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Recent Trends in Alternative Fuels – (A Review)

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Abstract – Internal combustion engines are widely used worldwide for transportation, shaft energy production, marine applications etc. The conventional fuels used in these engines such as diesel and gasoline have quantity limitations due to finite reservoirs. As I C Engines have prominent applications everywhere in the world, the need of future is to find out alternative fuels. Along with the problem of depletion, conventional fuels cause environmental pollution due to emissions as exhaust gases. Many alternative fuels have been discovered which can replace these conventional fuels. As a future trend, alternative fuels are supposed to be used in engines with certain modifications. But the effects of these renewable or, alternative fuels on pollution must be checked. This article aims to compare effects of various alternative fuels on engine emission including Hydrogen, Di Methyl Ether (DME) and Biodiesels from Karanja, Jatropha and Rapeseed oil. The results presented in this paper will show particulate matter (PM) emissions have decreased significantly with the increase of alternative fuels. The emission level varied depending on the type alternative fuels used and the engine conditions.

Keywords— Alternative fuels, Emission, Biodiesel, DME, I C Engines

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1. INTRODUCTION

The pollution in urban area is significant because of use of internal combustion engines. In particular, vehicles equipped with Compression Ignition (CI) engines are widely used because of their higher performance and fuel efficiency with respect to the Spark-Ignition (SI) engines. Now days, the production of diesel engines has increased that consume more diesel. Due to consumption of these fuels air pollution has increased. The pollutants like Nitrogen Oxides (NOx), Hydro Carbon (HC), Carbon Monoxide (CO) emissions and PM are found in the atmosphere. However approximately 30% of the world's greenhouse gas emissions are produced from the transportation sector, leading to global warming [1]. The use of these conventional fuels is increasing day by day but as their reservoirs are very limited, alternative fuels like Ethanol, Bio-diesel, DME, Natural gas, Hydrogen are becoming need of the hour. This review articles aims for a comparative study of emission characteristics of the fuels (Karanja and Jatropha Biodiesel, Rapeseed oil, DME and hydrogen) when blended with conventional fuels, used in engines [1], [2],[3],[4][5]. The engines using these alternative fuels with or without blends require certain modification [1].

A. World's scenario of emission

Majority of the energy used today is obtained from fossil fuels. During last decade, energy consumption has largely gone up due to developments in technology, increase in population. The global consumption of energy in terms of fuels is increasing thus, the emission level also is found more. G20 countries were responsible for 81.5 % CO_2 emissions in 2015.

B. India's scenario of emission

According to Survey of energy demand 2001, India ranks sixth in the world in terms of energy demand. The energy demand is expected to grow at 4.8%. The demand for diesel is projected to grow 5.5% per annum [3]. India as a developing country, contributes high in energy consumption.

C. Need of alternative fuels

Conventional diesel engine which uses diesel as a fuel has hazardous effects on human health. It has dangerous emission like unburnt carbon compound, CO, CO_2, NOx, Sulphur compounds, polycyclic aromatic compounds etc. CO_2 is one of the greenhouse gases producing dangerous effects. Unburnt carbon compounds become lung and eye irritants and can cause lung cancer. Nitrogen dioxide reduces plant growth and sulphur affects respiratory system. Carbon monoxide reduces oxygen carrying capacity of blood.

Further increasing prices of conventional fuels is the major reason for searching of alternative fuels. The reservoirs of conventional fuels are limited. They would exist for next 50 to 70 years. This is the reasons for search for alternative fuels.

Types of alternative fuels:

1. Compressed Natural Gas (CNG)
2. Liquefied Natural Gas (LNG)
3. Liquefied Petroleum Gas (LPG)
4. Methanol (M85)
5. Ethanol (E85)
6. Biodiesel (B20)
7. Hydrogen
8. Electricity

2. DEVELOPMENTS IN ALTERNATIVE FUELS

Various researchers have been taking efforts on studying the emissions from engines using alternative fuels like natural gas, Hydrogen, Bio-diesel, Dimethyl ether (DME). Silvana Di Iorio et al. [6] had studied the impact of biofuels on performance and emission of CI and SI engines. In this study they have experimentally analysed the in-cylinder pressure, various emission contents from exhaust of cylinder of engines using gasoline, diesel and blend of biofuel (ethanol in SI engines and Rapeseed methyl ester in CI engines) with them. The soot formation was observed with optical measurements for better analysis. For SI engines, appreciable effect of ethanol addition on combustion behaviour was not observed. For CI engine, RME fuelling resulted in more advanced combustion only at high engine speed.

