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Prominence of Bio-Fuels as an Alternate Fuel in CI Engines

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Abstract: ***CI engine have always been the primary choice for on-road, agriculture and industrial applications. On-road operations are dominated by CI engines because of their better efficiency, fuel availability and fuel economy. Worldwide, nearly 14% of greenhouse gas emissions are releasing from the world's highest energy demanding sector, transportation. The day-by-day increase in diesel engine's use associated with the aspiration of underdeveloped or developing countries to improve their economic status has led to increase the demand for diesel fuel supply, which is causing running out of fossil fuel very shortly. The increasing fuel usage will increase the level of air pollutants in the atmosphere, which are threatening the environment and human health. Fossil fuel depletion and harmful exhaust gas emissions has created an intensive interest for the development of renewable alternative fuel. Since last three decades, researchers are showing interest to develop an alternative fuel from biomass-based feed stock. Fuels developed from biomass-based feed stock are referred as biofuels. These biofuels can be categorized into bio-alcohols and biodiesel, which are more suitable to use as an alternate fuel for SI and CI engines because of their high octane and cetane numbers respectively. This paper presents the exhaustive review of literature on testing of different renewable alternative biofuels under different testing conditions in CI engine to replace petroleum diesel and to have effective control over the harmful exhaust emissions. This paper also gives insight of recent trends in development of fourth generation biofuels based on photobiological solar fuels and electro fuels, which can be a more promising alternate fuel in the field of biofuels.***

Keywords: CI Engine, Biofuel, Engine Performance, Engine Emissions.

I. INTRODUCTION

The huge increase in human population have increased the energy demands. The fossil fuel cannot supplement the energy demands in the near future, as consumption of fossil fuel is much more times greater than the nature can provide [1]. Diesel engines are very efficient power plants, which can convert the fuel energy in to mechanical power most efficiently. Because of their better efficiency, fuel economy, superior torque, longer durability and low maintenance cost CI engines have become the primary engine for on-road, agriculture and industrial applications. Diesel engines play an important role in public and private on-road applications (transportation) and their use will increase in the future. Besides their fuel economy advantage, diesel engines emit extremely low concentrations of unburned hydrocarbons and carbon monoxide emissions compared to spark ignition engines, because diesel engine operates at very lean air/fuel mixture [2].

The day-by-day increase in diesel engine's use associated with the aspiration of underdeveloped or developing countries to improve their economic status has led to increase the demand for diesel fuel supply, which will be responsible for the fossil fuel shortage in the near future. The increasing usage of diesel fuel for energy supply is releasing more pollutants to the atmosphere which are threatening human health and the environment. Even though diesel engines emit less pollutants compared to SI engines, the increase in usage of diesel engines increasing the pollutants released to the atmosphere. Worldwide around 14% of greenhouse gas emissions are releasing from world's highest energy demanding sector, transportation. Transport sector is the major source of urban air pollution. The fossil fuel depletion, day by day increasing demand for fuel supply, cost of crude oil and necessity for reduction in the harmful exhaust gas emissions leads us to develop an alternate fuel for petroleum-diesel and should have effective control over the pollutants emitted to the atmosphere. Controlling the emissions in CI engine can be achieved by advancements in the engine technology and also the implementation of alternative fuels. This paper presents the review of literature on testing of different renewable alternative biofuels and issues created by biofuels under different testing conditions in CI engine to replace petroleum diesel and their effective control over the harmful exhaust emissions.

II. TYPES OF ALTERNATIVE FUELS

The day by day improvement in fuel economy of engines and enormous increase in number of vehicles has increased the demand for fuel and in the near future the petroleum-based fuels will become most costly and very scarce. A research interest in the area of alternative fuel technology is developed due to the increased use and depletion of fossil fuel. Alternative fuels mainly classified into three groups, viz. solid, liquid, gaseous.

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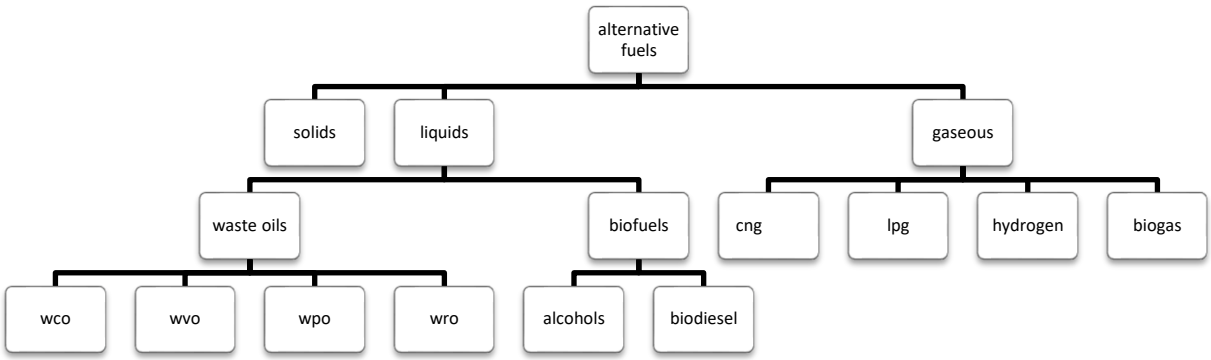

