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# Assessment of Different Alternative Fuels For Internal Combustion Engine: A Review

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**ABSTRACT—**
The development of alternative fuels such as CNG, bio-diesel, hydrogen, ethanol etc. has become very essential because of continuously decreasing petroleum reserves as well as increasing their contribution in pollution. Alternative energy source now a day, gaining much interest of research work. In this review paper, we investigated the behavior of different fuels on the basis of their properties of combustion at different parametric conditions. The aim of the present study is to evaluate the influence of bio-diesel, hydrogen, CNG and alcoholic fuels (as an oxygenation additive for the diesel fuel) on exhaust emissions in a small internal combustion engine.

**Keywords**- Alternate fuels; internal combustion engine; Compression ratio, Higher Heating Value, Lower heating value

## I. INTRODUCTION

An engine where combustion of fuel with air in combustion chamber occurs is known as Internal Combustion Engine. Mainly, fuels used in Internal combustion engine are the by products of crude oil like Gasoline, Diesel, Petrol etc. First commercially successful internal combustion engine was created by Elenne Lenoire around 1859. During 1859, where environment was not the major concern. Since the pollutants level were at the low level, the climate and pollution was not alarming. In present scenario, all health related issues are considered one of the major causes of pollution across the globe. Today in developing world automobiles are becoming the necessity in which IC engine is the integral part. Due to which there is an urgent need for the development of alternate fuel.

Gases emitted by the gasoline engine which gets combined with air results in polluting it, which further comes back to us in the form of acid rain, global warming, and other health the issues. There has been a noted improvement in I.C engine in last decade but due to the increasing rate of automobile there is lot more to be done.

As we know petrol and diesel are derived from crude oil i.e. fossil fuels, and as per the rate of consumption there will be direct impact on our near future as gasoline will become rare mineral therefore cost will rise accordingly. So the main issue is regarding sustainable development of alternate fuels for our futures which includes lower fuel costs, higher octane number and certainly cleaner exhaust emission. That's why; the use of possible alternate fuel is required for sustainable development of environment as well as our resources.

**BIODIESEL**

Biodiesel is more entirely from sources. It does not contain any sulphur, aromatic hydrocarbon metal or crude oil resources. Biodiesel is produced from renewable vegetable animal fats and hence improves fuel or energy security and economy independence. But the high viscosity and low volatility affected the atomization and prey pattern leading to incomplete combustion and severe carbon deposits, injection, choking etc. Trans-esterification is the reaction of vegetable oil or animal fat with an alcohol, in most cases methanol, to form esters and glycerol. The trans-esterification reaction is affected by alcohol type, molar ratio of glycerides to alcohol, type and amount of catalyst, reaction temperature, reaction time and free fatty acids and water content of vegetable oils or animal fats. The trans-esterification reaction proceeds with or without a catalyst by using primary or secondary monohydric aliphatic alcohols having 1–8 carbon atoms [11]. The reaction temperature near the boiling point of the alcohol is recommended. Nevertheless, the reaction may be carried out at room temperature. The reactions take place at low temperatures (65°C) and at modest pressures (2 atm, 1 atm = 101.325 kPa). Bio-diesel is further purified by washing and evaporation to remove any remaining methanol [15]. The oil (87%), alcohol (9%), and catalyst (1%) are the inputs in the production of bio-diesel (86%), the main output .Pre-treatment is not required if the reaction is carried out under high pressure (9000 kPa) and high temperature (240°C), where simultaneous esterification and transesterification take place with maximum yield obtained at temperatures ranging from 60 to 80°C at a molar ratio of 6:1[15]. The alcohols employed in the transesterification are generally short chain alcohols such as methanol, ethanol, propanol, and butanol. It was reported that when transesterification of soybean oil using methanol, ethanol and butanol was performed, 96–98% of ester could be obtained after 1hr of reaction.The alkyl esters, having favorable properties as fuel of use in IC engine. Biodiesel can be used in diesel engine without modification and can be blended with petrol diesel fuel effectively. A blend of 20% biodiesel and 80% biodiesel fuel called B20. Biodiesel's high viscosity and low volatilities cause problems in long-period engine performance tests. The higher viscosity in bio-diesel affects the fuel droplet size, poor atomization qualities and fuel penetration in the cylinder which is very important for the combustion quality [15]. Due to the emission benefits derived from the oxygen in the fuel molecule, the interest in the use of bio-alcohols fuel blends in compression ignition engines has been increased [17]. Butanol is a feasible alternative fuel that has a number of desirable properties for use with diesel engines [18]. Compared to ethanol, butanol has superior fuel properties which make it more suitable for application in diesel engines, such as higher heating value, good inter-solubility with diesel fuel, and no corrosion to existing pipelines [19]. Most studies have focused the use of ethanol as fuel in reciprocating engines. Fewer studies have reported the use of butanol as fuel, although butanol posses some better fuel properties than ethanol [16]. Studies about utilization of butanol as fuel in diesel engines found that the soot emissions were effectively reduced [18–20]. Benefit from the use of biodiesel through improving air quality with the reduction of harmful vehicle emissions. Several oil bearing trees like karanja, mahua, polang, kusum, etc are native to India. Oil seeds bearing seeds can be chosen depending upon the local agro-climate condition and economic feasibility of large scale production. The ultra low sulfur diesel program will offer an opportunity for bio-diesel a lubricity additive and Cetane booster as well. It increases the diesel engine also. Condition and economic feasibility of large scale production. The ultra-low sulphur diesel program will offer an opportunity for biodiesel a lubricity additive and Cetane booster as well. It increases the diesel engine life also.

