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A Comprehensive Review on Biodiesel as Alternative Fuel for a Compression Ignition Engine

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Abstract-The declining reserves of fossil fuel reserves, rise in population and hazardous exhaust emissions due to combustion of fossil fuels has raised concern to search for a new alternative renewable fuel. Recently biodiesel has become a promised feasible alternative biodegradable fuel to diesel fuel. This is because of similar physio-chemical properties almost same as biodiesel and nearer combustion characteristics. In the present paper, a systematic comprehensive review was presented to reveal the different research accomplishments on biodiesel that was prepared using vegetable oils and animal fats oils as feed-stock and which can be used in unmodified compression ignition engine. The literature has revealed that the engine has reduced engine power with higher brake specific fuel consumption, energy consumption when biodiesel and its diesel blends used as fuel. But engine released very lower smoke emissions, carbon dioxide, carbon monoxide, particulate matter, smoke opacity with the biodiesel when compared to diesel with a minor increased in NOx emissions.

Index Terms-Biodiesel, Methyl Ester, Renewable Energy, Edible Oil and Non-Edible Oil, Vegetable oil.

1. INTRODUCTION

The rapidly increasing usage of automotives, the harmful exhaust emissions that causing global warming inescapability to search for more economic and more ecological friendly fuel to satisfy the current and future energy demand. The episodic rise in petroleum oil prices due to elevated demand, stringent emission rules, and feared shortages of crude oils due to rapid depletion and emission of hazardous gases such as oxides of carbon and sulphur from combustion sources have revive interest in renewable bio-fuels. Recently animal fats, neat and waste vegetable oils derived from vegetation can be used in the production of alternative fuel. The main expenditure in preparation of biodiesel is feedstock and selecting them is a major problem and essential to reduce the production cost. And also availability of raw material continuously for transesterification process is another preference to minimize the cost to preparation biodiesel fuel. Biodiesel is currently not cost-effectively viable, and further updated cutting-edge technological changes are required to make it feasible. Thus fortifying policies are consequential to promote biodiesel research and make their prices competitive with other conventional sources of energy. At present, biodiesel can be more efficient and best alternative fuel because of nearer chemical characteristics of diesel [1,2]. Many nations such as USA, Brazil, Malaysia, Australia, were initiated to use bioethanol and biodiesel as partial replacement of fossil fuels. These biodiesel was produced using the locally and cheaply available vegetable oils.

2. PRODUCTION OF BIODIESEL

Transesterification is a chemical process of transformation of carboxylic acid ester into a dissimilar carboxylic acid ester. Generally traditional technique of transesterification is the reaction of the ester with methyl/ethyl alcohol in the presence of catalyst. In organic chemistry, transesterification is the process of exchanging the organic group R″ of an ester with organic group R^1 of an alcohol in the presence of an acid or base catalyst. Transesterification process can be written as shown in Figure 1.

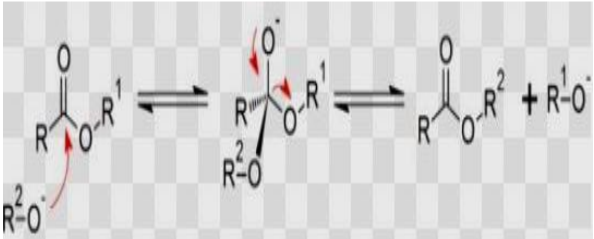

Fig 1. Chemical Reaction of Transesterification

Anitha and Dawn analyzed the properties of waste cooking oil and vegetable oil. The high viscosity and low volatility of vegetable oil is not compatible to be used CI engine for longer period and hence a chemical process such as transesterification, pyrolysis etc. is required to make it at least nearer characteristics as fossil fuel. The methyl esters are obtained from veg. oils/animal fats were meet the ASTM standards of bio-diesel. The comparable engine performance and lower exhaust emissions when compared with conventional fuel confirming that biodiesel is an alternative fuel [3]. Ma, F et al., experimental analysis demonstrated that alkali catalysts are more auxiliary to amend the chemical characteristics of the vegetable oils [4]. Senthilraja et al. evaluated the Kirloskar engine performance and emission characteristics utilizing Diesel–Ethanol – Cotton seed oil methyl ester and its blends. The experimental results shown that brake thermal efficiency (BTE) has incremented at low and high load of the engine, but CO2 emission incremented with incrementing load of the engine [5].