Su Han Park et al. [5] had evaluated the combustion performance and emission characteristics of DME engine system. In this review article, the spray, atomization, combustion and exhaust emissions characteristics from a DME-fuelled engine are described. This article also describes various technologies to reduce NOx emission from DME-fuelled engines, such as multiple injection strategy and premixed combustion. Baste Shrikant et al. [3] had studied the emission and vibration characteristics of Pongamia Pinnata (Karanja) Biodiesel and its blending in C.I. Engines. In this experimental study, Vibrations analysis was done for various blends of Karanja Biodiesel with diesel at various stages of gearbox. It was observed that CO emission increases for low load conditions but starts decreasing for higher loads. Peng Geng et al. [1] comparatively studied various alternative fuels including ethanol, DME, biodiesel and natural gas. In this review paper the best option suggested is DME which offers a longer injection delay, lower maximum cylinder pressure, lower pressure rise ratio and shorter ignition delay.

Venkateswarlu Chintala et al. [4] had evaluated utilization of hydrogen in a compression ignition engine under dual fuel mode. Hydrogen as alternative fuel decreases HC, CO and smoke to zero level. But hydrogen causes high level of NOx emissions. Avinash Kumar Agarwal et al. [7] studied Spray evolution, engine performance, emissions and combustion characterization of Karanja biodiesel fuelled common rail turbocharged direct injection transportation engine. The brake-specific carbon monoxide and carbon dioxide emissions were found decreased with increasing brake mean effective pressure. It showed increasing trend with increasing engine speeds.

P. Mohamed Shameer et al. [8] had studied a comparative analysis of various biodiesel and their emission characteristics. It has been concluded that the biodiesel production from various feed stocks have an immense significance as a substitute power source for diesel. The emission characteristics of the compression ignition engine fuelled with biodiesel can be enhanced to an eco-friendly rank by advancing the injection timing and increasing injection pressure to an extent based on the biodiesel properties.

3. PROPERTIES OF ALTERNATIVE FUELS

Table I Properties of various alternative fuels used for comparison.

Fuel property	Diesel	Karanja oil (K100)	Jatropha oil (J100)
Specific gravity	0.84	0.860	0.832
Density (kg/m^3)	840	860	832
API Gravity	40.24	29.3	-
Water content (%)	0.070	NA	NA
Carbon residue (%)	0.080	0.530	
Flash point (^oC)	66	128	67
Pour point (^oC)	15	7	-4
Fire point (^oC)	72	134	70
CalorificValue(kJ/Kg	44000	37700	38600
Viscosity (cst)	4.2	28.14	2.65
Cetane number	48	49	49

Stoichiometric AFR	14.45	12.7	13

Table II Properties of Diesel and DME

Fuel property	Diesel	Karanja oil (K100)
Density (kg/m^3)	667	832
Viscosity (cst)	3	<0.1
Cetane number	48	>55
Auto-ignition temperature(^{0}C)	523	508
Stoichiometric AFR	14.6	9
LHV (MJ/kg)	42.5	27.6
Boiling point (^{0}C)	450-643	248.1

4. NOMENCLATURE

DME	Dimethyl ether	LHV	Lower Heating Value
CO	Carbon monoxide	CI	Compression ignition
CO2	Carbon dioxide	PAH	Polycyclic Aromatic Hydrocarbon
HC	Hydrocarbon	EGR	Exhaust Gas Recirculation
PM	Particulate matter	LPG	Liquefied Petroleum Gas
NOx	Oxides of Nitrogen	RME	Rapeseed Methyl Ester

5. ENGINE EMISSIONS

Various researchers have studied the emission from use of biodiesels in CI Engines. In this paper, comparative study of various biodiesels has been done. The emissions like CO, HC, NOx, and PM from these biodiesels when used in engines show some specific characteristics.

A. Karanja Biodiesel

The research paper [3] showed, for biodiesel (B10) and biodiesel (B20) CO emission increases for 20% load but, gradually decreases as load increases. The CO emission reaches to 54.7%, for biodiesel blend (B50). For biodiesel, (B100) the CO emission decreases as compared to diesel engines. As per Euro V norms [9] and Bharat stage IV norms [10], the CO emission must be in the 35-60% of exhaust. Hence, this biodiesel can be used in CI engines. It does not alter the engine performance for greater extent. Another research paper [7] shows that, at higher engine speeds, the fuel consumption increases and the CO2 emission also increases.

Table III Experimental results of variation in CO emission for Karanja Biodiesel. [3]

CO (%) LOAD (%)	Diesel	B10	B20	B50	B100
0	91.5	78.9	88.1	88.7	91
25	81.8	96.2	94.9	57.2	93.4
50	94.4	75.45	75.05	53.1	85.5
100	59.4	54.7	55.2	55.3	76.7

Limitations of Karanja oil have been observed as follows:

- Higher viscosity of oil causes problem in fuel injection.
- Collection of Karanja seed is a manual operation and hence requires more time.
- Problem of carbon deposits and oil ring sticking can be found on prolonged use.

