Alternative Fuels a Sustainable Solution for Gas Turbine: An Overview

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***Abstract*—**The crude oil prices are increasing immensely as the fossil fuels are depleting, bio-diesel has emerged as an alternative fuel for the petroleum. In this context the use of bio-diesel in the gas turbine seems a solution for power generation problems and their environmental concerns. Vegetable oils, due to their agricultural origin, are able to reduce net carbon dioxide emissions to the atmosphere. However, there are several operational and durability problems which may arise in using straight vegetable oils, which are because of their higher viscosity and low volatility compared to mineral diesel fuel. Bio-diesel is an alternative fuel which has environmental benefits and they are renewable in nature. It can be blended in any proportion with mineral diesel. Sufficient literature is available on performance and emission tests on reciprocating diesel engines with bio diesel as a fuel but there is limited information on its use in gas turbine engines. The use of bio-diesel for reduction in emissions of unburned hydrocarbons, carbon monoxide and particulate without reducing the output power significantly is encouraging. But there is very less information available about bio-diesel utilization in gas turbine. The use of bio-diesel to fuel gas turbine seems a sustainable solution for the problems of escalating crude oil prices and its diminishing supplies due to depletion of fossil fuel, as they are made from renewable sources.

***Keywords*—** *Bio-diesel, Vegetable oils, alternative fuel, gas turbine, emissions, fossil fuel.*

I. INTRODUCTION

In this global scenario, the combustion of biomass or biofuels as an alternative to fossil fuels for electrical power generation has become an active area of research in recent years. Worldwide petroleum reserves are expected to exhaust in less than 50 years at the present rate of consumption. In this scenario, bio-fuels have emerged as an alternative source of energy and offer other benefits including sustainability, reduction of greenhouse gas emissions, rural development and security of supply. The concerns of environmental impacts and energy security have led the R&D of alternative energy sources such as biofuels, solar and wind energy. World oil crisis of 1971 has changed the approach of many developing countries towards energy. Last two decades saw special considerations for vegetable oil as a alternative sources of fuel. Biofuels have attracted huge attention in different countries due to their renewability and environmental benefits. Biofuels include bio-alcohols, biodiesel, biomass and other biomass derived fuels. Biodiesel is one of the most popular biofuels being used in the transport sector[1]. Biodiesel can be one of the alternative renewable energy sources for gas turbine. At present bio-energy use covers 9–14% of the global demand, most of which is traditional and inefficient like in cooking and heating specifically in developing countries. Different global energy studies indicate that in India biomass may contribute up to 30% of the energy supply by 2100 [2].

A. Global and Indian scenario

India is one among the largest petroleum consuming nations with its current yearly consumption of diesel oil touching 40 million tones which is about 40% of the total petroleum product consumption. India and all developing countries of the world need to explore this area with conviction in a planned manner. A dangerous effect of burning fuel emissions on environment is a fact which cannot be left in the research [3]. Gas turbine and Internal Combustion engines running on diesel are a major contributor to air pollution especially within cities and along urban traffic routes. Global bio-fuel production has tripled from 4.8 billion gallons in 2000 to about 16.0 billion in 2007, but still accounts for less than 3 percent of the global transportation fuel supply. About 90 percent of production is concentrated in the United States, Brazil, and the European Union (EU). Bio-fuel production is growing roughly 15 percent per year. Under mounting pressure to improve domestic energy security and combat global climate change, countries are now turning to ethanol and bio-diesel to meet rising transportation fuel demands. In 2005, the U.S. pledged to nearly double ethanol production by 2012, and the European Community recently announced that bio-fuels will meet 10 percent of their transportation fuel needs by 2020. In the year 2004 – 2005, India imported 75 % of crude oil from other countries to meet the energy requirements. The demand for diesel and gasoline increased drastically in the year 2008 - 2009. It has been estimated that the demand for diesel will be 66.90 Mt for the year 2011-2012 [4]. India's fuel consumption will be further double in the transport sector by the year 2030.[5] In our country the ratio of diesel to gasoline fuel is 7:1 [6]. This increasing demand of energy and consequent pollution problems and the predicted shortage of petroleum resources have forced us to search the substitute of petroleum derivatives such as biomass, alcohol, vegetable oils, wind, solar and hydrogen etc. Government of India aims to start blending of bio-diesel in diesel to an extent of 20% by 2017. This alternative energy source is also beneficial for environmental improvement and sustainability as it is of plant origins. Substitution of even a small fraction of total consumption by bio-diesel will have a significant impact on the economy, agriculture and the environment [7, 8].

