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An Alternative Fuels to An IC-Engines.

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ABSTRACT

The world is facing a huge problem of high fuel prices, air pollution and a lot of climatic changes. Alternate Fuels play an essential role in the present scenario in Internal Combustion Engines as the mineral fuels are depleting. This paper presents the maneuver and origin of the use of alternative fuels in internal combustion ignition engines. Analyzing the literature, this article shows various alternative fuels utilized in India and all over the world. Furthermore, this article describes the research directions for alternative fuels usage in road transport powered by internal combustion engines.

Keywords: Alternative Fuels, IC-Engine

I.INTRODUCTION (*HEADING 1*)

Energy crisis has been matter of concern to all over the world and it is better understood by more and more energy users. Almost 90% energy needs the world are provided by fossil fuels which are depleting at an alarming rate. Apart from the depleting resources of petroleum products, another aspect of their use is in the alarming rise of pollutants like CO, HC, NOx , soot, smoke, etc. by automobiles and industries which have tremendous effect on human life and vegetation.

Researches all over the world , for the reasons mentioned above have to focus their attention in conservation of petroleum products and look for developments of various alternative fuels including renewable resources and blending of renewable and non-renewable resources .Various alternative fuels considered for automobiles are LPG , CNG , bio-gas , producer gas , alcohols, (methanol and Ethanol) , vegetable oils and their blends , hydrogen gas etc.

Following factors are considered to use alternative fuels in IC engine:[1]

1. An alternative fuels which can be used as a substitute for conventional fuels without or with minimum changes in the existing engines.
2. Comparative cost.
3. Exhaust emissions within prescribed limits.
4. Its availability on large scale continuously as a substitute to petroleum products and its production facilities.
5. High calorific value per unit mass.
6. Safety to handle..

VARIOUS ALTERNATIVE FUELS FOR IC ENGINES [2]

List of various alternative fuels to SI and CI Engines are as follows:

1. For SI Engines :
- LPG
- CNG
- Alcohols (methanol and ethanol)
- Hydrogen

2. For CI Engines :
- CNG
- Methanol – Diesel fuel blends
- Vegetable oils : karanji oil , sunflower oil etc

Details of use of above fuels are being discussed below.

II.LPG AS SI ENGINE FUEL

- Various hydrocarbon like methane , ethane , propane butane with small percentages of other hydrocarbons are obtained during refining process of petroleum
- Out of these gases, methane and ethane cannot be easily liquefied under pressure being too volatile.
- Hence the liquefied petroleum gas (LPG) mainly consists of propane (35-93%), propylene (.62-2.8%), and butane (2.1-2.9%) [2]which is supplied in containers under pressure and evaporates into gas before being supplied to the engine.
- LPG is Supplied in cylinders coded red for easy identification
- At present the biggest use of LPG is for domestic and industrial application.
- However, there is an increasing trend to use LPG as fuel for SI and CI Engines.

Advantages of LPG as fuel are:

- It presents least difficulty in mixing with air and disturbing homogeneously to various cylinders in a multi cylinders engine
- It is cheaper than gasoline.
- It is highly knock resistant (octane rating 120) and it can be used at high compression ratios.
- It does not pre-ignite easily.
- It leaves little combustion deposits compared to other fuels.
- Crankcase dilution is small, hence it increases the engine life.
- Since LPG can use higher C.R. it improves the thermal efficiency and reduces exhaust emissions.

Disadvantages of LPG are:

- It has high latent heat of vaporization, therefore it reduces the volumetric efficiency of the engine.
- Its advantages can be better realized in engines using high compression ratios.
- It needs to be handled under pressure of about 18 bar.

- Blending of LPG with fuels is poor.
- Leakages of LPG cannot be detected easily since its characteristics odor is faint.
- Propane in LPG is not viscous enough, hence it cannot maintain the lubrication of injection pump of CI engines, thereby, needing auxiliary system.

Since the use of LPG for automotive engines necessitates the use of LPG for certain classes of vehicles only, for example, in trucks, tractors and irrigation and drilling projects. Presently, the use of LPG as main fuel in dual fuel diesel engines is being explored.