Fig. 1.1: Alternate Fuels for IC Engines

Since the last two decades biomass derived fuels (biofuels) has gained interest as alternative liquid fuels to substitute petroleum-based fuel. Bioethanol and biodiesel are two major types of biofuels have used as a substitution for gasoline and diesel because of their high-octane number and high cetane number respectively. The current research is mainly interested in developing an alternative liquid fuel (biodiesel) which should be renewable in nature and economically viable as transportation fuel without affecting the feed and food demand.

According to the FAO (Food and Agriculture Organization of the united nations), biofuels are "fuels generated from biomass feedstock such as wood, bio-alcohol, biodiesel, bio-hydrogen, syngas". The main reasons to develop biofuels to substitute the petroleum based fuels are they derived from renewable sources, they can reduce GHG emissions, can create employment, will helps in rural development and helps to maintain air quality as feedstocks will absorb [3], [4]. In countries like India in which most of the land used for agriculture and good water availability, fuels like biodiesel and bio alcohol can be best alternative fuels [5]. With respect to their feedstock, biofuels are categorized in to different groups such as first generation (food crops), second generation (non-food and discarded biomass from food crops), third generation (aquatic cultivated) and fourth generation (advanced) biofuels [6]. Among four generation biofuels third and fourth generation biofuels are gaining more interest for alternative fuel production for the energy demanding sector to the future years. The main advantages of aquatic crops over the first- and second-generation feedstocks are they are potentially faster in growth, no need for arable land and fresh water resources like terrestrial plants. Aquatic crops are an economical choice for biofuel production because of its availability, low-cost, easy cultivation and its ability to fixing the CO_2 from the atmosphere.

Table 1.1: Biofuel classification with respect to feedstock.

Generation	Feedstock	Examples of Feedstocks	Fuels can be produced
First	Food crops	Palm, soya bean, sunflower, castor etc.,	biodiesel, bioethanol, biobutanol
Second	Non-food and lignocellulosic biomass	Jatropha, Karanja, Jajoba etc.,	biodiesel, bioethanol, biobutanol and syngas
Third	Aquatic crops	Algae, cyanobacteria, diatoms	biodiesel, bioethanol, biobutanol, syngas as well as biohydrogen and methane
Fourth	Modified (high yield) 2nd and 3rd generation feedstocks	-	Bio-hydrogen and carbon-based fuels

1.1 Key issues associated with first- and second-generation biofuels

Fuels produced from food crops are called as first-generation biofuels, require huge arable land and water resources to produce required amount of fuel to replace petroleum-based fuel. Biofuel's expansion resulting in food and fuel competition and environmental degradation [7].

In case of second-generation biofuels, the land usage for cultivation of lignocellulosic crops compete with land required for human food production. Non-food and discarded biomass from food crops are generally used as animal feed, however reveals a more complex story [8].

1.2 Third generation biofuel

The liquid fuels produced from aquatic cultivated biomass (algae) are called as third generation biofuels. Algae oil has a similar fatty acids profile like edible and non-edible oil which are produced from first and second-generation biofuels [9]. Social, economic, environment degradation and sustainability issues associated with 1st and 2nd generation biofuels has shifted the interest of research to 3rd generation biofuels as they are not competitive with land and water resources [10].

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Algae oil production is not yet commercialized because many of the algal species are not suitable for industrial level cultivation and chemical composition of every microalgal lipid may not suitable to produce biofuel. To accumulate lipids in cell optimal stress conditions are needed causing a strong limitation of biomass productivity [11] . Based on literature survey algae can able to produce 30 to 100 times more energy than the terrestrial crops [6]. The fuels derived from microalgae seems to be very promising and sustainable alternate fuel due to its greater oil production per unit mass, consumes more CO_2, does not require fresh aqua resources as it can grow in any type of water and require very less land area [1], [12]. Intensive research efforts are needed in third generation biofuel field because we have not yet recognised one algal strain which can be called as algal crop for biofuel production effectively [13]. Increasing lipid content without compromising in growth rate has achieved by recent advancement in metabolic engineering of algae and it is an achievement in developing a sustainable fuel [14].

