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Renewable Eco Friendly Alternate Fuels

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Abstract— Fossil Fuels such as coal and gasoline provide most of the energy needs of the world today, but because of their diminishing reserves, high prices and most importantly, their damaging effect on the environment, alternative sources of energy and environment friendly fuels are now being developed. There is an ardent need for saving the environment that is being polluted by emissions given out by the extensive use of gasoline. There are promising discoveries in alternative fuels such as Alcohols, Bio-diesel and Natural gas, which give hope that before any crisis occurs, mankind would have perfected and commercialized alternate sources of fuel that will be eco- friendly and affordable too. This paper proposes more than a dozen alternative and advanced fuels in production or use today from the perspective of protecting the environment.

Keywords—Alternative fuels, renewable fuels, clean fuel.

I. Introduction

During the recent years there has been a growing demand for petroleum fuels. Petroleum based fuels are 'stored' fuels, extracted from earth. There are limited reserves of these 'stored' fuels and they are irreplaceable. With our present known reserves of petroleum fuels and their growing rate of consumption, it is feared that they are not going to last long [1]. Apart from this problem of fast depleting reserves and non-renewable nature of petroleum fuels another very important aspect of their use is the extent and nature of environmental pollution caused by their combustion in vehicular engines. Diesel exhaust has traces of over 40 substances that are listed by California Air Resources Board (CARB) as toxic contaminants and probable human carcinogens. In gasoline fuelled vehicle exhaust alkenes and benzene together with poly-aromatic compounds add to carcinogenicity of vehicular emissions.

In view of these problems of fast dwindling reserves of non-renewable petroleum fuels and the hazards of environmental pollution caused by their combustion, attempts must be made to develop the technology of alternative "clean" burning fuels. These fuels in order to be useful should be such that they have attributes of perennial renewal, they perform well in the engines, and their potential for environmental pollution is quite low.

Various fuels have been considered as substitutes for petroleum fuels [2, 3]. The most prominent among these are Alcohols (Ethanol/Methanol), Bio-diesel, Natural Gas (CNG/Methane) and Hydrogen (table 1). The suitability of each of these fuels for vehicular engines has been under investigation by the author. Some of the findings of these investigations are briefly discussed in the following pages.

II. ALCOHOL FUELS

Only the first two members of the monohydric series namely methanol and ethanol are suitable engine fuels. The importance of ethanol lies in the ease with which it can be prepared from an astonishingly wide range of raw materials, something which is available in every habitable part of the globe. These raw materials include vegetable matter, growing crops, farm waste, tropical grasses, and waste organic products such as straw and saw dust, water gas, industrial wastes like molasses from sugar industry, sulphide liquor from paper and pulp industry and many others [7].

India is one of the largest producers of ethanol in the world with its 287 and odd distilleries produce 1.3 billion litres of ethanol annually from sugar molasses alone while operating at only 40-45% of their installed capacity (2.6 billion litres). Around 1.6 billion litres of additional ethanol can be produced even if only 10% of the 350 million tons of the available agricultural waste are utilized for alcohol production.

Cassava –a wild growth down south and the untapped khandsari molasses are additional potential sources available for augmenting ethanol production. If used as a vehicular engine fuel, ethanol offers certain advantages; the chief among them is the possibility of higher compression operation without knock, smoother engine performance and cleaner combustion. Extensive experimental tests and theoretical investigations have shown that ethanol can be utilized with great advantage in automobile engines in any of the following ways.

In the form of ethanol-gasoline blends, in the existing vehicles, without any engine modifications. Its higher latent heat of vaporization, uniform composition, stoichiometric air requirements, higher flash points etc. impart to its blends certain useful properties which not only improve engine performance but also reduce engine emissions and make the blends safer as compared to gasoline. Its lower calorific value, higher surface tension, greater solvent power etc. restrict its use as a complete motor vehicle fuel. It can be best utilized as a blend constituent with upto around 30% ethanol-gasoline blends useable in the present day automobiles without requiring any major engine modifications; and giving reduced levels of exhaust CO and HC emissions [7]. Analysis of lubricating oil samples periodically drained from automobiles operating on the blend indicated a comparable trend of oil deterioration with no undue degradation of the important physical and chemical characteristics of the oil, vis-à-vis conventional gasoline operation. The rate of lubricating oil consumption also was comparable to that with gasoline neat operation.