B. Gas turbine alternative fuels

Biofuels have the greatest potential for use in gas turbines are biodiesel and ethanol, due to factors such as availability physical-chemical characteristics similar to fossil fuels such as diesel or jet fuel. Table 1 presents a summary of requirement of liquid fuel as defined by the manufacturers of gas turbines for efficient operations[9] .

TABLE 1. REQUIREMENTS LIQUID FUEL FOR GAS TURBINES

Sr. No.	Properties	Range
1.	Carbon Residue	1.0 % (p.) maximum
2	Dew-Point	20 °C at ambient temperature
3	Hydrogen	11% (p.) maximum
4	Moisture and sediment	1.0 % (v%) maximum
5	Sulfur	1% (p.) maximum
6	Viscosity	20 cS at injector

The gas turbine is a continuous flow engine which develops steady flame during its combustion; this favorable feature allows the use of various fuels and also provides clean combustion in the gas turbine. Therefore the use of different bio-fuels in gas turbine has been investigated by a good number of researchers. The suitability & modifications in the existing gas turbine systems are also reported. Therefore the use of bio-fuels to fuel gas turbine seems a viable solution for the problems of decreasing fossil fuel reserves and environmental concerns. Bio-fuels are alternative fuels, made from renewable sources and having environmental benefit.

Biofuels including biogas, bioethanol and biodiesel have become more attractive recently as they are "carbon neutral", as the plant absorb CO2 emissions while they grow [10, 11, 12] and release it when the biofuel is burned. However, this process is not carbon neutral if carbon emissions are generated in the growing, harvesting and biomass to biofuel manufacturing process. This is known as the sustainability of biofuels i.e. what is the proportion of carbon reduction taking these upstream CO2 generation issues into account. First generation liquid biofuels could have as much as 80% upstream CO2 (Ethanol from corn in the USA for example), but 60% efficiency was typical for biodiesel. The production of biofuels should avoid competition with food production, as the availability of growing crops can be affected by the limitation of the land for food. Biodiesel is one of the best available renewable liquid fuel sources [12, 13].

Some alternative liquid fuels such as vegetable oil, biodiesel or pyrolysis oil, ethanol and methanol are being tested in gas turbines [14]. As biodiesel has similar properties to diesel, it can be used directly in a gas turbine, blended with diesel in various proportions (usually uses 5 to 30% biodiesel in the blend with diesel). The properties of biodiesel are slightly different to those of diesel in terms of energy content or physical properties.

Gas turbine driven co-generation plants using bio-fuels can be located close to energy consumption centres, especially for remote areas of developing countries where grid power is not available. They can produce their own fuel such as biomass derived fuels i.e.- bio-diesel, bio-ethanol, bio-methanol, biogas, synthetic gas (Di-methyl ether) etc. Gas turbines are having large power range, and they are suited with certain modifications in fuel supply systems. Current gas turbine systems though, are capable of burning such fuels, are normally developed for a single specific fuel (such as natural gas or diesel fuel) [15].

1) Vegetable oils

Many researchers have concluded that pure vegetable oils have a great potential to be alternative fuels for diesel engines [16]. However, they cannot be used directly in gas turbines because they can cause numerous engine problems. The higher viscosity and lower volatility of oils compared with diesel lead to engine cold-start problems, engine deposits, injector coking, piston ring sticking, and decreasing the combustion efficiency [17].

Vegetable oils mainly contain triglycerides (90% to 98%) and small amounts of mono- and di-glycerides. Triglycerides contain three fatty acid molecules and a glycerol molecule. They contain significant amounts of oxygen. The fatty acids vary in their carbon chain length and number of double bonds present in their molecular structure. Vegetable oils contain free fatty acids (generally 1–5%), phospholipids, phosphatides, carotenes, tocopherols, sulfur compounds and traces of water. Commonly found fatty acids in vegetable oils are stearic, palmitic, oleic, linoleic and linolenic acid [15].

The problems attributed to high viscosity and poor volatility of straight vegetable oils is due to large molecular weight and bulky molecular structure. Four techniques can be used to reduce the viscosity of vegetable oils; namely heating, dilution/blending, micro-emulsion, and trans-esterification. The main purpose of this process is to lower the viscosity of the fuel, which is the main drawback of the direct use of biodiesel that causes poor combustion [18].

