BIOFUELS RESEARCH AT ENGINE RESEARCH LABORATORY

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1. Introduction

The world is presently confronted with the twin crises of fossil fuel depletion and environmental degradation. Indiscriminate extraction and lavish consumption of fossil fuels have led to reduction in underground-based carbon resources. The search for alternative fuels, which promise a harmonious correlation with sustainable development, energy conservation, efficiency and environmental preservation, has become highly pronounced in the present context.

The fuels of bio-origin can provide a feasible solution to this world wide petroleum crisis. Petrol and diesel driven automobiles are the major sources of green house gases (GHG) emission [1-3]. Scientists around the world have explored several alternative energy resources, which have the potential to quench the ever-increasing energy thirst of today's population. Various bio-fuel energy resources explored include biomass, biogas [4], primary alcohols, vegetable oils, biodiesel, etc.

The world reserves of primary energy and raw materials are, obviously, limited. According to an estimate, the reserves will last for 218 years for coal, 41 years for oil, and 63 years for natural gas, under a business-as-usual scenario [1,5-6]. The prices of crude oil keep rising and fluctuating on a daily basis. The crude oil prices are at near record levels and have already crossed US $ 100 per barrel and predicted to stabilize around US $ 200 per barrel as of now. Import bills and energy security are the main reason behind the growing awareness and interest for unconventional bio-origin energy sources and fuels in various developing countries, which are striving hard to offset the oil monopoly.

There are several factors that need to be taken care before recommending any alternative fuel to be used in existing technologies on a large scale. These factors are stated below.

- Extent of modifications required in the existing hardware i.e. if any alternative fuel needs extensive modification in the existing hardware involving huge capital then it may be difficult to implement.
- Investment costs for developing infrastructure for processing these alternative fuels. Excessive infrastructure cost may act as a constraint for the development of the energy resource.
- Environmental compatibility compared to conventional fuels. If the new fuel is more polluting then it will be unacceptable as fuel.
- Additional cost to the user in terms of routine maintenance, equipment wear and lubricating oil life. Excessive additional cost will have an adverse effect on the widespread acceptance of this fuel.

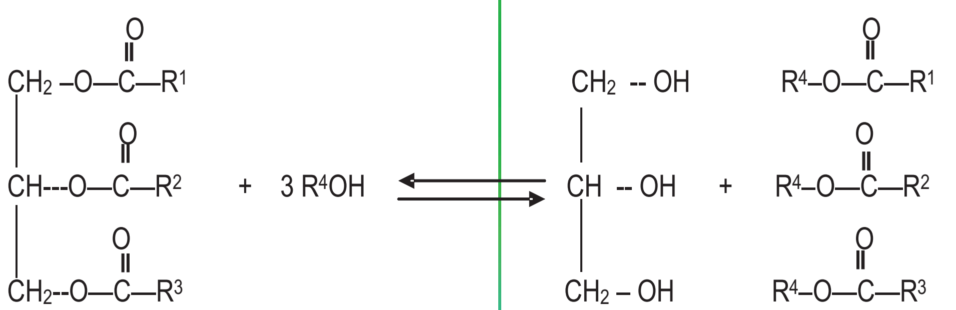
2. Vegetable Oils as Engine Fuels

Dr. Rudolf Diesel invented the diesel engine to run on a host of fuels including coal dust suspended in water, heavy mineral oil, and, vegetable oils. Dr. Diesel's first engine experiments were catastrophic failures, but by the time he showed his engine at the World Exhibition in Paris in 1900, his engine was running on 100% peanut oil. Dr. Diesel was visionary. In 1911 he stated *The diesel engine can be fed with vegetable oils and would help considerably in the development of agriculture of the countries, which use it.* In 1912, Diesel said, *The use of vegetable oils for engine fuels may seem insignificant today. But such oils may become in course of time as important as petroleum and the coal tar products of the present time.*

3. Biodiesel as Engine Fuel

The best way to use vegetable oil as fuel is to convert it in to biodiesel. Biodiesel is the name of a clean burning mono-alkyl ester based oxygenated fuel made from natural, renewable sources such as new/used vegetable oils and animal fats. The resulting biodiesel is quite similar to conventional diesel fuel in its main characteristics. Biodiesel contains no petroleum, but it is compatible with conventional diesel and can be blended in any proportion with petroleum diesel to create a stable biodiesel blend.