As a duo-fuel for separation injection when required. While operating the engine with a cheaper low octane fuel. Such an arrangement would permit operation of the automobile engine with low-grade hydrocarbon fuel most of the time, with automatic arrangement of ethanol injection whenever maximum power is required or there is need of quick acceleration. Use of ethanol in this way can well result in greater economy. As complete fuel in specifically designed ethanol engines, having a higher compression ration of the order of 12 or so. Such engines would have specially designed combustion chamber and fuel induction/injection system, to efficiently utilize ethanol fuel. Theoretical considerations and experimental data generated by the author show that such engines will have much greater power output, higher efficiency and cleaner exhaust. As ethanol-diesel emulsion with an ignition improver (triethylene-glyconitrate) in existing diesel engine powered vehicles to achieve knock free engine operation over the entire engine speed and load range with 20 to 30% (by volume) saving of diesel oil and with up to 50% reduction of diesel smoke.

In India five percent ethanol blend (B5) was introduced in 2003 on a commercial scale in ten states (Goa, Gujarat, Haryana, Karnataka, Maharashtra, Punjab, Uttar Pradesh, Uttranchal, Andhra Pradesh except two districts and in some districts of TamilNadu) and three Union Territories (Daman and Diu, Dadra and Nagar Haveli and Chandigarh). The government is planning to expand this B5 distribution to 21 states so that except for the North-East all other parts of India will be able to avail the facility of fuelling of cars, two and three wheelers with ethanol blend. It is also envisaged that by the end of next year the proportion of ethanol in the blend will be raised to 10 percent.

Methanol, in contrast to gasoline and other hydrocarbon fuels, has also relatively good lean combustion characteristics. Its wider flammability limits and higher than gasoline flame speeds have been demonstrated in variety of combustion situations. Tests on unmodified private automobiles run with methanol, added in varying proportions from 5 to 30 percent to gasoline, showed an improvement in fuel economy (5 to 13%) decrease in exhaust carbon monoxide (14 to 70%) reduction of exhaust temperature (1 to 9%) and improved acceleration (up to 7 percent). Phase Separation, vapour lock and low temperature starting difficulties are some of the problems associated with the use of methanol-gasoline blends in automobiles. It's highly toxic nature, tendency towards pre ignition and lower heating value make it inferior to ethanol [6]

III. NONEDIBLE OILS – BIODIESEL BLENDS

In India, biodiesel is proposed to be sourced from non-edible oils. These include Jatropha curcas and Pongamia pinnata (Honge or Karanjia) plants. The seeds are rich in oil and are expected to be used for production of biodiesel through a trans-esterification process, which is meant for reducing high viscosity of the vegetable oil and make it suitable for diesel engines [5]. The India government has decided to promote a blend of five per cent biodiesel in the regular diesel sold in the country. The percentage of biodiesel blend is expected to increase in stages to 20 in course of time. Pilot programmes have begun in some Indian cities including Ahmedabad, Pune and Hyderabad where a small fleet of buses have begun to run on biodiesel blend. The Andhra Pradesh government is also looking at the possibility of increasing the proportion of the blend. In the West, biodiesel is largely produced from crop oils like rapeseed, sunflower or soybean.

The other key biodiesel users, including Thailand and Malaysia, use palm oil, while Nicaragua uses Jatropha oil. Ireland on the hand is utilizing frying oil and animal fats. The emissions tests carried out have shown that as the percentage of biodiesel blend increases HC, CO, and PM emissions reduce but NO_X emissions show an increase of 10 per cent from the base line (0 per cent blend).

Similar results are also reported by a study done by Mahindra and Mahindra, an Indian automobile company. It shows reduction in all pollutants except a slight increase in NO_X emission. The life cycle analysis of biodiesel shows approximately 80 per cent less CO_2 and almost 100 per cent less SO_2 emissions compared to conventional diesel. The Bureau of Indian Standards (BIS) has issued specifications for biodiesel neat. During the finalization of the specifications the sulphur norms were strongly contested by the industry. However, in the final rule sulphur content has been specified at 50 mg/kg (maximum). It is important to note that the report of the committee on the development of biofuel set up by the planning commission of the government of India has stated that biodiesel should generally contain less than 15 ppm sulphur. High cost and large-scale non-availability of this fuel are considered to be the current barriers to this programme. Biodiesel Industry however is expected to grow not only to meet the market demand within India but also the growing European demand which is promoting this fuel as part of its renewable energy programme.