2) Biofuels

The term biofuel refers to liquid or gaseous fuels for the transport sector that are predominantly produced from biomass. Biofuels are produced from raw vegetable seed oils, palm oil, sugar beet, solid biomass, and other biomass-derived fuels. Ethanol, biogas and biodiesel are the main biofuels, and can be used in vehicles (cars, trucks), turbines, and boilers on the whole or blended with fossil fuels.

There are many qualified biofuels in the European Union, including biodiesel (fatty acid methyl ester (FAME)). Its heating value is 30–50% lower than typical coal. Liquid biodiesel is one of the most popular biofuels used in the transport sector.

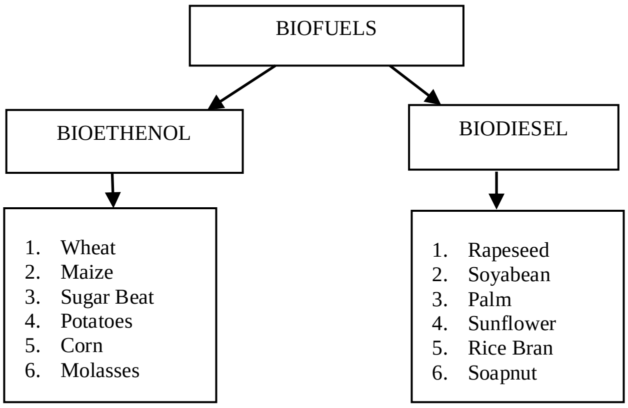

Figure1 Sources of main liquid biofuels

3) Hydrogenated vegetable Oil (HVO)

HVO is obtained by converting unsaturated compounds into saturated compounds through the addition of hydrogen. It is more expensive than BTL production and less expensive than FAME production.

4) Orcryogenic fuels

Orcryogenic fuel refers to a condition where the material in gases faces normal, ambient conditions, has been cooled to its boiling point, and stored as liquid at low temperature, e.g. liquid hydrogen, liquid methane, liquid propane, and liquid ammonia.

5) Bio-ethanol

Ethanol is derived from alcoholic fermentation of sucrose or sugar cane and corn (60-70% starch). It is a well-established and well known technology, generally used for human consumption in the form of beers, wines and spirits [19].

The chemical reactions are the enzymatic hydrolysis of sucrose followed by fermentation of sugar. Invertase enzyme in the yeast catalyzes the hydrolysis of sucrose to convert it into glucose and fructose. Zymase enzyme present in the yeast converts the glucose and the fructose into ethanol.

$$\underset{Sucrose}{C_6H_{22}O_{11}} \rightarrow \underset{Glucose}{C_6H_{12}O_6} + \underset{Fructose}{C_6H_{12}O_6}$$

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

The production process of ethanol from the corn (starch) includes conversion of starch in to D-glucose in the presence of gluco-amylase. Then it is followed by distillation and dehydration to yield anhydrous bio-ethanol.

6) Bio-methanol

Methanol is currently made from natural gas but can also be made using biomass via partial oxidation reactions. Biomass and coal can be considered as a potential fuel for gasification and syngas production followed by methanol synthesis [20]. Most processes require extra/ additional oxygen for the intermediate conversion of the biomass into a synthesis gas (H2+CO). Syngas or biogas is reformed to methanol under high pressure and temperature in presence of catalyst [19].

$$CH_4 + H_2O \rightarrow CO + 3H_2$$
$$CO + 2H_2 \rightarrow CH_3OH$$

Methanol from coal may be a very important source of liquid fuel in the future. The coal is first pulverized and cleaned, then fed to a gasifier bed where it is reacted with oxygen and steam to produce the syngas. Methanol made using synthesis gas (syngas) with H2 and CO in a 2:1 ratio. The syngas was transformed to methanol in a fixed catalyst bed reactor. Coal derived methanol has many preferable properties as free of sulfur and other impurities.

$$CO + 2H_2 \rightarrow CH_3OH$$

Methanol is poisonous and burns with an invisible flame. As the flash points of methanol and ethanol fuels (11 and 130C, respectively) are within normal range of ambient temperatures, it means that any fuel tank containing alcohol fuel will have a flammable atmosphere within it. This is in marked contrast to current hydrocarbon fuels. Therefore, the use of alcohol fuels as direct replacements to petrol or diesel introduces a significant hazard of an explosive mixture being present in the fuel tank [19].