3. EFFECT OF EDIBLE OIL BASED BIODIESELS ON ENGINE CHARACTERISTICS

For last few decades, many researchers conducted experiments with vegetable oils with and without heating for CIDI engine and found that the vegetable oils have higher viscosities, lower calorific values, relatively higher densities and low volatility that originate the engine problems such as massive carbon deposits, nozzle coking, slow burning, high smoke emissions, erratic combustion and engine durability. I.T Nazzal et al. carried-out an experimental analysis with the help of TD111 model, single cylinder, air-cooled diesel engine using diesel blends of sunflower oil in three mixtures of sunflower oil/diesel in the ratios of 5:95, 8:92 and 11:89 in addition to diesel fuel and revealed that the brake power (BP), brake thermal efficiency (BTE) and exhaust gas temperature were lower than the diesel fuel while brake specific fuel consumption was increased [6]. Kusy et al., have evaluated the engine performance using soybean oil ethyl-ester and revealed that engine has demonstrated 5% lower power and torque with soybean oil ethyl-ester used as fuel and when compared with diesel fuel. But the visible smoke was almost comparable to as diesel fuel [7]. A.S.Silitonga et al. were assessed the single cylinder CI engine's characteristics when fuelled with blends of biodiesel-bioethanol-diesel. Their exploratory outcomes demonstrated that brake specific fuel consumption (BSFC) is substandard while the brake thermal efficiency is predominant for the biodiesel-bioethanol-diesel mixes. And furthermore saw that there is a drop in carbon monoxide (CO) and smoke murkiness (SO) for these fuel mixes [8]. B.S Chauhan et al. evaluate the performance and emission characteristics of Kirloskar CIDI engine using unheated and preheated Jatropha oil. Their experimental evaluation shown that the engine has poorer brake thermal efficiency (BTE) and superior brake specific energy consumption (BSFC) with unheated Jatropha oil when compared with diesel fuel. But with preheated Jatropha oil, these parameters were superior to Jatropha curcas oil when it is not heated. The exhaust emissions (CO, HC and smoke opacity) were lower than diesel for both conditions [9]. Mehra et al. led exploratory examinations to assess the thermal efficiency, BSEC, brake mean effective pressure (BMEP), emission characteristics of a single cylinder, CIDI engine fueled with blends of transesterified sesame oil and neem oil. Their experimental results shown that B10 and B20 blends of transesterified sesame oil and neem oil can be used as a substitute biodegradable fuel in CIDI engine[10]. Usta conducted experimental study on the effect of tobacco seed oil methyl ester and its blends on emission and engine performance of a turbocharged IDI diesel engine. The reduced performance with reduced CO emission, but higher NOx emission was noticed from the experimental results [11]. Schlick et al. conducted experiments and evaluated the performance of 2.59 Lit, 3 cylinder Ford diesel engine using blends of diesel with soybean oil and sun-flower oil on a 25:75 v/v basis and noticed that the power persistently constant throughout 200 hr of operation. Large amounts of deposits including Carbon on all parts of combustion chamber prevent the use of above oil blends in diesel engine [12]. Agrawal et al., done performance analysis of low heat rejection diesel engine operating with biodiesel of rice bran oil, it was observed that NOx emissions with bio diesel was higher due to presence of molecular oxygen. An exhaust gas recirculation was used for controlling the NOx emissions. However, application of EGR resulted in higher BSFC, increased HC, CO and particulate emissions [13]. Spataru et al., utilized methyl ester of soya and canola oils with diesel blends in a Detroit CIDI engine. It was noticed that the emissions of CO_2, NOx, and particulate matter has increased and reductions in total hydrocarbons. It was also reported that the engine wear was within suitable limits during stability tests carried-out [14]. Dhinagar S. et al. reviewed the performance and emissions of low heat rejection engine (LHE) using pre-heated neem, rice bran and karanji oils and noticed improvement in brake thermal efficiency(BTE) for all tested oils when compared to diesel fuel. They noticed maximum performance at 110^0 C for karanji oil and at 80^0C for both rice bran and neem oils. These three vegetable oils have shown less BTE without heating condition than that of diesel fuel [15]. Hemmerlein et al. carried-out various contemporary diesel with respect to fuel consumption, performance, exhaust emissions and durability characteristics using neat (100%) rapeseed oil as fuel and noticed that brake specific energy consumption (BSEC) and performance were almost similar as diesel, and higher exhaust emissions with rapeseed oil [16].