IV. NATURAL GAS/ METHANE

While the last century belonged to liquid fuels, this century will witness their replacement with gaseous fuels. In India natural gas with an indigenous proven reserve of 32.58 trillion cubic feet could provide a relief in the mounting oil import expenditure. Compressed natural Gas (CNG) is mainly methane (80-90%) with small percentages of ethane, butane propane and other paraffin along with carbon dioxide, nitrogen and traces of hydrogen sulphide. Its low density and ready miscibility with air permits engine to be started with ease and have smooth running even in the coldest weather. It's very high Octane rating (120-130) compared to gasoline (87-98) allows the engine to be operated at high compression ratios without any problem. Its higher concentration in air to burn or detonate, colder flame radiating less heat, low density enabling it to escape into atmospheres in case of leakage, higher self-ignition temperature which reduces the possibility of fire or explosion in the event of fuel leaks, and its non-toxic and non-carcinogenic nature makes it safer and less hazardous than gasoline. Present day automobiles can be converted for CNG fuelling by installing a bi-fuel conversion kit with the flexibility of vehicle operation on either CNG or gasoline. However, this mode of CNG induction entails loss of power (10-15%) because of reduction of engine volumetric efficiency due to the displacement of intake air by the lighter CNG. Timed manifold injection (TMI)/ in cylinder injection (ICI) of CNG-techniques that are being perfected by the author could eliminate/reduce this power loss substantially. Higher compression operation with optimized spark timing in a dedicated CNG engine could further reduce this power loss (3 to 9%) [9]. With CNG conversation kit the present day automobile gives on energy equivalent basis comparable kilometrage/liter to that obtained with gasoline. Improved kilometrage/liter figures could be obtained with the dedicated CNG engine having higher compression ratio, optimized spark timing and CNG injection instead of pre-mixed charge induction.

The real advantage of CNG fuel substitution in motor cars is obtained in drastically reduced exhaust emissions. With CNG fuelling mass emission in gms/ /km of exhaust carbon monoxide, hydrocarbon and oxides of nitrogen may reduce to one-third of that with gasoline with virtually no-SO_x and SPM emissions. Test carried out on Three-wheelers of various make showed reduction of CO by around 65% HC upto 72% and NO upto 20% with CNG fuelling [8]. Studies carried out to compare the cancer potency of emissions from vehicles running on various fuels show that diesel engine emissions have the highest Cancer Risk Index (CRI) being more than double that of gasoline engine emissions while ethanol and CNG engine emissions have CRI figures around one-half and one-fourth that of gasoline engine emission respectively [4]. There is problem of lack of infrastructure facilities for the storage and dispensing of CNG and the enormous amount of capital and time required to build them up. Non-availability of land in the densely populated metros for building up CNG stations is yet another bottleneck in wide spread use of CNG.

V. LIQUIFIED PETROLEUM GAS (LPG)

LPG is a mixture of light HCs, predominantly propane and butane. It is pressurized into liquid for use as an automotive fuel and is cleaner than petrol and diesel. LPG contains fewer highly reactive HCs and has lower sulphur content than conventional fuels. As a fuel for spark ignition engines, it has many of the advantages of natural gas, with the additional advantage of being easy to carry abroad vehicles. A Large tank is needed for storing CNG at 200 bar pressure. But LPG can be stored at relatively low pressure of (14-15 bar) for automotive application.

This makes its distribution easier and its application, even in smaller vehicles like two-wheelers, more convenient. Auto LPG also called auto gas is by far the most widely used and accepted alternative automotive fuel worldwide. Global consumption of auto gas reached an estimated 17.1 million tons in 2004 and is increasing rapidly. Today, there are over 10 million LPG vehicles in use in the world.