II. BIO-DIESEL IN GAS TURBINE

The characteristics of bio-diesel are close to diesel fuels, and therefore bio-diesel becomes a strong alternative to replace the diesel fuels. The conversion of triglycerides into methyl or ethyl esters through the trans-esterification process reduces the molecular weight to one-third that of the triglyceride reduces the viscosity by a factor of about eight and increases the volatility marginally. Bio-diesel has viscosity close to diesel fuels. These esters contain 10 to 11% oxygen by weight, which may encourage more combustion than hydrocarbon-based diesel fuels. Bio-diesel has lower volumetric heating values (about 12%) than diesel fuels but has a high cetane number and flash point. The high flash point attributes to its lower volatility characteristics [21]. Tan et al [22] have run the gas turbine with bio-diesel derived from waste cooking oil (WCO) and found that it requires less air for stoi-chiometric combustion due to the presence of oxygen in the fuel and such a bio-diesel stand as a potential alternative fuel for power generation application with the good efficiency at blended ratio of 20% bio-diesel and 80% distillate. This has shown the feasibility of using bio-diesel and its blends for gas turbine application. Bio-diesel was produced from waste cooking oil, mainly from palm oil sources. The oil burner was able to fire these blends of fuel without any modification or pretreatment.

Nascimento et al [23] have performed an experiment aim to assess the thermal performance and emissions at full and partial loads of a 30kW diesel micro-turbine engine fed with diesel, bio-diesel and their blends as fuel. The micro-turbine was tested with automotive diesel/castor bio-diesel blends. Castor bio-diesel is the one that presented the highest viscosity. In order to avoid problems regarding the overload of the micro-turbine dosing pump in the fuel system because of the fuel's high viscosity, a pre-heating system was designed to be placed in the bio-diesel reservoir, aiming at reducing its viscosity

Habib et al [24], have determined performance and emissions characteristics of a 30 kW gas turbine engine burning Jet A, soy methyl ester, canola methyl ester, recycled rapeseed methyl ester, hog-fat bio-fuel, and their 50% (volume) blends in Jet A over a range of throttle settings. The performance characteristics, including static thrust, thrust-specific fuel consumption (TSFC), thermal efficiency, and the exhaust concentrations of NO and CO, were studied and compared with those obtained with pure Jet A.

Schmellekamp [25] used was pure rapeseed oil without any additives and the tests performed on a modified Capstone C30 liquid fuel use. The main adaptations were made at the fuel system. From two fuel tanks of diesel and rapeseed oil, a mixture is produced. In a heating section both fuels are heated to a constant level and mixed with a stirrer. Tests started with running the turbine on 100% diesel and the amount of rapeseed oil will be increased by 10% steps to evaluate effects on turbine emissions and efficiency.

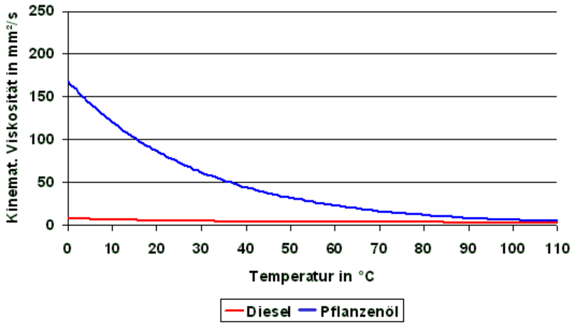

Figure 2: Variation of kinetic viscosity with temperature [25]

It shows that the fuel consumption increases as the blending ratio increases; it may be contributed due to less calorific value of the vegetable oil as compared to diesel fuel. It shows that the CO2 emission for B10 is less than diesel. But for higher blending ratios the CO2 emission is higher than the diesel emission label.

Dunn [26] examines the fuel properties of Bio-Jet fuel blends consisting of 0.10–0.30 vol. fraction Methyl soyate (SME) in JP–8 jet fuels. Testing of cold flow properties indicated that blends with as little as 0.10 vol. fraction SME may limit operation of aircraft to lower altitudes where ambient temperature remains warmer than –29 0 C. Treatment of SME with cold flow improver additives may decrease this limit to –37 0C.

