

Experimental Investigation of Diesel Engine Fueled with Jatropha Oil Blend with Ethanol

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ABSTRACT

Dwindling petroleum reserves and alarming level of air pollution has been an issue of great concern in recent times and researchers across the world are experimenting on variety of renewable fuels for meeting the future energy demands. Within the gamut of alternative fuels, biofuels are the most promising and have the potential to mitigate climate change and lease a new life to existing IC engines. The vegetable oils are having immense potential in this context and have been used either in neat or modified form by large number of researchers. Jatropha curcus is a perennial plant and bears non edible oil. The plant is drought tolerant and has been cultivated all over the arid and semi-arid areas for reforestation. In the present study, blends of jatropha oil and ethanol have been prepared in 5, 10, 15 and 20% (v/v) and evaluation of important properties of blends has been carried. The results show that properties are quite similar to diesel fuel. Performance and emission characteristics were evaluated for straight vegetable jatropha ethanol (SVJE) blends. Engine performance (brake specific energy consumption, brake thermal efficiency) and emissions (CO, HC, NO_x, and smoke opacity) were measured to evaluate the behavior of the diesel engine running on SVJE blends. It has been found that at part load condition, the brake thermal efficiency and brake specific energy consumption of blends of SVJE were insignificant. HC, CO emissions and smoke opacity were reduced at part load condition. However, there was a decrease in NO_x in case of SVJE diesel blends at full load condition.

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INTRODUCTION

Today world is marveling at the technological revolution and this has helped the human race but mismanagement has led to various problems on the same hand. Now a day, one of the major burning issues is energy crisis. The Internal combustion engines have revolutionized the world in last

hundred years but also contributed significantly towards environmental degradation. Post Kyoto Protocol; there have been considerable efforts to reduce GHG emissions and more emphasis is now given on using clean source of energy. Though, majority of fuels used in IC engines are still petroleum derived fuels despite exhaustive research carried

on renewable fuels. The gulf crisis proved to be very crucial for both developed and developing countries and oil exporting countries started demanding higher prices. It was then for the first time the world seriously started looking for alternative source of energy along with efficient utilization of energy.

With the exception of hydroelectricity and nuclear energy, the majority of world energy needs are met through petrochemical sources, coal and natural gas. Nevertheless, fossil fuels are not considered sustainable and are also questionable from an economic, ecological and environmental point of view. It should also be realized that, as the more accessible deposits become depleted, the global distribution of those remaining will attract progressively heightened political attention, since not all nations can assume proportional future supplies. The recent increase in petroleum prices and the growing awareness related to the environmental consequences of the fuel over-dependency have stimulated the recent interest in alternative energy sources [1,2,3,4].

India is rich in coal and possesses renewable energy in the form of solar, wind, hydro and bio-energy, however, the utilization of these resources are very much limited. India accounted for 11.63% of Asia-Pacific primary energy consumption and 4.5% of world consumption in 2011. Moreover, its hydrocarbon reserves represent only 0.3% of the global reserves and India is mainly dependent upon crude import to sustain its socio-economic growth [5]. India's per capita consumption is very low at 560 KGOE as compared to the world average of 1790 KGOE in 2009[6]. In 2010-11, India spent 190 billion US \$ in foreign exchange towards import of crude oil. Despite sustained effort taken by the government, the production of crude oil in 2010-11 raised to 37.71 million metric ton which is 11.91% higher than the production in 2009-10, however, the consumption also increased from 192.95 MT (2009-10) to 201 MT (2010-11) [7].

Exhaustive research has been done on renewable resources to meet the current energy demands which include biomass, biofuels such as alcohols, biodiesel, ethers, and other renewable resources [8]. Among these fuels, biodiesel is a biofuel made from transesterification of vegetable oils or animal fats which can be used in diesel engines either as an additive or extender of diesel with satisfactory performance [9,10,11].

Worldwide biodiesel production is mainly from edible oils such as soybean, peanut, coconut, sunflower and canola oils. However, biodiesel production from edible oils are not sustainable in India as India is not self-sufficient in edible oil production and imports substantial amount of edible oil for meeting its requirement. In this context, non-edible oils are very promising for biodiesel production in India with abundance of forest and plant based non-edible oils being available in India such as Pongamia (Karanja), Jatropha curcas (Jatropha), Madhuca indica (mahua), Shorea robusta (sal), Azadirachta indica (neem),

Schleichera oleosa (Kusum) and Hevea brasiliensis (rubber) [12,13].

