% ethanol fumigation. After 18% ethanol substitution unburned HC emissions remain constant.

4.1.7: Exhaust temperature

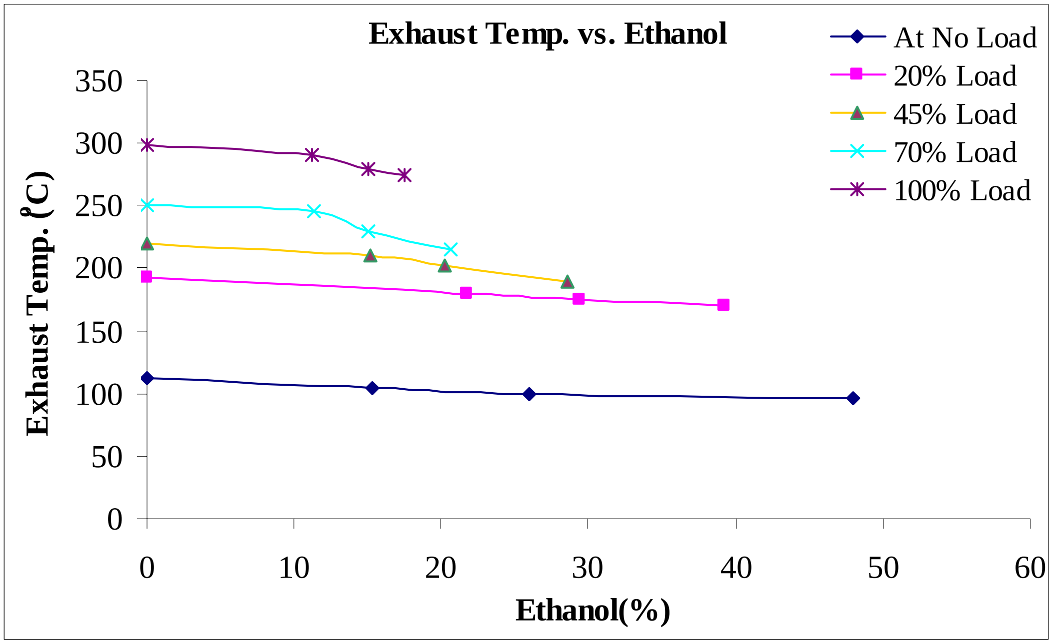

Fig.4.7 Exhaust temperature Vs Ethanol

Fig.4.7 shows the variation of exhaust gas temperature with ethanol fumigation. The results show that the exhaust gas temperature decreased with increase in ethanol substitution. Ethanol fumigation thru carburetor result decrease in temperature due to atomization. Due to this cooling effect of ethanol fumigation exhaust gas temperature decrease. At no load and 20% load temperature decrease slightly. But at 45%, 70%, and full load temperature decrease sharply. At full load exhaust temperature start from 300°C and decrease to 265°C as ethanol substitution increases .At 80% load exhaust temperature start from 250°C and decrease to 220°C as ethanol fumigation increase. So it is found that on increasing of ethanol fumigation exhaust temperature decreases.