Chiang et al [27] has performed a testing of bio-diesel on a micro-turbine. A 150kW micro-turbine generator set with twin rotating disk regenerators was used. This micro turbine is originally designed as a vehicular micro-turbine engine; the twin rotating ceramic disk regenerators dramatically improve fuel consumption by transferring heat energy from the exhaust gas stream to compressor discharge. They found higher efficiency by using bio-diesel.

III. OTHER BIO-FUELS FOR GAS TURBINE

There is a wide range of bio-fuels which can be use with/without modification in the existing gas turbine. Out of these alternative fuels gaseous and liquid fuels derived from biomass are also studied by different researchers.

Jurado et al [28] have shown that the micro-turbine systems are able to use the bio-gas from biomass, which will be important technologies for electricity production in future. Micro-turbines are the subset of combustion gas turbines being used. It tends to fall in the range of 5 to 500 kW sizes. This power plant generates electric power using biomass from olive trees in Spain. The gasifier is capable of converting tons of wood chips per day into a gaseous fuel that is fed into a micro-turbine.

As per Ganesh [29], pyrolysis is another emerging technology, wherein biomass is converted to liquids, gases and char. Power generation using this technology is essentially the use of pyrolytic oils for the gas turbine integrated into a combined cycle. Using this process has an inherent advantage of potentially decoupling of the fuel-generation from the power-generation site. A comparative study of this technology for power generation, with other technologies is made to determine its economic viability and it is found comparable with the other routes studied.

Rodrigues et al. [30] have performed a performance evaluation of atmospheric biomass integrated gasifier combined cycle systems. This system was operated under different strategies for the use of low calorific fuel in gas turbines. The fuel is a synthetic gas derived from gasification of sugar cane residues. Two analyzed strategies for surge control on gas turbines originally designed for operation on natural gas are de-rating and air extraction from the compressor. Another strategy for use of biomass derived gas is the retrofit of a gas turbine through modification of the expander geometry. It is clear that gas turbine gives higher losses for the output power working under de-rating conditions. This strategy can result in a 30% power reduction for the use of LCV fuels. So the redesign of the gas turbine expander is clearly the best strategy and should be used.

Marcus [31] has experimented wood gas to run a gas turbine and find its suitability with Rover 1S 60 gas turbine.

Figure 3: Tubular Combustor of Rover turbine

IV. EFFECT OF FATTY ACID COMPOSITIONS ON THE PROPERTIES OF BIO-DIESEL

The individual fatty esters in bio-diesel influences on the properties of bio-diesel related to combustion and exhaust emission such as viscosity, lubricity, cetane number, oxidative stability and cold flow properties. Cetane number, heat of combustion, melting point, and viscosity of fatty compounds increase with increasing chain length and decreases with increasing un-saturation. It is therefore possible to enrich certain fatty ester(s) such as Oleic acid in the fuel in order to improve the properties of the fuel. It may be possible in the future to improve the properties of bio-diesel by means of genetic engineering of the parent oils, which could eventually lead to enrich the fuel with certain fatty acid(s) [32].

The fuel properties of bio diesel are strongly influenced by the properties of the individual fatty esters in bio-diesel. The fatty acid and alcohol have considerable influence on fuel properties related to combustion and exhaust emission such as viscosity, lubricity, cetane number, oxidative stability and cold flow properties. Cetane number, heat of combustion, melting point, and viscosity of fatty compounds increase with increasing chain length and decreases with increasing un-saturation. It is therefore possible to enrich certain fatty ester(s) such as Oleic acid in the fuel in order to improve the properties of the fuel. [32].

By altering the fatty acid composition of the feed stocks can play an important role to improve critical properties of the bio-diesel. Since the source of bio-diesel varies with the location and other sources such as recycled oils are continuously gaining interest, it is important to know that how the various fatty acid profiles of different sources can influence bio-diesel fuel properties. The properties of the various individual fatty esters that comprise bio-diesel determine the overall fuel properties of the bio-diesel. In turn, the properties of the various fatty esters are determined by the structural features of the fatty acid and the alcohol molecule that comprise a fatty ester.

So, the important fuel properties of bio-diesel that are influenced by the fatty acid profile and, in turn, by the structural features of the various fatty esters are cetane number, ultimately exhaust emissions, ignition quality, heat of combustion, cold flow, oxidative stability, viscosity, and lubricity.