LPG has wide scope in Indian cities, those which do not have access to CNG. It is produced and supplied from oil refineries by gas plants in oil and gas fields. In refineries, it is a by-product of processes that produce gasoline. LPG is separated from crude oil and from natural gas. In its natural state, LPG is a gas. It turns to liquid under moderate pressure. For use in vehicles, it is stored in special fuel tanks under a pressure of around 14 bars. When liquid it is drawn from the tank, it changes back into gas as it is inducted in the engine. One gallon of propane contains less energy than a gallon of petrol. As a source of energy, LPG's carbon content is lower than that of petrol and diesel. When used in spark ignition engines, it produces near zero particulates, very little CO and moderate HC emissions. Variations in the concentration of HC in LPG can affect the composition and reactivity of HC emissions. Exhaust non-methane HC and CO emissions from LPG are lower than those from gasoline. The CO_2 levels are typically lower. NOx emissions are similar to those from gasoline fuelled vehicles and can be effectively controlled using three way catalytic converters. Tests conducted by the author show that LPG vehicles can produce 30-90 percent less CO, and about 50 percent fewer toxins and other smog producing pollutants compared to gasoline fuelled engines. According to an estimate, Delhi is having more than 60,000 illegally using LPG such vehicles. In Kerala, reportedly more than 100,000 vehicles are running on domestic LPG. Similarly, Kolkata has more than 300 cars running on illegal LPG. Chennai has more than 10,000 call taxis many of which run on LPG using illegal kits and domestic cylinders as well as 60,000 such three wheelers.

TABLE-I

COMPARISON OF RENEWAL AND NON- RENEWAL FUELS ON VARIOUS PARAMETERS

	Gasoline	**Biodiesel**	**CNG**	**Ethanol (E85)**	**Methanol (M85)**	**Liquefied Natural Gas LNG**	**Liquefied Petroleum Gas (LPG)**	**Hydrogen**
Chemical Structure	C4 to C12	Methyl esters of C16-C18 fatty acids	CH_4	CH_3CH_2OH	CH_3OH	CH_4	C_3H_8	H_2
Cetane number	5 to 20	46 to 60	N/A	N/A	N/A	N/A	N/A	N/A
Octane number	86 to 94	~25	120+	100	100	120+	104	130+
Main fuel source	Crude oil	Soy bean oil, waste cooking oil, animal fats, and rapeseed oil	Underground reserves	Corn, Grains, or agricultural waste	Natural gas, coal, or, woody biomass	Underground reserves	A by-product of petroleum refining or natural gas processing	Natural Gas, Methanol, and other energy sources
Energy Content per Gallon	109,000 - 125,000 Btu	117,000 - 120,000 Btu (compared to diesel #2)	33,000 - 38,000 Btu @ 3000 psi; 38,000 - 44,000 @ 3600 psi	~ 80,000 Btu	56,000 - 66,000 Btu	~74,000 BTU	~84,000 Btu	Gas~6500BTU @3000psi, And 16000btu @ 10000psi

Types of vehicles available today	All types of Vehicle classes.	Any vehicle that runs on diesel , no modifications are needed for up to 5% blends.	Many types of Vehicle classes.	Light-duty vehicles, medium and heavy-duty Trucks and buses. Vehicles that can be fuelled with E85	Mostly Heavy-duty Buses are available.	Medium and Heavy-duty trucks and buses.	L & H duty vehicles, which can be fuelled with propane or gasoline, trucks and buses that run on Propane.	No vehicles are available for commercial sale yet, but some vehicles are being leased for demonstration purposes.
Fuel Availability	Available at all fuelling stations.	Available in bulk from an increasing number of Suppliers.	More than 1,100 CNG stations can be found across the country.	Rare, it is blended with traditional fuels at present.	Methanol remains a qualified alternative fuel as defined by EP Act.	Public LNG stations are limited through several suppliers in line.	LPG is the most accessible alternative fuel in India, more than 2200 Stations.	There are only a small number of hydrogen stations across the country. Most are available for private use only.

It is unfortunate that a very large number of vehicles in some states are operating on LPG using ordinary removable domestic type LPG cylinders which neither meet the design requirements nor have the necessary fittings and attachments for safety. Domestic cylinders so used are generally not properly secured and this makes them vulnerable in a crash situation. Moreover, with these cylinders the cylinder valve is not provided with excess flow protection, which means that if the valve or the supply line is sheared in a crash, there would be uncontrolled flow of LPG creating hazardous conditions.

The weight of LPG vapours at ambient temperature is around 150% the weight of air. If there is a leak LPG vapours tend to settle against the ground and are also invisible. They cause substantial fire risk since the mixing of these vapours with the surrounding air may result in the occurrence of air-to gas ratios in the flammable range over a substantial volume of space in the vicinity of the vehicle. A spark or flame anywhere in this area can ignite a fire. Incorrect use of dispensing valves during refuelling can also cause excess LPG vapour discharge. From safety considerations odorisation of the gas and the use of gas detectors in the distribution system is necessary as the gas is colourless, extremely volatile and LPG fires burn twice as hot as gasoline fires.