III.COMPRESSED NATURAL GAS (CNG) AS AUTOMOTIVE FUEL

- CNG is considered as an important fuel with potential to substitute the conventional liquid petroleum fuel to a significant extent in foreseeable future
- CNG has methane as the main components constituent (80-98%) with some fractions of ethane, butane, propane.
- Natural gas reserves are present in Mumbai High , Godavari Basin in A.P. , Gujarat and Assam .It is being a clean gas , it can either be stored in cylinder at about 200 bar pressure or it can be transported in pipe lines
- Owing to light gaseous fuel its energy density is low, therefore it needs to be compressed to about (160-200) bar pressure to facilitate storage in vehicles.
- CNG is a much clean burning fuel having methane as its main coefficient which is highly knock resistance.
- It has narrower flammability limits (5-15% by volume). Therefore, it is safer fuel to work.
- Since, CNG has high self ignition temperature, it requires high ignition energy.
- It is observed that working with CNG gives substantially low exhaust emissions, low exhaust smoke and substantial reduction in noise levels. Since the Exhaust emissions have vital importance to us, the CNG has become an important vehicular fuel. It is being used in vehicles in Delhi , Mumbai etc

1. *CNG Operation on Automotive SI Engine:*

- In case of SI engines, CNG is fed to the engine through a gas regulator via a gas flow meter. In the regular the pressure of the gas is reduced to slightly above atmospheric pressure and the flow rate is measured by the gas flow meter.
- Experiments were conducted on 4 cylinder , 4 stroke , water cooled automotive SI Engine of 1.089 liter capacity having 68 mm bore ×75 mm stroke . Engine uses a compression ratio of 7.8 and its rated power was 29.4 KW at 5000 rpm.
- The wide open throttle (WOT) performance Tests were conducted both for petrol and CNG modes.
- The results obtained are shown in FigA3.1 for the variation of brake power (B.P) with speed. Fig A3.2 shows the variation in brake specific energy consumption (BSEC) with speed, and the Fig A3.3 shows the CO emissions by volume Vs Speed.

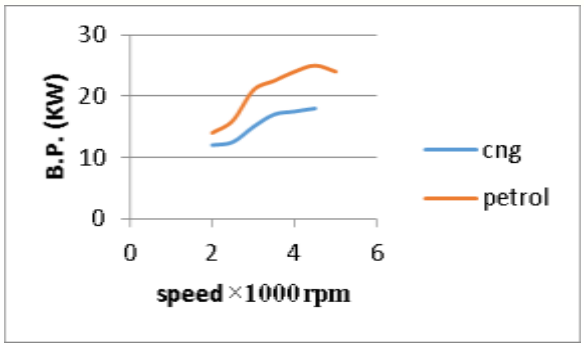

Fig A3.1: speed Vs B.P.[3]

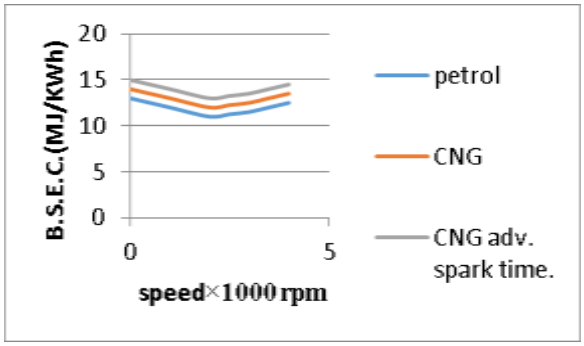

Fig A3.2: speed Vs BSEC[3]

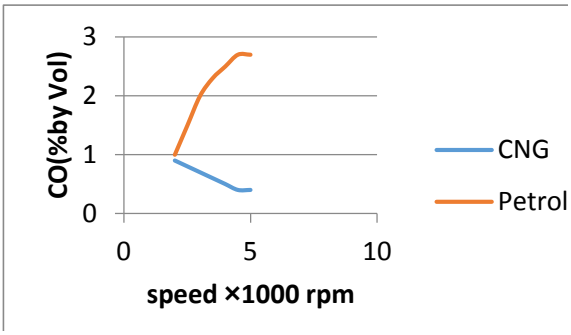

Fig A3.3: WOT exhaust emissions [3]

Following observations can be made:

- BP is less when working with CNG compared to petrol at all speeds. It may be due to reduced volumetric efficiency since CNG is lighter fuel compared to petrol. It is also due to the Fact CNG has reduced mixture calorific value.
- Power losses with CNG is higher with higher speeds, however, in terms of percentage loss it is fairly constant.
- BSEC under CNG operation higher than petrol operation throughout the range of rated speed. However , In case spark timing is advanced with CNG operation by 8 – 10 degrees compared to specified ignition timing of the Engine , BSEC were found to be reduced at all speeds .
- Substantially lower exhaust emission and exhaust temperatures were obtained during CNG operation compared to petrol operation.