A. Cetane number

It is a prime indicator of fuel quality. It is related to the ignition delay time and combustion quality. Higher cetane number gives better ignition properties. High cetane numbers help to ensure good cold start properties and to minimize the formation of white smoke. The shorter the ignition delay time, the higher the cetane number and vice versa. The higher the cetane no, the more fuel-efficient, is the fuel. Bio-diesel has a higher cetane number than diesel because of its higher oxygen content.

In bio-diesel, cetane number depends on the feedstock used for its production [33].Cetane number decreases with decreasing chain length and increases branching. Low cetane numbers have been associated with more highly unsaturated components such as the esters of linoleic (C18:2) and linolenic (C18:3) acids. High cetane numbers were observed for esters of saturated fatty acids such as palmitic (C16:0) and stearic (C18:0) acids [32]. Fatty acid esters obtained from branched alcohols have higher cetane numbers than methyl esters.

B. Exhaust emission

NOx exhaust emissions reportedly increases with increasing unsaturation and decreasing chain length. With increased cetane number causing significant reductions in the NOx emissions due to shorter ignition delay times and the resulting lower average combustion temperatures.

C. Viscosity

Viscosity is a measure of the internal friction or resistance of an oil to flow. As the temperature of oil is increased, its viscosity decreases and it is therefore able to flow more readily. Viscosity is the most important property of bio-diesel since it affects the operation of fuel injection equipment. High viscosity leads to poorer atomization of the fuel spray [34]. The viscosity values of vegetable oils are in between 20 and 55 mm2/s, whereas viscosity values of vegetable oil methyl esters are in between 2.5 and 5 mm2/s. The viscosity values of vegetable oil methyl esters decreases sharply after trans-esterification process. Compared to diesel, all of the vegetable oil methyl esters were slightly viscous [35].

Viscosity of methyl esters depends upon its fatty acid composition [36].Viscosity increases with chain length and with increasing degree of saturation and polymerization. The viscosity of unsaturated fatty compounds strongly depends on the nature and number of double bonds [37]. One double bond was shown to increase viscosity, whereas two or three double bonds caused a decrease in the viscosity of the systems. Branching in the ester, however, has little or no influence on viscosity. Free fatty acids or compounds with hydroxyl groups possess significantly higher viscosity. The viscosity of ethyl esters is slightly higher than that of methyl esters [36].

D. Lubricity

With the advent of low-sulfur petroleum-based diesel fuels, the issue of diesel fuel lubricity is becoming increasingly important. No significant effects of biodiesel fatty acid composition on lubricity were reported, though unsaturated acids exhibits better lubricity than saturated species. Ethyl esters had improved lubricity compared to methyl esters. Fatty acids possess excellent lubricating properties.

E. Heat of combustion

Gross heat of combustion is another fuel property indicating the suitability of fatty compounds as diesel fuel. Heat of combustion increases with chain length. The higher heating value of a fuel increases with increasing carbon number in fuel molecules and also increases as the ratio of carbon and hydrogen to oxygen and nitrogen increases [38]. The higher heating value is an important property defining the energy content and thereby efficiency of fuels. The higher heating value of vegetables oil and biodiesel increases with viscosity and it may be predicted from iodine value and saponification value of the biodiesel [39].

F. Iodine value

Iodine value is a measure of total un-saturation within a mixture of fatty acid. It is expressed in grams of iodine, which react with unsaturated methyl esters in 100 g of the sample. If more un-saturation is present in the oil, higher the iodine value. The iodine value of a vegetable oil or animal fat is almost identical to that of the corresponding methyl esters. It is an important parameter to measure the stability of bio-diesel.

G. Acid value

It is the mass of potassium hydroxide (KOH) in milligrams that is required to neutralize one gram of fatty acid. Its unit is mg KOH/g. Acid number for bio-diesel should to be lower than 0.50 mg KOH/g. The quantity of free fatty acids in the vegetable oil or bio-diesel will be equal to half of its acid value. Higher amount of free fatty acids > 2% creates hindrance to complete the base trans-esterification process.