B. Jatropha Biodiesel

Jatropha Biodiesel is produced from seeds of Jatropha Plant. Faizan [11] showed vibration and noise analysis of Jatropha oil in CI Engine. Noise is minimum for B100 blend (100% Jatropha oil) which was recorded as 85.8 dB at 0 kg load. The maximum noise reduction was recorded as 2.7 dB (approximately 3 %). Tan [2] evaluated different emissions in the experimentation and the HC emissions were observed to have continuously reducing trend with increasing biodiesel blend ratios. The reactions forming NOx are highly temperature dependent, so the NOx emissions have a close relation with the engine load. The NOx emission tends to increase with engine load. The CO emissions of different blends continuously decrease with increasing engine load but don't show consistent results with increasing biodiesel blends.

The smoke emissions showed a continuous decreasing trend with increasing biodiesel blends for the same engine operating conditions. Other emissions like Formaldehyde, Acetaldehyde also showed decreasing trend with increase in engine load. Limitations of Jatropha are observed:

- Similar to Karanja oil, Jatropha oil also, has greater viscosity than diesel.
- Collection of seed and production of Jatropha oil is time consuming.

C. Rapeseed oil

The rapeseed oil is chemically known as Rapeseed Methyl Ester (RME). The compound is made by trans-esterification process [6]. The larger oxygen content of these biodiesels, results in reduced HC and CO emissions. The NOx emission does not show a special trend in case of biodiesels. But it was observed in experimentation, that NOx emission had increased for lower engine speeds. The NOx emission was observed less for higher engine speed. Rapeseed biodiesel is effective in reducing particle mass concentration because of both larger oxygen content and lower aromatic compound. It is less toxic to human body when compared to conventional diesel engine.

The soot formation does not have any significant variation on engine performance. The conventional diesel engine and RME showed same trend of soot formation. Use of pure RME in engines resulted in significant reduction in particle emissions.

Limitations of RME

- Compared to conventional diesel fuel, RME has low heating value.
- As load increases, the consumption of RME biodiesel increases to fulfil the lad condition.

D. Dimethyl ether

DME has different properties than conventional diesel. It shows quick evaporation and better atomisation characteristics. Unlike biodiesel, DME has low viscosity and lubrication. It has high Cetane number and high oxygen content which gives better combustion properties. Due to faster ignition of DME, charge temperature attained is higher. The higher temperature increases NOx formation. The slightly high NOx emission during DME combustion can be remarkably reduced by the application of EGR.

HC emission from DME is lower than or sometimes equal to diesel engines. The combustion efficiency of DME is greater hence; the unburnt carbon is less in exhaust [5]. DME has good mixing characteristics, hence tendency of formation of homogeneous mixture was observed. The tendency of complete combustion was observed and the quantity of CO emission was reduced.

The oxygen content in DME is found to be more. There is no chance of incomplete combustion. Soot formation in DME-fuelled engine is almost zero.

Limitations of DME

- Lower heating value than diesel engine.
- Engine performance is found to be less than diesel engine due to low heat content. Therefore there is chance of improvement in engine performance by adding some additives or blends in DME.

E. Hydrogen gas

Hydrogen is a carbon free fuel. It's utilization in IC engines leads to zero carbon based emissions such as CO, CO_2, HC and smoke/soot/PM [4]. Hydrogen has highest heat content per unit mass among all fuels. It has many advantageous properties such as high flame speed, short quenching distance and high diffusivity. PM emission could be reduced significantly along with thermal efficiency improvement using hydrogen in the engines under dual fuel mode (diesel-hydrogen). In hydrogen dual fuel engines, other emissions including HC, CO and smoke decrease to near zero level whereas greenhouse gas emissions CO_2 and CH_4 from CI engines decrease substantially. In addition to this, NOx emission in the engine under dual fuel mode is higher (about 29–58%) than conventional diesel mode due to high localized in-cylinder temperature.

In hydrogen based dual-fuel engines with increasing hydrogen energy share, the NOx emission increases at high and medium loads while decreases at low loads. Smoke emission in CI engines is mainly caused due to heterogeneous air-fuel mixture and it decreases significantly with increase in degree of homogeneity in air-fuel mixture.

Limitations of hydrogen fuel:

- High levels of NOx emission due to high temperature in the cylinder during combustion.
- Knocking at high amount of hydrogen substitution due to pre-combustion.
- A limited hydrogen energy share (6-25%).

6. CONCLUSIONS

From different literatures and overview of conclusions, it is found that alternative fuels are better than conventional diesel fuel from emission point of view. It is also observed that these alternative fuels may be used as regular fuel in future to overcome the shortage of conventional diesel fuel. It is found the NOx emission for alternative fuels decreases as engine speed increases except Hydrogen fuel. It is suggested that some or little modifications may be carried out to reduce the problems in engine due to higher viscosity. It is also suggested that all alternative fuels may be used as conventional fuel to reduce harmful effects on human being, animals and plants.

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