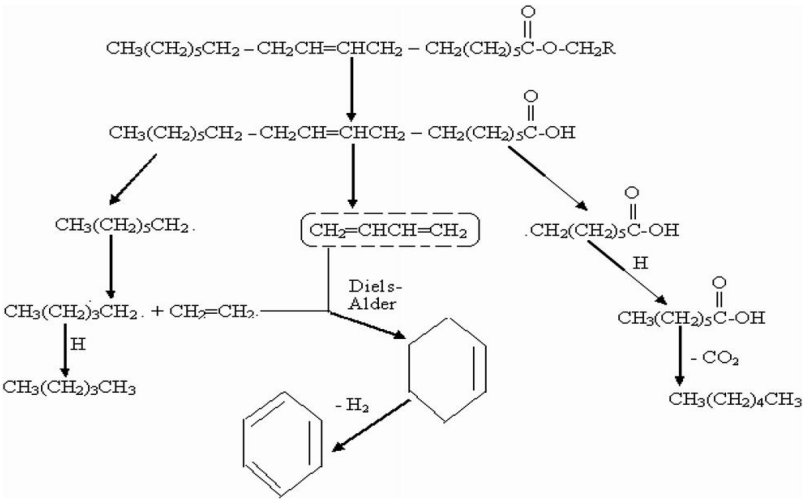


**Fig.1: The mechanism of thermal decomposition of triglycerides [14]**

## ETHANOL

Using alternative fuels, ethanol in internal combustion engines has the potential to reduce the dependency on petroleum fuels [21]. Alcohols can be used in compression ignition (CI) engines as pure or blended with conventional diesel fuel [22-23].

The advantages of alcohols as a fuel include:

– Low viscosity compared to diesel fuel, therefore it can easily be injected, atomized and mixed with air.

– Less emission because of its high stoichiometric fuel–air ratio, high oxygen content, high H/C ratio and low sulfur content.

– High evaporative cooling, which results in a cooler intake process and compression stroke. This raises the volumetric efficiency of the engine and reduces the required work input in the compression stroke.

– High laminar flame propagation speed, which may make combustion process finish earlier, thus improve engine thermal efficiency [24-25]. Diesel-Ethanol blends are also used in CI engine with some modification and the use of ethanol Cetane also improves. Bio-ethanol is manufactured through a bio chemical reaction using hydrolysis to produce simple from sugar beet and wheat, corn and sugarcane. Sugars are then fermented to produce bio-ethanol. Currently, these processes are rather expensive and not yet competition for market place.

The auto-ignition temperature and flash point of ethanol are higher than those of gasoline, which makes it safer for transportation and storage. The latent heat of evaporation of ethanol is 3-5 times higher than that of gasoline this makes the temperature of the intake manifold lowers and increases the volumetric efficiency. The most notable problem are degradation of plastic material and degradation of metal due to the acidic or galvanic property of ethanol. Ethanol can be used in gasoline-ethanol blends with 5% to 10% ethanol called E5 and E10. The blended fuel was used and engine power and specific fuel consumption of the engine is slightly increase. Carbon mono-oxide emission decreases dramatically as a result of the leaning effect caused by the ethanol addition. HC emission is also decreases but $CO_2$ emission increases because of improved combustion. Ethanol blends are quite successful in replacing pure gasoline in spark ignition engine. 10% ethanol blended gasoline is best for Internal Combustion Engine for use in the SI engine without any modification to increases efficiency.