1.3 Fourth generation biofuels:

The fuels which are produced by conversion of solar energy into fuel directly without a biomass phase using raw materials which are widely available and renewable in nature are called as fourth-generation biofuels. This fuels also called as advanced biofuels and drop in fuels which are expected to be more promising alternate fuels in the field of biofuels [15]. Synthetic biology techniques are needed for the production of advanced biofuels to replace all fossil fuels in energy demand sector. Synthetic biology comprises the design and construction of new biological parts, devices and systems, and the re-designing, altering the existing natural biological systems as per the requirement.

1.4 Testing of biofuels in CI engine:

The alternate biofuel should mimic the physicochemical properties of standard petroleum derived fuel, because those properties will effec the combustion, performance and pollutant formation of engine [16]. Biofuels are oxygenated fuels which can enhance the combustion and increases the CO_2 emissions i.e reducing the CO emissions. Beyond improving the combustion efficiency biofuels contains higher nitrogen as compared to standard diesel which increases the NO_x emissions in exhaust [17], [18]. Usage of biofuels can neglect the SO_x emissions and emit very less PM as they contain negligible aromatic compounds and sulphur. Most of the researchers have pointed that esterified vegetable oil can be a most efficient alternative fuel for existing engines. As discussed about the dominance of diesel engine, most of the researchers investigated the effect of different parameters of diesel engine when biodiesel or biodiesel blends are used as fuel. The major advantage of biodiesel is it can directly use as a fuel for internal combustion engine without any engine modifications. As existing diesel engines are developed on the basis of diesel fuel properties, the physiochemical properties of biodiesel should be similar to standard diesel fuel properties. Following table shows the similarity between standard diesel and different biodiesels derived from different biomass feedstocks.

III. RESULTSANDDISCUSSIONS

Table 1.2 Fuel properties of different biodiesel

Fuel	Cetane number	Flash point (°C)	Cloud point (°C)	Reference number
Standard diesel	45–55	50–98	−10 to −5	[19]
Palm oil	52	181	15	[20]
Jatropha	46–55	162	10	[20]
Algae oil	58	176	-1	[21]

IV. KEY ISSUES WITH BIODIESEL IN CI ENGINES

The issues which are associated with the use of biodiesel in CI engines are high fuel consumption, oxidation instability of fuel and increase in NO_x emissions. The high fuel consumption is because of low heating value of biodiesel to produce same amount of power as fossil fuel [22]. The Oxidation instability of fuel is due to the presence of unsaturated fatty chains. When biodiesel exposed to air the double bonds present in unsaturated fatty chains will react with oxygen and becomes acidic in nature. The problems raised due to oxidation of biodiesel can be solved by modifying the fatty chain and by adding some kinds of anti-oxidants to the fuel [23]. The higher content of nitrogen in biofuel is a cause of high NO_x emissions, which can be reduced by exhaust gas treatment devices [24], fuel adulterations [25] and internal engine modifications [26].

V. CURRENT STATUS AND FURTHER SCOPE

According to the energy consumption rate transportation sector is consuming nearly 30% of the total energy produced from fossil fuels and releasing 14% of total GHG emissions in to the atmosphere [27]. Presently the demand for liquid fuel supply to the transportation sector is around half of the of total liquid fuel demand and this sector is developing very fast which consequently increases the energy demand. As per EASAC report (2012) first generation biofuels are creating threat to the food, agriculture and natural ecosystems with providing little or no reduction in greenhouse gas emissions from energy demand sector. The EASAC report (2012) advised a systematic research

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to develop biofuel from inedible parts of plants without effecting the animal feed and development in lipid content of Aqua crops for third generation biofuels to increase the production rate. The fourth-generation biofuels (solar fuels) deal with the photosynthetic microorganisms which are developed by an advanced biology and engineering has a history of over 10 years.

As in transportation sector CI engines consume a major portion of the fossil fuel, developing an alternative fuel to replace fossil fuel from biomass based renewable sources became an immediate solution for fossil fuel depletion. Different antioxidants can add to biofuel to increase the oxidation stability. By using different techniques and fuel alterations NO_x emission can be reduced. Very innovation research is required for improvement in second generation biofuel production like algal biomass which is having higher photon to biomass conversion efficiency. In case of third generation biofuels recognizing an algal strain, which can call as algal crop for biofuel production. Developing a high yield and cost-effective harvesting technology and oil extraction technology for biofuel production from algae. In near future the development of engine should takes place in the direction of more efficient and clean combustion engines. Oil industries should develop a biofuel which should decrease the fuel consumption to reach the increasing energy demand for petroleum-based fuels [28].

VI. CONCLUSIONS

After the exhaustive review of literature, it has concluded that the biofuels are being and would be used widely in the energy demand sector to attain a sustainable environment in the near future. Third generation biofuels can replace the fossil fuels because of their higher oil productivity and they can fix the GHG emissions effectively. The fourth-generation biofuels and its techniques to create fuel can make the production of biodiesel cheaper and sustainable.

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