It can be concluded that existing SI engines can be successfully run on CNG with advanced ignition timing with lower emission levels.

2. ***CNG Operation on Automotive CI Engines:[4]***

- Generally, due to the requirement of high compression ratio due to high self ignition temperatures, CNG is best employed in dual fuel engines where a liquid fuel i.e. diesel is used to start the ignition.
- The gaseous fuel CNG is added to the air and inducted into the cylinder through natural aspiration during its suction stroke at atmospheric pressure.
- The air gaseous fuel mixture is compressed in cylinder like any diesel fuels.
- Few degrees before compression stroke, diesel is injected in metered quantities through the conventional fuel injection system.
- The finally atomized liquid fuel auto ignites and propagates wave front which burns the natural gas.
- In actual practice each diesel droplet acts as focus of ignition from where a flame from propagates which burns surrounding natural gas. This ensures complete burning of the mixture and results into better efficiency.
- The proportion of diesel has to be kept certain minimum level to avoid fall in efficiency and knocking at high loads respectively.
- The results of experiments conducted on 4 cylinder , 4 stroke , water cooled automotive CI engine having 5.085 liter capacity with dimensions of 92mm bore × 120 mm stroke . Compression ratio 17 and rated power 73 KW at 2800 rpm are as shown in fig A3.4 to FigA3.7.

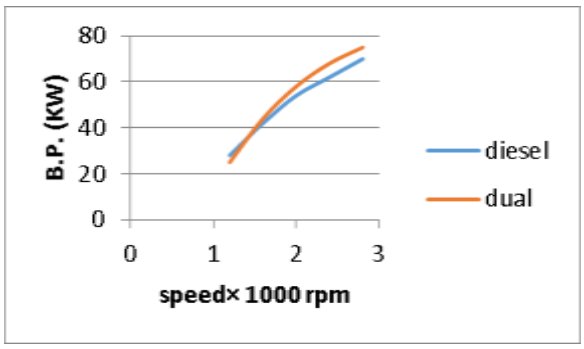

Fig A3.4: speed Vs B.P.[4]

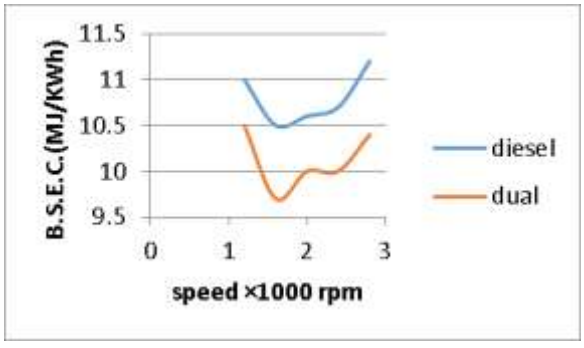

Fig A3.5: speed Vs BSEC[4]

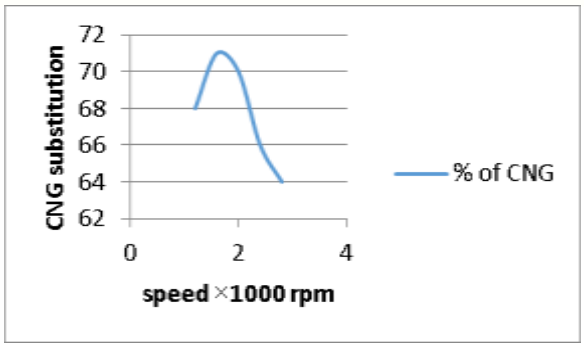

Fig A3.6: speed Vs % of CNG [4]