Vegetable oils mainly contain significant amounts of oxygen. The fatty acids vary in their carbon chain length and number of double bonds present in their molecular structure [14]. These oils can be produced even on a small scale for on-farm utilization to run tractors, pumps and small engines for power generation/irrigation and save lot of money and fuel which is expended on transportation of fossil fuel. Suitability of vegetable oils as fuels for diesel engines depends on their physical, chemical and combustion characteristics as well as the type of engine used and operating conditions. Vegetable oils can be used directly or blended with diesel to operate compression ignition engines [15,16]. Use of blends of vegetable oils with diesel has been experimented successfully in several countries. It has been reported that use of 100% vegetable oil is also possible with minor fuel system modifications [17].

Short-term engine performance tests have indicated good potential for most vegetable oils as fuel but long-term engine performance test show problem such as severe engine deposits, piston ring sticking, injector coking, gum formation and lubricating oil thickening [18,19]. This problem arises due to high viscosity and poor volatility of straight vegetable oils due to large molecular weight and bulky molecular structure. High viscosity of vegetable oils (30-200 cSt at 40°C) as compared to mineral diesel (4 cSt at 40°C) lead to unsuitable pumping and fuel spray characteristics. Larger size fuel droplets are injected from injector nozzle instead of a spray of fine droplets, leading to inadequate air-fuel mixing. Poor atomization, lower volatility, and inefficient mixing of fuel with air contribute to incomplete combustion. Since straight vegetable oils are not suitable as fuels for diesel engines, they have to be modified to bring their combustion related properties closer to diesel. This fuel modification is mainly aimed at reducing the viscosity to eliminate flow/atomization related problems. Undoubtedly, transesterification is well accepted and best suited method of utilizing vegetable oils in CI engine without significant long-term operational and durability issues. However, this adds extra cost of processing because of the transesterification reaction involving chemical and process heat inputs. In rural and remote areas of developing countries, where grid power is not available, vegetable oils can play a vital role in decentralized power generation for irrigation and electrification. In these remote areas, different types of vegetable oils are grown / produced locally but it may not be possible to chemically process them due to logistics problems in rural settings. Hence using blend of vegetable oils with ethanol as petroleum fuel makes an attractive proposition. Keeping these facts in mind, a set of engine experiments were conducted using blend of Jatropha and ethanol on an engine, which is typically used for agriculture, irrigation and decentralized electricity generation. The Jatropha and ethanol both are agriculture product and can be cultivated and produced almost all over in India. [20] A wide range of exhaustive engine trials have been carried out

so far on variety of blend on vegetable oil based fuels and alcohol and, an exhaustive review of some of the research findings are summarized below.

Neuma et al. studied new blend systems containing diesel and different percentages of vegetable oils (soy, palm and ricin), that can be used as alternative fuels. The results showed that it was possible to obtain new micro-emulsion of diesel and vegetable oils through a simple methodology with low cost. From the point of view of the physico-chemical properties, the results indicated the possibility of the blends to be used as fuels. [21].

Kerihueled et al focused on effective solution to improve the combustion of low quality animal fat (duck fat) by making stable emulsions with water. Animal fat emulsions were prepared by mixing the fat with water, surfactant and co-surfactant. Ethanol is chosen as the co-surfactant because of its dilution ability. Sesquiolate was used as the surfactant for Stable animal fat emulsions. Emulsions and micro-emulsions were prepared for different co-surfactant/surfactant (C/S) ratios. Results were presented in pseudo ternary diagrams. Influence of different parameters affecting the emulsion characteristics were studied experimentally. According to the stability, structure, viscosity, fat content and economical aspects, the optimum emulsion was found as the emulsion with 36.4% of ethanol, 3.6% of SPAN 83, 10% of water and 50% of animal fat by volume. This fine dispersed phase had a Sauter mean diameter of 10 nm and a stability period over one week at 25 C. [22].