H. Cold flow properties

One of the problems associated with the use of bio-diesel is poor low temperature flow properties, indicated by relatively high cloud points and pour points [37]. The cloud point is the temperature at which a liquid fatty material becomes cloudy due to formation of crystals and solidification of saturates. Solids and crystals rapidly grow and agglomerate, clogging fuel lines and filters and causing major operability problems. With decreasing temperature, more solids form as the material approaches the pour point, the lowest temperature at which it will still flow. Saturated fatty compounds crystallize at higher temperature than the unsaturates. Thus biodiesel fuels derived from fats or oils with significant amounts of saturated fatty compounds will display higher cloud point and pour point [80].

I. Oxidative stability

The reason for autoxidation is the presence of double bonds in the chains of fatty compounds. The autoxidation of unsaturated fatty compounds proceeds with different rates depending on the number and position of double bonds. Therefore, vegetable oils rich in linoleic and linolenic acids, such as soybean and sunflower oil tend to give methyl esters with poor oxidation stability [38].

From the above discussion it shows that the fuel properties of bio-diesel are strongly influenced by the properties of the individual fatty esters in bio-diesel. Both fatty acid and alcohol are having influence on bio-diesel fuel properties such as ignition quality, cetane number, viscosity, and lubricity, heat of combustion, cold flow properties, oxidative stability and exhaust emissions [38].

Cetane number, heat of combustion, melting point, and viscosity of fatty compounds increase with increasing chain length and decreases with increasing un-saturation. Therefore to enrich the bio-diesel fuel with desirable properties, certain fatty acids, possibly oleic acid, must be there to exhibits a combination of improved fuel properties.

The degree of un-saturation in a fatty acid molecule affects its reactivity. Un-saturation in a fatty acid chain significantly lowers its cetane number and increases NOx emissions. Un-saturation results in an increased tendency to undergo oxidative degradation, may decrease the lubricity of bio-diesel, and contribute to gum formation in the engine. Saturated fatty acid esters increases the cloud point, cetane no and stability[40,41].

Based on the properties & availability, the different bio-diesels can be used in the gas turbine for power generation. Non-edible oils and its bio-diesel using as pure or blended in diesel can be important alternatives under Indian perspectives. Out of the given bio-diesels Karanj oil and Jatropha oil bio-diesels seems the most suited bio-diesels for the gas turbine applications.

The development of additives is needed for improving cold flow properties, material compatibility & prevention of oxidation in storage for bio-diesel. Further there is a need to reduce the production cost and ensure its availability & quality. For this purpose there is a need to develop less expensive quality test. Testing of bio-diesel by HPLC is an option in this regard.

TABLE 2: FATTY ACID COMPOSITION BASED ON HPLC ANALYSIS OF DIFFERENT METHYL ESTERS

Fatty Acid	Chemical Formula	Structure	Molecular Weight	Karanj	Jatropha	Linseed	Cotton Seed	Soya
Palmitic Acid	C16H32O2	C16:0	256.4	9.89	11.4	12.71	31.12	13.9
Stearic Acid	C18H36O2	C18:0	284.4	3.37	1.18	1.69	1.78	2.1
Oleic Acid	C18H34O2	C18:1	282.3	55.67	78	31.5	8.5	23.2
Linoleic Acid	C18H32O2	C18:2	280.2	27.87	3.4	21.2	49.96	56.2
Linolenic Acid	C18H30O2	C18:3	278.2	0.39	--	22.95	3.48	4.3
Eicosanoic	C20H40O2	C20:0	312.54	1	1.6	0.42	---	--
Behenic	C22H44O2	C22:0	340.6	1.1	---	---	--	--

V. CONCLUSION

Biofuel represents a feasible solution for the issues of the increase in fuel price and reducing GHG emissions Gas turbine has an access to a broad range of primary energies such as natural gas, vegetable oils, esters (bio-diesels) , flash pyrolysis oils, alcohols, synthetic fuels (biomass to liquids), biogas, industrial process gases rich in hydrogen, etc. Out of these alternatives use of bio diesel in gas turbine seems more promising, as the potential of bio-diesel in reduction of emission and to maintain the performance is established by so many performance and emission tests carried out in reciprocating diesel engines and a few in gas turbines. The use of bio-diesel for reduction in emissions of unburned hydrocarbons, carbon monoxide and particulate without reducing the output power significantly is encouraging. But there is very less information available about bio-diesel utilization in gas turbine. The use of bio-diesel to fuel gas turbine seems a sustainable solution for the problems of escalating crude oil prices and its diminishing supplies due to depletion of fossil fuel, as they are made from renewable sources.

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