## CNG

CNG**,** is a mixture of hydrocarbons in gaseous form, consists of approximately 80-90 % of methane along with some percentage of ethane, propane, nitrogen [26]. A gaseous form of natural gas, clearly has some

substantial benefits compare to petrol and diesel. Many investigations were carried out in order to use of CNG as an alternative fuel according to their fuel usage and they are:
Dual fuel: like the CNG buses the mixture of CNG and diesel introduced in the engine. As natural gas will not ignite under combustion chamber alone so diesel is required [4].
Bi-fuel: like cars and light motor vehicle, convention petrol engine where the fuel system has been modified to operate either petrol gas [4].
Mono-fuel: this is specialized engine type which has been designed and optimized to operate only on natural gas [4].
Natural gas is produced from a gas wells or tied in with crude oils production. Natural gas is basically methane ($CH_4$) which is prime component but frequently small traces like $CO_2$, $N_2$, and He etc are present. Being pressurized the cylinder is heavier than that of conventional fuel tanks. The advantages of CNG compared to petrol are: Unique combustion and suitable mixture formation; Due to high octane number of CNG, engine operates smoothly with high compression ratios without knocking; CNG with lean burning quality will leads to lowering exhaust emissions and fuel operating cost; CNG has a lower flame speed; Engine durability is very high [27]. The octane rating of natural gas is about 130, meaning that engines could operate at compression ratio of up to 16:1 without "knock" or detonation.

Many of the automotive makers already built transportation with a natural gas fuelling system and consumer does not have to pay for the cost of conversion kits and required accessories. Most importantly, natural gas significantly reduces $CO_2$ emissions by 20-25% compare to gasoline because simple chemical structures of natural gas (primarily methane – $CH_4$) contain one Carbon compare to diesel ($C_{15}H_{32}$) and gasoline ($C_8H_{18}$). The use of natural gas as a vehicle fuel is claimed to provide several benefits to engine components and effectively reduce maintenance requirements. It does not mix with or dilute the lubricating oil and will not cause deposits in combustion chambers and on spark plugs to the extent that the use of petrol does, thereby generally extending the piston ring and spark plug life. In diesel dual-fuel operation evidence of reduced engine wear is reported, leading to expected longer engine life. The use of natural gas in a diesel spark-ignition (SI) conversion is expected to allow engine life at least as good as that of the original diesel engine. Because of its very low energy density at atmospheric pressure and room temperature, natural gas must be compressed and stored on the vehicle at high pressure - typically 20 MPa. The alternative storage method is in liquid form at a temperature of -162°C. Because of the limited capacity of most on-board CNG storage systems a typical gas-fuelled vehicle will need refuelling two to three times as often as a similar petrol or diesel-fuelled vehicle - a typical CNG-fuelled car engine will provide a range of 150-200 km and a truck or bus some 300-400 km. It is possible that the space required and weight of CNG fuel storage systems will fall in the future as a result of improved engine efficiencies as with dedicated designs and light weight storage tanks.

**HYDROGEN**

The use of hydrogen as fuel in the internal combustion engine represents an alternate use to replace the hydro carbon fuels, which produces polluting gases such as CO, HC during combustion. Hydrogen is a long term renewable and less polluting fuel. Hydrogen is clean burning characteristics and better performance drives more interest in hydrogen as fuel. Hydrogen produces only water after combustion. It is non-toxic, non-odorant gaseous matter .when hydrogen is burned, hydrogen combustion does not produce toxic products such as hydrocarbon, carbon monoxide etc. except only the formation of nitrogen monoxide.
Since pure hydrogen does not occur naturally on earth. But the hydrogen found on earth in abundant in the form of compound like water and other chemical like hydrogen peroxide etc.