4. EFFECT OF NON-EDIBLE OIL BASED BIODIESELS ON ENGINE CHARACTERISTICS

Georgios F. et al. conducted a detailed study on a Euro-3-compliant passenger diesel car at elevated injection pressure using 90% diesel-10% cotton seed oil as fuel. The test included fuel consumption and emission measurements. The aim of the experiment was to accurately evaluate the effect of bio-fuel on a common rail engine. Results from the bench engine measurements were in line with those retrieved from the vehicle and indicate that under certain conditions it can be applied as automotive fuel in a broader scale [17]. Deepak Agarwal et al. has experimented to observe the influence of viscosity of Jatropha curcas oil by heating the oil using the waste heat of exhaust gases and thereby providing condition for complete combustion and decreasing the exhaust emissions of the engine. The thermal efficiency, BSFC, smoke opacity, and COx and HC emissions were estimated and the results revealed that performance and emission readings were very close to diesel for lower blends of tested biofuel. However, for higher blend concentrations, the performance and emissions were observed to be slightly substandard. The B20 blend has the finest performance than all other blends of Jatropha curcas oil. Long run tests were conducted using optimized blend. It was found that the blend fuelled engine has higher carbon deposits inside combustion chamber than diesel fuelled engine. The utilization of these blends requires frequent cleaning of fuel pump, filter and the combustion chamber. Hence, it was recommended that the rubber seed oil and diesel blend fuel was more suitable in unmodified CIDI engine [18]. Pugazhvadivu et al. carried-out an experimental investigation on waste frying oil and disclosed that the waste cooking oil requires heating temp of 135°C to bring down the viscosity similar to diesel at 30°C. It was also observed that the performance was improved and carbon monoxide and smoke emissions were reduced using preheated waste frying oil and concluded that the waste frying oil preheated to 135° C could be used as a biodiesel for short term engine operation [19]. Murayama et al., conducted experiments and evaluated the engine performance and emission characteristics of a waste vegetable oil as biodiesel using direct injection and indirect injection diesel engines. The research results revealed that, for engine performance, the esterified fuel was at par with light oil. For the emission of particulates, with the IDI diesel engine there was no major disparity between the light oil; however, the DI engine proved to emit a higher particulate matter than diesel [20]. Venkateswara Rao et al. have done experimental analysis on methyl esters of pungamia, jatropha and neem as bio-diesel on C.I. Engine. Experimental investigations were carried out to examine characteristics of CIDI engine at various ratios of diesel-biodiesel blends (B10, B20 and B40) in comparison to diesel. The outcome of experiments specified that B20 blend has nearer performance to diesel, but lowest brake thermal efficiency found with neat biodiesels. However, its lower diesel-biodiesel blends showed equitable efficiencies, lower emission (smoke, CO and HC). Pungatnia methyl ester has shown superior performance in among all tested blends of biodiesel [21]. Forson et al. were carried-out experimental study on Jatropha oil-diesel blends on a single cylinder air cooled Lister model direct injection diesel engine. It was noticed that 2.6% Jatropha oil with 97.4% of diesel was the optimum blend to give higher thermal efficiency and power output and lower oxides of carbon emissions at all engine loads [22] . Reddy et al., carried out experiments to study the effect of variation of injection system parameters such as injection rate, injection timing, and injector opening pressure on the performance and emission of Jatropha oil fuelled small, air cooled, single cylinder, direct injection compression ignition engine used for agricultural purposes. They reported the optimum injection parameters for higher thermal efficiency and lower emissions as: static fuel injection timing 33.5° BTDC, injector opening pressure 220 bar, injection rate corresponding to 9 mm plunger diameter. They also demonstrated the effect of injection system parameters on the heat release diagram and on various stages of combustion. They employed swirl enhancement to determine its effects on performance and emissions and found that the thermal efficiency has not been improved, but HC and smoke levels were decreased significantly with swirl, but it increased NO level considerably [23]. Reheman et al. assessed the performance and exhaust emissions of one-cylinder CIDI engine utilizing karanja oil methyl ester and its diesel blends as fuel and concluded that biodiesel mix with diesel up to 40% shown adequate performance without much power loss with reduced exhaust emissions such as carbon monoxide smoke density, and NOx when compared with diesel [24]. Huzayin et al. have led investigations to assess the engine's characteristics utilizing blends of jojoba oil with gas oil and their trial results demonstrated that marginally diminished engine power, better brake specific fuel consumption (BSFC), decrease in NOx and ash outflow utilizing mixes of jojoba oil with gas oil when contrasted with gas oil [25]. Matheaus et al., conducted experimental investigation of PCCI-DI combustion on a four cylinder light duty diesel engine with ultra-low Sulphur diesel fuel. Electronic control unit of the engine was replaced with custom designed controller for obtaining the premixed charge with early pilot injections (up to three). The study reveals that the engine has exhausted reduced NOx emissions with PCCI-DI combustion at light loads (below 30%) and medium to low speeds. The test results indicated NOx reduction of 9 to 15% under various operating conditions [26] . Lu-Yen Chen et al., were developed correlations for the calorific heat, cold filter plugging point, density, kinematic viscosity, and oxidation stability of Jatropha oil methyl esters blended with diesel at various volumetric percentages. The results revealed higher brake thermal efficiency at higher power output. The concentration of carbon monoxide (CO) and NO were observed to increase with load while the concentration of O2 and CO decreased [27].

5. CONCLUSTIONS

The comprehensive research review on biodiesels emphatically substantiate that edible oils and non-edible oils and their diesel blends can be used as complete or partial substitute for diesel as renewable energy sources. The transesterification process will help to improve the quality of the biodiesels by reducing the viscosity, boiling point, flash point, pour point and completely removing the glycerides which make the vegetable oils compatible with diesel. It also endorsed that the usage of edible oils in the biodiesel production is not preferred, because it may compete with food products and creates food crisis in extremely populated countries. Instead, non-edible oils are other best options for biodiesel preparation. The non-edible oil plants are less expensive to cultivate with little amount of water, requires less maintenance, can grow on all types of weather conditions and soils with high crop yield and has the ability to cultivate well on infertility soils.

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