Vegetable oils have to undergo the process of



(Triglyceride esters) Alcohol Glycerol Esters

R^1, R^2, R^3, R^4 represent various alkyl group.

transesterification to be usable in internal combustion engine. Biodiesel is the product of the process of transesterification. Biodiesel is biodegradable, non-toxic and essentially free from sulphur; it is renewable and can be produced from agriculture & plant resources. Biodiesel is an alternative fuel, which has a correlation with sustainable development, energy conservation, management, efficiency and environmental preservation.

Transesterification is the reaction of a fat or oil with an alcohol to form esters and glycerol. Alcohol combines with the triglycerides to form glycerol and esters. A catalyst is usually used to improve the reaction rate and yield. Since the reaction is reversible, excess alcohol is required to shift the equilibrium to the product side. Among the alcohols that can be used in the transesterification process are methanol, ethanol, propanol, butanol and amyl alcohol [7]. Alkali-catalyzed transesterification is much faster than acid-catalyzed transesterification and is most often used commercially.

The process of transesterification brings about drastic change in density of vegetable oil. The biodiesel thus produced by this process is totally miscible with diesel oil in any proportion. Biodiesel viscosity comes very close to that of diesel oil hence no problems in the existing fuel handling system. Flash point of the biodiesel gets lowered after esterification and the cetane number gets improved. Even lower concentrations of biodiesel act as cetane number improver for biodiesel blend. Calorific value of biodiesel is also found to be very close to diesel oil. Some typical observations from the engine tests suggested that the thermal efficiency of the engine generally improved, cooling losses & exhaust gas temperature increased, smoke opacity generally gets lowered for biodiesel blends. Possible reason may be additional lubricity properties of the biodiesel; hence reduced frictional losses (FHP). The energy thus saved increases thermal efficiency, cooling losses and exhaust losses from the engine. The thermal efficiency starts reducing after a certain concentration of biodiesel. Flash point, density, pour point, cetane number, calorific value of biodiesel comes in very close range to that of mineral diesel oil [8-9].

Diesel engine can perform satisfactory for long run on biodiesel without any hardware modifications. 20% biodiesel is the optimum concentration for biodiesel blend with improved performance. Increase in exhaust temperature however lead to increased NO_x emissions from the engine. While short term tests are almost positive, long term use of neat vegetable oils or their blend with diesel leads to various engine problems such as, injector coking, ring sticking, injector deposits etc. [10-11]. High viscosity, low volatility and a tendency for polymerization with in the cylinder to be at the root of many problems associated with direct use of these oils as fuels. The process of transesterification yield vegetable oil ester, which has shown promises as alternative diesel fuel as a result of improved viscosity & volatility.

4. Engine Emissions from Biodiesel

Since biodiesel is free from sulphur hence less sulfate emissions & particulate reduction is

Table 1: Biodiesel Emissions Compared to Conventional Diesel

(Ref: www.epa.gov/otaq/models/biodsl.htm)

Emission Type	B100	B20
Regulated		
Hydrocarbon	-93%	-30%
Carbon Monoxide	-50%	-20%
Particulate Matter	-30%	-22%
NO_x	+13%	+2%
Non-regulated		
Sulfates	-100%	-20%
PAH (Polycyclic Aromatic Hydrocarbons)	-80%	-13%
Ozone potential of speciated HC	-50%	-10%

reported in the exhaust. Due to near absence of sulphur in biodiesel, it helps reduce the problem of acid rain due to transportation fuels. The lack of aromatic hydrocarbon (benzene, toluene etc.) in biodiesel reduces unregulated emissions as well like ketone, benzene etc.

Breathing particulate has been found to be hazard for human health, especially in terms of respiratory system problem. Biodiesel is oxygenated fuel (hence more complete combustion) and causes lesser particulate matter formation and emission. Smoke opacity is a direct measure of smoke & soot. Various studies show that smoke opacity for biodiesel is generally lower [8-9]. Several experimental investigations are performed on 4-stroke DI diesel engine with vegetable oil methyl esters & found that hydrocarbon emissions are much lower in case of biodiesel compared to diesel. This is also due to the oxygenated nature of biodiesel fuel where more oxygen is available to burn hydrocarbons and reduces hydrocarbon emissions in the exhaust [11].