VI. HYDEROGEN FUEL/ HYDROGEN FUEL CELL

Hydrogen is an excellent fuel, and since it can be produced from water, it can be made easily available everywhere. It is an exceptionally clean burning fuel easily manageable and is superior to natural gas and fuel oil in many combustion engine applications. It is highly combustible but with proper management, it should not be more hazardous to use than conventional fossil fuels.

The energy content per unit volume for hydrogen gas is very low. Its heat in k cal/cum is less than one third of the corresponding value for natural gas. This means that approximately 3.2 SCM of hydrogen gas are required to replace the energy content of 1 SCM of natural gas. In liquid from, however the picture is not that bad, as tank capacity of 73 gallons will be required to replace 20 gallons' tank of gasoline. This size may not very unwieldy especially because the fuel will weigh only 20 kg.

The real problem will be of storage of liquid hydrogen because liquid hydrogen must be maintained in vacuum insulated tanks at below its boiling point of 158º K. Problems relating to flash back during induction, pre-ignition during compression and detonation during combustion, common with hydrogen can be overcome by using Timed Manifold Injection Systems developed by the author. Use of flame traps in the intake systems can ensure greater safety with hydrogen. Hydrogen storage and handling problems are being tackled by developing carbon nano fiber and metal hydride storage systems. Use of hydrogen fuel via the fuel cell route is an emerging trend for hydrogen-fuelled vehicles. In the fuel cell vehicle, the conventional automobile engine is replaced by a traction motor, which drives the vehicle wheels using the electricity generated by the fuel cells by electrochemical conversion of the chemical energy of hydrogen directly into electricity. The fuels cells are comprised of two electrodes, which are separated by an electrolyte. Hydrogen gas is fed to the anode and air (oxygen) is fed to the cathode. They ultimately react to from water and produce electricity. Polymer Electrolyte Membrane Fuel Cells (PEM) which have an operating temperature range of 80-110º C are preferred for automobile application because of low temperature range, high power density (100w/lt) and ease of operation. They are made in modular from and can be configured into a relatively wide array of shapes to fit in the available space. Fuel cells can also be used in conjunction with batteries for additional power.

A wide range of electrical vehicles NECAR (acronym for New Electric Car) have been developed by Daimler Chrysler in NECAR III is a compact 4/5 passenger car which is powered by two compact 25 kW Ballard PEM fuel cell stack, each consisting of 150 cells. With about 65 horsepower NECAR III being commercialized has a range of 40 kilometres on full tank of 38 litres of methanol which is converted into hydrogen through an on board reformer. NECAR IV generates forty percent more power than NECAR III from its liquid hydrogen system and has a range of 450 kilometres. General Motors of USA and Toyota of Japan are also in the race for commercialization of fuel cell cars. Fuel cell vehicles are almost twice as efficient as gasoline fuelled vehicles, can attain the same range of speed and give similar kilometrage figures are zero emission vehicles that leave only a trail of water vapour and not cloud of carbon dioxide, nitrous oxide and other pollutants [10-11]. However high capital cost and non-availability of infrastructure for refuelling hydrogen are serious constraints, which may take some time before hydrogen fuelled vehicles will become commercially viable [8].

VII. CONCLUSIONS

Energy sources of the future will have to be cleaner and more efficient than current sources alternate eco-friendly fuels can fulfill these requirements. Several challenges remain before we will see wide-spread commercialization

As an immediate measure, to meet the present day automobile fuel scarcity and exhaust pollution problems, ethanol can be blended into existing gasoline, while future automobiles can be designed to accommodate ethanol, neat and cleaner burning fuel with attributes of perennial renewal, use of CNG and LPG in running vehicles can reduce their emission of suspended particulate matter by as much as 90% while emission of harmful gases like carbon monoxide by 70% or so. Vehicles powered by alternative fuels face the biggest hurdles in the form of lack of recharge stations. That's why people hesitate to take the inter-state highways in alternative fuel vehicles. As a long-term measure intensive R & D effort should be directed towards the development of alternate eco-friendly fuelled automobiles, which can provide the complete answer to supply and pollution problems of road transport vehicles at a reasonable operating cost.

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