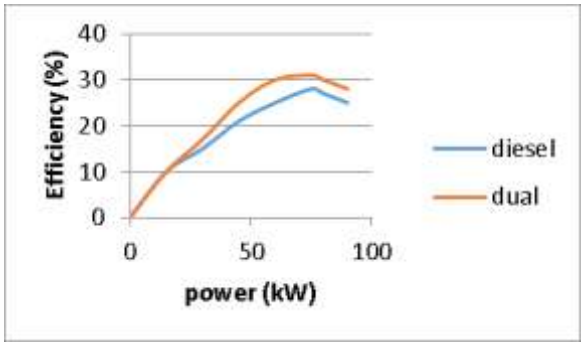

Fig A3.7: power Vs Efficiency

Following observations and conclusions can be made:

- Dual fuel engine operation gives more brake power than diesel operation except in the low speed range because of the high calorific value of CNG.
- In addition, the gaseous fuel CNG makes more homogeneous mixture and results into efficient combustion. Natural gas burns easily as it is devoid of any long chain molecules.
- Brake Specific energy consumption (BSEC) with dual fuel operation is lower than diesel operation since the dual fuel engines is able to utilize most of the energy of the charge.
- Smoother operation resulting in lesser losses.
- CNG substitution can be made up to 80%.
- CNG substitution is less at low speed due to lesser concentration of CNG in air preventing the flames starting from ignition source to propagate through lean mixtures. At higher speeds the CNG substitution is higher since the combustion temperature is higher and pilot quantity of fuel is also more leading to better combustion.
- But at very high speeds CNG substitution falls due to higher ignition delay of CNG.
- Thermal efficiency with CNG operation is higher compared to diesel except at low loads. Advanced injection timings improve the efficiency of dual fuel engine.
- CO emission of dual fuel engine is more at low loads and decreases with the increased load.
- Substantial reduction in NOx and smoke emissions are obtained with dual fuel operation.

I. ALCOHOLS:[5]

- Alcohols , particularly , Methanol , Ethanol are likely to be the most alternative automobile fuel in foreseeable future
- Methanol can be produced can be produced from fossil fuels like lignite or coal, or from municipal solid waste under extreme pressures and temperature.
- While Ethanol can be produced from sugar or grain.
- The important properties of gasoline , methanol , ethanol are given in table
- Methanol appears to be better substitute for gasoline.

sr.no	Property	Gasoline	Methanol	Ethanol
1	Molecular weight	112	32	46
2	Specific gravity at 15.5 C	0.75	0.796	0.794
3	Boiling point	30	65	78
4	Latent heat of vaporization kJ/kgk	350	1105	855
5	Lower calorific value KJ/kgK	43965	19680	26800
6	Stiochimetric air fuel ratio	14.17	6.4	9
7	Self ignition temp.	350	478	420
8	Octane n.	82	94	94
9	Cetane n.	8.14	3	8

10	Vapour pressure at 58 c	0.8	0.32	0.21

1. Methanol Engines:

Disadvantages /difficulties of methanol engines:

Following major difficulties have to be overcome before 100% methanol can replace the gasoline in commercial vehicles .

- Since the methanol has high boiling point and high latent heat of vaporization coupled with low vapor pressure, it lowers the temperature of the mixture in combustion chamber. It causes cold starting below 15 degree C difficult and during warm up period.
- It makes an explosive mixture in the tank.
- Alcohol is a good solvent for gum and other materials. It attacks the rubber and plastic parts. It causes corrosion and wear of the engine and fuel system materials.
- Since the calorific value of methanol is almost half of the gasoline, it reduces the vehicle range for a given capacity of the fuel tank.
- Methanol engine have to work with higher compression ratios compared to gasoline engines .It makes the engine bulkier.

Advantages**:**

However, the advantages of operating the Engine with pure methanol over gasoline are:

- Methanol engines have about 15-20% higher output compared to a gasoline engines due to better combustion and the use of high compression ratio as shown in fig A4.1.
- Methanol engines are more efficient.
- It gives lower NOx exhaust emissions due to lower flame temperatures.
- It gives lower hydrocarbon exhaust emissions.