Hydrogen is extracted from electrolysis and steam-methane reforming. in electrolysis , electricity is run through water to separate hydrogen and oxygen atom and obtaining hydrogen from this process is being suited as a viable way to produce it domestically at low cost . The energy can be delivered to fuel cells and generate electricity and heat or burned to run a combustion engine. Hydrogen after burning emits water and warm air. Hydrogen has the highest energy content by weight of any fuel but its energy content by volume is

low. This fuel property makes strong challenge because it requires high pressure, low temperature or chemical processes to be stored in small spaces.

**Combustive Properties of Hydrogen**

There are several important characteristics of hydrogen that greatly influence the technological development of hydrogen internal combustion engine.

- **Wide range of flammability**

Compared to nearly all other fuels, hydrogen has a wide flammability range (4-75% versus 1.4-7.6% volume in air for gasoline). This first leads to obvious concerns over the safe handling of hydrogen. But, it also implies that a wide range of fuel-air mixtures, including a lean mix of fuel to air, or, in other words, a fuel-air mix in which the amount of fuel is less than the stoichiometric, or chemically ideal, amount. Running an engine on a lean mix generally allows for greater fuel economy due to a more complete combustion of the fuel. In addition, it also allows for a lower combustion temperature, lowering emissions of criteria pollutants such as nitrous oxides ($NO_x$) [3].

- **Low density**

The most important implication of hydrogen's low density is that without significant compression or conversion of hydrogen to a liquid, a very large volume may be necessary to store enough hydrogen to provide an adequate driving range [3].

- **Small quenching distance**

Hydrogen has a small quenching distance (0.6 mm for hydrogen versus 2.0 mm for gasoline), which refers to the distance from the internal cylinder wall where the combustion flame extinguishes. This implies that it is more difficult to quench a hydrogen flame than the flame of most other fuels, which can increase backfire since the flame from a hydrogen-air mixture more readily passes a nearly closed intake valve, than a hydrocarbon-air flame [3].

- **Flame velocity and adiabatic flame**

Hydrogen burns with a high flame speed, allowing for hydrogen engines to more closely approach the thermodynamically ideal engine cycle (most efficient fuel power ratio) when the stoichiometric fuel mix is used. However, when the engine is running lean to improve fuel economy, flame speed slows significantly
Flame velocity and adiabatic flame temperature are important properties for engine operation and control, in particular thermal efficiency, combustion stability and emissions. Laminar flame velocity and flame temperature, plotted as a function of equivalence ratio [3].

- **Minimum ignition source energy**

The minimum ignition source energy is the minimum energy required to ignite a fuel-air mix by an ignition source such as a spark discharge. For a hydrogen and air mix it is about an order of magnitude lower than that of a petrol-air mix 0.02 MJ as compared to 0.24 MJ for petrol - and is approximately constant over the range of flammability [3].

| Property | BIO-DIESEL | CNG | ETHANOL | HYDROGEN | Petrol | Diesel |
|---|---|---|---|---|---|---|
| Cetane number/OCTANE NUMBER | 51.34 | 120 | 8 | 13/130 | 95 | 45-50 |
| STOICHIOMETRIC RATIO | 13.5 | 17.2 | 9 | 34.3 | 14 | 14.6 |
| MOLECULAR WEIGHT | 292.2 | 16 | 46 | 2 | 114 | 200 |
| AUTO IGNITOON TEMPERATURE °C | 316 | 540 | 363 | 858 | 357 | 257 |
| COMPRESSION RATIO | 18:1 | 12:1 | 16:1 | 11:1 | 9:1 | 15:1 |
| HHV (MJ/KG) | 40.56 | 49 | 29.847 | 142.18 | 46.536 | 45.576 |
| LHV(MJ/KG) | 36.96 | 45.9 | 26.952 | 120.21 | 43.4 | 42.6 |
| CARBON% | 94 | 75 | 52.2 | - | 80-85 | |

**Table1: Properties of different alternate fuels.**

## CONCLUSION

Based on the reviewed papers for the different property and emission of different fuels, it is concluded that hydrogen will be the best alternative fuel for the future aspect. But at present CNG is the best alternative for the conventional fuel because it does not have production and storage problem as we face in the hydrogen. It has higher volumetric, mechanical efficiency as compared to the petrol/ diesel. On average the reduction of CO, $CO_2$ and HC emission are 20-98%, 8-20% and 40-87% Respectively by CNG. Higher $NO_x$ emission is the main emission concern for CNG as automotive fuel that can be reduced by increasing fuel density and blending small quantities of hydrogen [4].

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