CO is a toxic combustion product resulting due to incomplete combustion of hydrocarbons. In presence of sufficient oxygen, CO is converted into CO_2. Biodiesel is an oxygenated fuel and results in more complete combustion, hence CO emissions reduces in the exhaust.

Biodiesel use also shows reduction in PAH, which is identified as carcinogen compound, so it reduces health risk also. A 1998 biodiesel life cycle study, jointly sponsored by the US department of energy and the US department of agriculture, concluded that biodiesel reduces net CO_2 emissions by 78% compared to petroleum diesel. This is due to biodiesel's closed carbon cycle. The CO_2 released into atmosphere, when biodiesel is burned is recycled by growing plants, which are later processed into fuel. Hence biodiesel also helps mitigate global warming. Peterson et al. also reported that CO_2 emissions are significantly lower with biodiesel [10].

5. Economic Feasibility and other issues with Biofuels

Economical feasibility of biodiesel depends on the price of the crude petroleum and the cost of transporting diesel long distances to remote markets. It is certain that the cost of crude petroleum is bound to increase due to increase in its demand and limited supply. Further, the strict regulations on the aromatics and sulphur contents in diesel fuels will result in higher cost of production of diesel fuels. The cost of producing methyl or ethyl esters from edible oils is currently much more expensive than hydrocarbon-based diesel fuels. Due to the relatively high costs of vegetable oils (about 1.5 to two times the cost of diesel), methyl esters produced from it cannot compete economically with hydrocarbon-based diesel fuels unless granted protection from the considerable tax levies applied to the latter. In the absence of tax relief, there is a need to explore alternate feedstock for the production of biodiesel.

The cost of biodiesel can be reduced if we consider non-edible oils and used-frying oils instead of edible oils. Non-edible oils such as mahua, karanja, babassu, Jatropha, neem etc. is easily available in many parts of the world, and are cheaper compared to edible oils. Most of these non-edible oils are not used to their potential and in fact produced in surplus quantities.

With the mushrooming of fast food centers and restaurants in the world, it is expected that considerable amounts of used-frying oils will be discarded. This oil can be used for making biodiesel, thus helping to reduce the cost of water treatment in the sewerage system and in the recycling of resources.

The problem regarding production is, the world already has little land to spare for growing food, let alone bioenergy crop [12]. Even with the strategy to focus more on non-grain oil crops such as jatropha, which can even grow in marginal lands, massive production would require conversion of agricultural and forest lands to grow these crops on a commercial scale. Satellite data reveal that 40% of the earth's land is already used up for agriculture. Estimates show that more than one-third of all agricultural lands would need to be converted to biofuel production in order to raise its share in domestic consumption of transport fuels to 10%.

6. Efforts at IIT Kanpur

IIT Kanpur is involved in utilization of biofuels (SVO, Biodiesel and alcohols), biodiesel production, characterization of fuel and performance, emission and durability investigations of the engines, and vehicles.

Engine research laboratory has developed a hardware, which is cheap and it allows the engine to operate on straight vegetable oils for long duration without any operational and durability problems. This has been successfuly experimented with in the ERL.

Engine research laboratory has also developed its own design of biodiesel pilot plant with a production capability of 30 liters per batch, which amounts to approximately 200 liters per day and can be used by semi-skilled workers and villagers. The plant will be commercialized by Khadi and Village Industries commission and it is suggested that they follow Amul Model for producing biodiesel in villages. An extensive investigation on transport engines has been done in ERL to replace petro-diesel with biodiesel. In fact, the results of research on biodiesel at ERL encouraged one of the leading vehicle manufacturer to tie up with ERL, IIT Kanpur for the field trials of their flagship vehicle on 100% biodiesel, which has been successfully concluded recently. This was the first vehicle in Asia in its class to be operated on 100% biodiesel for more than 30000 kms. The results of the project were very encouraging and this project will prove to be a milestone in commercializing the biofuels in the country.

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Figure 1. Comparative study of B100 and Diesel Fuelled Scorpio Vehicle

Figure 2. Biodiesel Pilot Plant at Engine Research Laboratory, IIT Kanpur

Figure 3. Engines fuelled with Straight Vegetable Oil (SVO) at ERL, IIT Kanpur

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