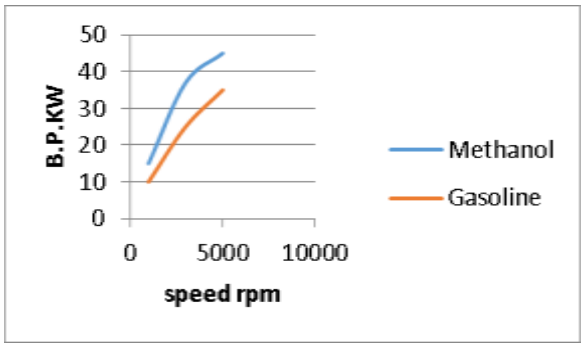

Fig A4.1: comparison of methanol and gasoline engines. [5]

2. Methanol – Gasoline Fuel Blends:

- Pure methanol is usually not used in engines except in racing cars due to its capability of producing higher outputs.
- The problems encountered working with pure methanol as a enumerated above in section can be resolved by using the blends of methanol and gasoline, however, the use of such mixtures may compromise on some key advantages of methanol.
- The results of the experiments conducted on a single cylinder engine at a wide open throttle (WOT) and at variable speed with 15% methanol blends in gasoline are as follows.

1. The improvement in Brake power is marginal in fig A4.2 Improvement in BP may be due to better combustion fuel caused by higher flame speed with methanol-gasoline blends and due to increased volumetric efficiency.
2. There is also decrease in specific energy consumption as shown in fig A 4.3 which may be due to better combustion and reduction in heat losses to the cooling medium due to reduced temperature attained during combustion.
3. There is a reduction both in CO and hydrocarbon emissions .It may due to higher air fuel ratios obtained with methanol-gasoline blends as compared to gasoline.
4. The temperature of air fuel mixture with methanol-gasoline blend is lower by 3-4 degree C, since the latent heat of vaporization of methanol is much greater gasoline. It improves the volumetric efficiency of the engine
5. No engine modifications are needed to work with 15% methanol blends with gasoline except it requires the retarded ignition timing by 1 degree compared to gasoline engine.
6. It is necessary to use some resistant materials to prevent the attack of methanol on rubber and plastic materials.

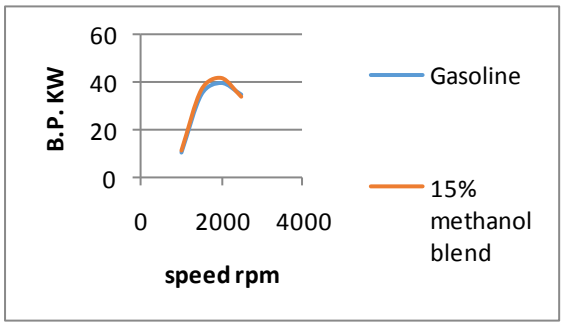

Fig A 4.2 Effect of engine speed on B.P.[5]

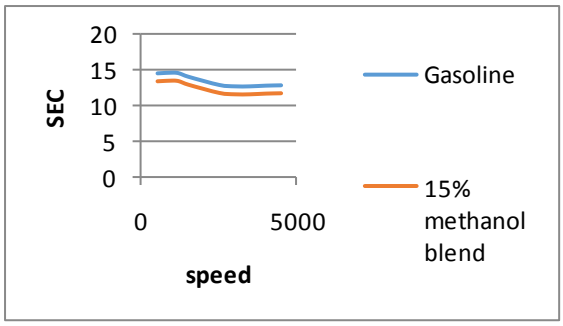

Fig A4.3: Effect of engine speed on SEC [5]

3. Methanol-Diesel Fuel Blends:[5]

- Though methanol can be successfully used in spark ignition engines without much modifications in the engines, it is extremely difficult to use a pure methanol in diesel engines because its low Cetane number , its tendency to attack on rubber and plastic materials and due to low lubricating qualities causing trouble in operation of injection pumps and nozzles.
- Therefore, methanol in diesel engines can only be used as supplementary fuel.
- Many fumigation techniques have been tried for admitting the methanol into cylinder as a supplementary fuel in diesel engines.
- In most of the fumigation techniques, the system utilizes a low pressure injector placed at the heated intake manifolds for continuous supply of, ethanol. However, due to replacement of suction air by methanol vapor, the volumetric efficiency of the engine reduces and causes engine power losses.
- Some engines use the dual injection system for injecting methanol and diesel .In this method, the charge of diesel fuel is used to initiate the combustion process, and later the methanol is injected.
- However, the onset of misfire limits the use of methanol up to a limit of 15 %approximately.
- In the method to avoid the reduction in volumetric eff. The low pressure methanol injector is located near the intake valve which supplies the methanol during the Intake valve opening period only.