Senthil et al. used animal fat as fuel in a diesel engine due to comparable cetane number and calorific value to diesel. The added advantage was that animal fats have fixed oxygen present in it. Drastic reduction in smoke, nitric oxide, hydrocarbon and carbon monoxide emissions were observed with the emulsion as compared to neat fat and neat diesel mainly at high power outputs. Only, hydrocarbon and carbon monoxide emissions were found as high. with the emulsion at light loads. [23]

Gvidonas et al. experimented on a four stroke, four cylinder, direct injection, unmodified, diesel engine operating on pure rapeseed oil (RO) and its 2.5 vol%, 5 vol%, 7.5 vol% and 10 vol% blends with ethanol (ERO), petrol (PRO) and both improving agents applied in equal proportions as 50:50 v/v % (EPRO). Brake specific fuel consumption (bsfc) at maximum torque (240.2 g/kWh) and rated power (234.0 g/kWh) is correspondingly lower by 3.4% and 5.5% in comparison with pure RO when biofuel blends EPRO5 and PRO2.5 are used[24]

Singh et al. had conducted engine test on hybrid fuels consisting of coconut oil, aqueous ethanol and a surfactant (butan-1-ol). The engine performance and exhaust emissions were investigated and compared with that of diesel. The experimental results show that the efficiency of the hybrid fuels is comparable to that of diesel. As the viscosity of the hybrid fuels decreased and approached that of diesel, the efficiency increased progressively towards that of diesel. Anhydrous butan-1-ol can be used as an effective surfactant

to prepare a stable and homogenous blend of coconut oil and aqueous ethanol of 95% purity. The performance characteristics were comparable with neat diesel. Hydrocarbon, carbon and nitrogen oxide emission were found lower than that of diesel. [25].

Qi et al. studied the efficient use of ethanol-biodiesel-water micro-emulsions in a diesel engine under variable operating conditions. It is found that the peak cylinder pressure of the micro-emulsions is almost identical, whereas the peak pressure rise rate and peak heat release rate were higher at medium and high engine loads. Performance parameters were higher for blend drastic reduction in smoke was observed with the micro-emulsions at high engine loads. Nitrogen oxide (NOx) emissions were found slightly lower under all range of engine load for the micro-emulsions. But carbon monoxide (CO) and hydrocarbon (HC) emissions were slightly higher for the micro-emulsions than that for biodiesel at low and medium engine loads. [26].

Silvestreed et al. worked on methodology for preparation on blend and use membrane emulsification in place of mechanical stirrer and emulsifier for water and oil. Water-in-oil emulsions (W/O) and ethanol-in-oil emulsions (E/O) emulsions were prepared successfully by membrane emulsification. The results confirmed that membrane emulsification could be an interesting alternative for preparation of E/O emulsions for the purpose of biodiesel fuels, considering the scale-up ability of membranes and their potentiality for industrial processes. [27].

Attaphong et al. studied the phase behavior of carboxylate-based extended surfactant micro-emulsion systems with the goal of formulating optimized systems for biofuel and found that carboxylate-based extended surfactants were able to form reverse micelle micro-emulsions without salt addition, thereby eliminating the phase separation and precipitation which had been observed with sulfate-based extended surfactants. This fuel system was stable for a temperature range of 0-40°C. Moreover, varying surfactant/co-surfactant ratio, cetane enhancers and anti-freezing agents did not affect the phase behavior and kinematic viscosity of micro-emulsion fuel. [28].

Nandkishore et al. evaluated performance and emissions of single cylinder, naturally aspirated, compression engine using Straight vegetable oil, its blends with ethanol and diesel fuel separately. Basic properties like viscosity, calorific value, specific gravity are evaluated for all test fuels. The Straight vegetable oil (SVO) showed lower thermal efficiency, higher un-burnt hydrocarbon emissions etc. due to high viscosity and poor volatility. In long term, SVO show injector choking, fuel pump damage, fuel filter clogging etc. The emulsions of SVO with alcohol show lower viscosity, improved volatility, better combustion and less carbon deposits. The engine performance with the micro-emulsion ESVO-70 is very close to diesel fuel. Reduction in nitric oxide, carbon monoxide, and smoke emission were observed with increase in amount of ethanol in emulsion. It could be concluded that blend ESVO-70 can substitute diesel. [29].