4.1.8 Smoke Opacity

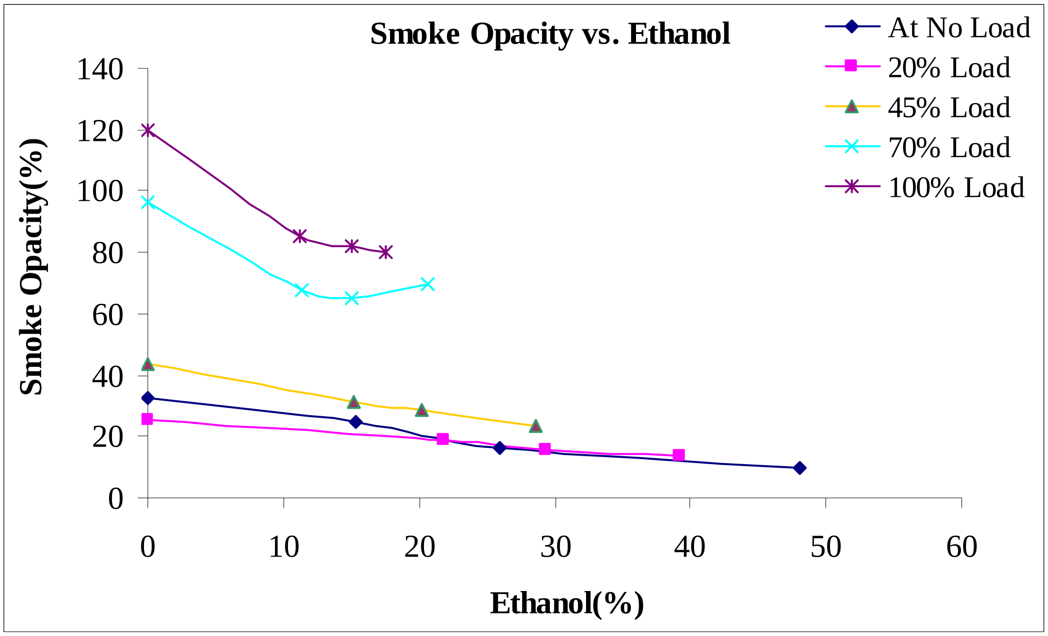

Fig 4.8 Smoke Opacity vs. Ethanol

Smoke opacity defines as darkness of smoke due to carbon content. Figure 4.8 shows the comparison of smoke opacity for different ethanol fumigation. For all load it is found that smoke opacity decrease as ethanol fumigation increase. It can be seen from graph that slopes of this decreasing in smoke opacity increase as we move towards high load.

At 70% and 100% load smoke opacity decrease sharply up to 14% ethanol fumigation and after that it decreases lightly. This is due to the fact that on ethanol substitution, oxygen content of ethanol is responsible for better combustion and resulting into lower smoke opacity. So it found that for full load 14% ethanol fumigation gives minimum smoke opacity value.

CHAPTER 5

CONCLUSIONS AND SCOPE OF FUTHER WORK

This work was undertaken to study the effects of ethanol fumigation on performance and exhaust emissions of a diesel engine. The fumigation was achieved by using a simple technique and a new method of introducing different percentages of ethanol. The conclusions drawn from the present study are as follows:

With fumigation of ethanol carburetion, exhaust temperature has been found to be lower than diesel operation except under certain low load condition, where as large ethanol substitution rates lead to erratic and incomplete combustion late in the expansion stroke, leading to exhaust temperature nearly the same as diesel mode. Due to cooling effect of ethanol fumigation exhaust gas temperature decrease. At no load and part load temperature decrease slightly. But at high load temperature decrease sharply.

Emission of carbon monoxide (CO) has been found to be lower then diesel operation except under no load condition. It is concluded that at no load CO% remains almost constant. At part load CO_2% decreases as ethanol substitution increases. At full load CO_2% found to be minimum at 15% ethanol substitution.

It has been found that NO_x emission decreases up to a certain limit of ethanol fumigation. This limit found 20%~22% in case of low load and 16% in case of full load.

Ethanol fumigation has resulted in increase of unburnt hydrocarbon (HC) emission in the entire load range compared to diesel operation. However, the increase being very small at high load and very large at partial load and no load conditions.

It is found that smoke opacity decrease as ethanol fumigation increase. It has been seen that slopes of this decreasing in smoke opacity increase on moving towards high load. At high load smoke opacity decrease sharply up to 14% fumigation of ethanol and after that it decreases lightly.

Ethanol is an oxygenating fuel and lead to smooth and efficient combustion. Atomization of ethanol also result in lower combustion temperature .On ethanol fumigation All emission found to be minimum This study shows that ethanol fumigation can be effectively employed in existing C.I. engine to achieve substantial saving of the scarce diesel oil and at the same to obtain improved engine performance with lesser exhaust NO and smoke pollution.

Based on the above results, the optimum percentage of ethanol appears to be 15% for ethanol fumigation.

SCOPE OF FUTHER WORK:

For a diesel engine, fuel injection timing is a major parameter that affects the combustion phenomenon and exhaust emissions. The present study was carried on a diesel engine in which injection angle was kept constant. Injection timing variation has a strong effect on the exhaust emissions, especially on the NOx emissions, because of variation of temperature in the engine cylinder. Therefore, there is an urgent need to study effect of variable injection angle in conjunction with fumigation on engine performance and emission characteristics. Also, it is strongly recommended that long term endurance test of the ethanol fumigated diesel engine may also be taken by future researchers.

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APPENDIX – I

TECHNICAL SPECIFICATION OF AVL Di-GAS ANALYZER

Measurement principle	CO, HC, CO_2	Infrared measurement
Measurement principle	O_2 NO (option)	Electrochemical measurement
Operating temperature	+5 ……. +45º C	Keeping measurement accuracy
	+1 ……. +50ºC	Ready for measurement
	+5 ……. +35º C	with integral NO sensor
		(Peaks of : +40ºC)
Storage temperature	-20 ….. +60º C	
	-20 ….. +50º C	With integrated O_2 sensor
	-10 ….. +45º C	With integrated NO sensor
	0 ….. +50º C	With water in filter and / or pump
Air humidity	90% max., non-condensing	
Power drawn	150 VA	
Dimensions	432 x 230 x 470 mm (w x h x l)	
Weight	16 Kg	