The results of the various experiments conducted by researchers are as follows:

1. Specific energy consumption increases with the increased levels of methanol fumigation.
2. Specific energy consumption substantially increases at low loads.
3. NOx emissions are reduced by almost 50%
4. CO emissions are also reduced.

IV.HYDROGEN AS A FUEL FOR ENGINE

1. Hydrogen as fuel in SI engine.[5]

- Researchers for long time had been trying to use hydrogen as an automotive fuel since hydrogen is available in abundance in water and it reduces the environmental pollution caused by the use of conventional fuels i.e. CO , CO2 and hydrocarbon emissions .

- Also, hydrogen provides a large amount of energy on combustion compared to petrol, it mixes very, easily with air and it can burn 4% lean mixtures to 75% rich mixtures on volume basis.
- But , the production of hydrogen by electrolysis of water is quite expensive , however , hydrogen is available as by product from chemical industries like caustic soda and the cost of production is quite comparable with petrol .
- The problem faced while working with hydrogen as fuel is due to its high explosive nature on combustion and development of high flame speeds.
- Therefore, an engine working with hydrogen as fuel needs to be provided with multiple flame quenchers and flame traps to avoid any possible explosions in the intake manifolds.
- SI Engines need to be modified for supplying the mixture of hydrogen and air.
- Hydrogen is usually inducted into intake manifolds after the carburetor and the air is supplied from the air tank through an orifice plate.

The results are obtained by various researches are appended below:

1. There is reduction in power up to an extent of 20% when the engine is run on hydrogen compared to petrol. It may be due to extremely low density of gaseous hydrogen displacing the air.
2. Thermal efficiency reduces by 3% - 4%.
3. Specific energy consumption (SEC) is lower with hydrogen operation compared to gasoline, though in both cases SEC is decreased with the increased load.
4. In case hydrogen is used for dual fuel diesel engine operation, for suppression of knock, the engine is required to be designed with lower compression ratios.
5. Improvement in power up to 10% can be obtained by retarding the ignition timing by 3 degree before TDC compared to specific gasoline ignition timings.

2. Hydrogen as fuel for CI engines:[5]

Hydrogen at present is not being as fuel for CI engines since its auto ignition even with CR of an engine using 30:1. Some researchers are trying to use glow plugs for ignition of H2 with ceramic parts in direct injection CI engines.

3. **Blend of H2 with CNG as fuel**:

The blend of H2 energy content up to 10% with CNG is called Hythane .Advantages of using Hythane is that it has safe combustion , lower inflammability , lower per ignition and gives reduced emissions .

V.VEGETABLES OILS AS DIESEL ENGINE FUELS

- Since the vegetables oils have high viscosity, poor volatility and high cost, these fuels were not considered as suitable fuels for diesel engines in the past.

- However , due to the problem of fast dwindling resources of petroleum fuels , environmental pollution caused by diesel and today's strict emission norms , the vegetable oils with modifications are again being tried by researches as alternative fuel for CI engine .
- Calorific value of vegetables is similar to diesel oil and their properties are better than methanol and ethanol, therefore the diesel engines can be operated upon with vegetable oils without or with certain modifications.

Properties of vegetables oils compared to diesel oil:

1. Viscosity is much greater than diesel. It causes the problem of fuel handling, pumping, atomization and fuel jet penetration.
2. Calorific value is slightly lower than diesel.
3. Cetane number is slightly less than diesel.
4. Density is slightly higher than diesel.
5. Volatility is much lower than diesel.
6. Flash points are much higher than diesel, hence vegetable oils are quite safe to store.
7. Carbon residue is much higher than diesel.
8. It gives rise to exhaust smoke.

Methods of modification of properties of vegetable oil:

The difference experienced in using the vegetable oil in diesel engines, as enumerated above, can be overcome to a certain degree by the following methods :

1. Vegetable oil heating
2. Esterification
3. Thermal cracking off oil

Various vegetable oils like karanji oil, sunflower oil, rice bean oil, neem oil etc. have been tried for use in diesel engine. Discussion on use of certain vegetable oils in CI engine is given below:

1. Karanji Oil Operation:

Various properties of karanji oil, blends and methyl ester of karanji oil are given in table.

Sr no	Fuel	Viscosity centipose	Cal. Value KJ/kg	Flash point Deg.	Density kg/m^3
1	Diesel	12.5	44000	57	0.821
2	Karanji oil	120	37100	205	0.91
3	20% karanji oil	29.4	42700	81	0.836

	blend with diesel				
4	Methyl ester of karanji oil	50	36910	165	0.885
5	35% karanji oil blend with diesel	36	41500	100	0.848

The results of the experiments conducted on single cylinder on single cylinder water cooled diesel engine of rated power 7.5KW at 1500 rpm are shown in fig A6.1 and fig A6.2 with injection timing at 27 degree BTDC

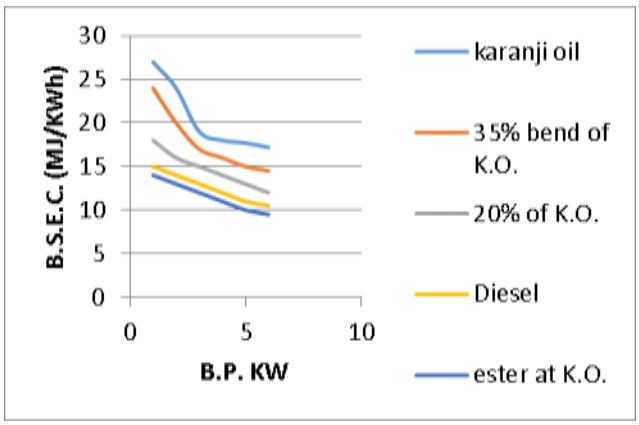

Fig A6.1: B.P Vs BSEC

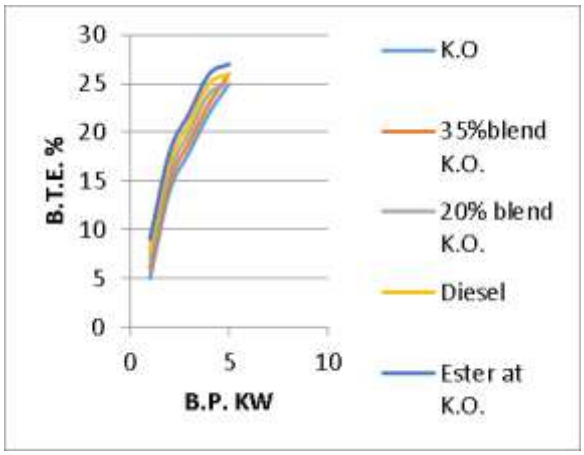

Fig A6.2: BP Vs Brake thermal efficiency (BTE)

Following are the results obtained:

1. The results of karanji oil are comparable with diesel oil.
2. The brake specific energy consumption (BSEC) and thermal efficiency with pure karanji oil and its blends with diesel oil were found to be higher and lower respectively as shown in figs and fig
3. With injection timing at 30 degree BTDC the performance with karanji oil and its blends improves.
4. Karanji oil gives performance comparable to diesel oil without any combustion knock.
5. There is problem of carbon deposits on injector tip, piston head and piston ring grooves with vegetable oils.
6. Injection pressures required are higher while working karanji oil compared to diesel oil.
7. CO emissions were lower with ester of karanji oil compared to diesel.

It can be concluded that ester of karanji oil and its blended up to 35% with diesel can be effectively employed in the existing CI engines. For better performance the injection timings need to be retarded by 3 Degree compared to diesel engine.

1. Sunflower Oil Operation:

The results of operation with sunflower oil on CI engines compared to diesel operation are as follows:

1. Sunflower oil needs to be heated before injecting up to 50 degree C for better performance and the injection timings needs to be retarded by 1-2 degree compared to diesel oil.
2. BSEC increases by 10% and the thermal efficiency reduces by about 1 to 2%.
3. Problem of filter clogging exists.
4. Carbon deposits increases.

VI.HOMOGENEOUS CHARGE COMPRESSION IGNITION ENGINES (HCCI)

There are two types of engine SI and CI engine which are commonly used. A spark ignition (SI) engines uses a homogenous mixture of fuel and air ignited by a spark. Such engines have low cost and low exhaust emissions but their part load efficiency is poor due to large heat losses. Whereas, compression ignition (CI) engines use a high compression ratio for auto ignition of mixture having high initial cost, high part load efficiency but these engine have emissions of NOx and particulate matters (PM).

In order to take advantages of SI & CI engines and to overcome their respective disadvantages, one of the design is the Homogeneous Charge Compression Ignition (HCCI) engine.

A HCCI engine is mix of both conventional SI and CI engines technology. It uses homogeneous mixture of fuel and air throughout the engine but using lean mixtures as in case of SI engines. However, instead of using the electric discharge to ignite a portion of the mixture of fuel and air, the mixtures of fuel and air auto ignites due to use of high compression ratio in these engines as in case of diesel engines. The result of such a HCCI engine is the optimum power output, low exhaust emission and high fuel efficiency. Therefore, the special characteristic of HCCI is that the ignition of mixture occurs at several places and burns the mixtures almost instantaneously.

Working of HCCI engine:

These engines use direct fuel injection system in which the fuel I injected into the cylinder during its suction stroke. Whereas, the air is sucked independently during suction as in case of diesel engines. By the end of suction stroke, a homogeneous lean mixture of air-fuel duly mixed is prepared inside the cylinder. The engine uses compression ratio of more than 15.

During compression stroke, the pressure and temperature of the mixture rises above its self ignition temperature (SIT) due to use of high compression ratio. The mixture auto ignites just at TDC almost spontaneously. Such an auto ignition results into high pressure. The combustion of fuel and air in this case is with lean mixtures at low temperatures with flameless release of energy across the entire combustion chamber unlike in this case of SI and CI engines. The power is produced during expansion stroke and finally the burnt gases are exhausted to the surroundings during its exhaust stroke.

In these engines, the exhaust valves are closed slightly early as compared to conventional engine. It helps to trap the heat of exhaust gases in the cylinder and a small quantity of fuel is injected so as to initiate the pre-combustion reactions before the start of the next intake stroke.

Merits of HCCI engines

1. Low emissions like SI engines with extremely low NOx emissions. Thus these engines do not require catalytic converters for treatment of NOx.
2. The HC and CO emissions are still high they need after treatment to meet the required standards of emissions.
3. Power output is high with high fuel efficiency.
4. Part load efficiency of engine is high.
5. Possibility of knocking is avoided since the entire mixture burns simultaneously without causing the pressure difference for shock wave to travel across cylinder. However, at high loads using high fuel air ratio, knocking is possible even in HCCI engines.

Challenges in HCCI Engine:

The control of combustion process in HCCI engines is challenging since there is no direct method of initiating the combustion as in case of SI & CI engines. The control of combustion in HCCI engine require the closed loop combustions control (CLCC). However, the microprocessors can be used for dynamic operation of these engine by controlling one or few variables like C.R. (in variable compression ratio engines), the suction gas pressures and temperature, air –fuel ratio , quantity of exhaust to e retained in the cylinder by varying the timing for exhaust valve closing etc. With these controls, the appropriate conditions needed for ignition to occur at desirable timings can be achieved.

VIII.CONCLUSION

Our dependence on energy is key to our economy and approach of life. Economically, new and renewable types of fuels are to be utilized, as our supplies of many current fuels are very limited. Environmentally, burning fossil fuels has been greatly affecting and damaging our planet. Thus, it is necessary to compare all types of fuels, in

order to determine the best ones, economically and environmentally, short term and long term in all aspects. And hence, alternative fuels are to be developed.

LPG, CNG, Alcohols, Hydrogen, Vegetable Oil are some of the Alternative Fuels that can be used in IC Engine. But we cannot use this fuel as 100% substitute in IC Engine. Thus we have to find certain blend which contains some amount of alternative fuel and diesel or petrol fuels. The solution to this problem is blend like methanol-gasoline blend, methanol-diesel blend, blend of H2 with CNG, and vegetable oil-diesel blend. As this concept is covered in above mention, so I can say that "We are on the way to replace the Diesel and Petrol.

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