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Performance, Combustion and Emission Characteristics of Major Biodiesel Blends: A Review

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Abstract**: The change in industrialisation and the increase in usage of automobile divesting the natural reserves of the fossil fuels which has driven the world towards alternative fuels especially renewable sources. One of the most prominent replaceable alternatives to the diesel is biodiesel. The research on usage of this biodiesel and modification of engines to suit these biodiesels started during the period of World War-II and the change in environmental conditions and decreasing reserves of the existing petroleum reserves formed as catalyst to accelerate this research to find better alternative biodiesel. Wide research is being done on many of the alternative biodiesels. This work mainly focuses on review of performance, emission and combustion characteristics of five most prominent biodiesels namely Jatropha, Cotton seed oil, Rubber seed oil, Mahua oil and Rapeseed oil. It is found that the brake specific fuel consumption is high for all the biodiesels because of less energy content in them in comparison with diesel. The variation of brake thermal efficiency depends on the percentage of fuel combustion and the percentage of blends used. From the review it was observed that. Even though the report of emission characteristics shows that the emissions of HC, smoke and CO by Rapeseed oil is little more comparative to that of other biodiesel blends but the performance of Rapeseed oil is superior and almost similar to that of diesel when compared with other biodiesel blends. Hence forth Rapeseed oil can be suggested as better alternative biodiesel to the diesel with certain modifications like Al_2O_3 coatings to the piston which controls CO and HC emissions.

***Keywords**: Alternative fuels, Biodiesel, Blends, Emission, Performance, Brake thermal efficiency*

I. INTRODUCTION

To move heavy vehicles economically diesel engines are modified accordingly and this increased interest of these diesel engines is all because of their thermal efficiency, which strives better fuel economy and lower emissions. The modification of these engines to improve better fuel economy and better combustion characteristics made them dominantly used. The output power of these engines is improved with the improvement of injection systems, and development of super chargers and turbo chargers. Unfortunately, the exhaust gas emissions are till high. The current research work is focused on reduction of these emissions, by the application of diesel particulate filter (DPF) and selective catalytic reduction (SCR), the particulates and NOx are reduced but they are not remarkable. The negative effect of NOx and sooth from compression Ignition (CI) engines increases on human health. Recent measurements of sooth deposition granule are almost the size of particulate matter, which increases risk of human life. On the other hand, it is depletion of the natural fuels which are non-renewable.

A search for good alternative fuel is being done from past few years, which include hydrogen, Dimethyl esters (DME), biodiesels etc... The major end-user requirements like cost, availability, efficiency, safety, supply etc. are limiting each of the different alternatives available for usage. On the other hand, each of these alternative fuels have their advantages and limitations as shown below in Table I.

Table I. Comparison of different Renewable Sources

Type of Fuel	Advantages	Limitations
Hydrogen	• Emissions are Zero • Potential Renewable source • Lower heating value is very high	• Difficult to handle and store • Difficult to refill the fuel
Dimethyl Esters	• Cetane number is high • Less particulate matter and NOx emissions	• Safety is one of the major concerns because of high pressure tank

		• This fuel is not as good as diesel
Biodiesel	• It has become most potential Renewable source as a fuel • HC and CO emissions are less	• Energy content is very less • There is no certainty on NOx

II. BIODIESEL PERFORMANCE, COMBUSTION AND EMISSION CHARACTERISTICS

Biodiesel fuels are gaining more importance as an alternative source in the recent years. Biodiesels cannot be used directly as a fuel in internal combustion engines, this requires changes or modifications to be done to the engine. Karthick. D et. al. has conducted experiment on single cylinder direct diesel engine by reduced compression ratios from 17:1 to 16.5:1 with different blends of diesel with Jatropha and analysed emission, combustion and performance characteristics, it is found that reducing compression ratios and usage of biodiesel produces almost similar amount of NOx but with lesser smoke [1]. M. Loganathan et. al. in their experimental investigation on emission characteristics of neat Jatropha and blended with Dimethyl Ether found that the brake thermal efficiency of the blended Jatropha is greater than that of the neat fuel, along with it was also found that the emissions like CO, HC and NOx is lesser in case of blended fuel than the neat fuel [2]. M. G. Bannikov et. al. in their experimentation on Jatropha Methyl Esters and diesel found the following variations: (1) engines fuelled with Jatropha Methyl Esters at high loads had increased specific fuel consumption, reduced NOx, unburned HC and smoke emissions, (2) increase in specific fuel consumption is because of lower heating value of the fuel, and (3) the analysis of combustion characteristics also revealed that the cetane index measured by ASTMD976 is not a proper measure for ignition quality of the fuel [3]. Bhaskar Kathirvelu et. al. in their experimentation on Jatropha and fish waste found that without major modifications to the diesel engine the emission of CO, unburned HC and soot is less but there is a slight increase in NOx at all loading conditions [5]. Rajneesh Kumar et. al. in their experimentation found that blends of Jatropha Ethyl Esters and diesel can be successfully used in diesel engines without any modifications to the engines, with superior performance and emission characteristics [4]. Venkateswarulu Chintala et. al. in their work on solar driven Jatropha biomass pyrolyzed oil on direct injection diesel engines found the following characteristics in performance and emission: (1) efficiency of the engine increased for PODB20 blends from 32% to 34% and whereas for PODB40 blends it was 35.6%, (2) there is a reduction of emission of HC, CO and smoke with both PODB20 & PODB40, whereas the emission of NOx first increased then it decreased [6]. Deep A et. al. prepared micro emulsions of jatropha and ethanol in different ratios when compared with diesel and found that in part loading conditions brake thermal efficiency and brake specific energy consumptions of blends of Jatropha and ethanol was insignificant. Where in the emission of HC, Co and smoke reduced at part load conditions [9]. Surya Dharma et. al. in their work on experimental and performance prediction of blends of Jatropha Curcas-Ceiba pentandra (J50C50) using artificial neural networks found the following variations in performance and emissions (1) initially there is a decrease in brake specific fuel consumption when the engine running condition changed from 1500 rpm to 1900 rpm and there on BSFC increases to a load of 2400 rpm this is because of lower energy content of the fuel blends. (2) high viscosity and lower calorific value of these biodiesel the brake power decreases. (3) Brake thermal efficiency of the engine decreases with the usage of this blends this is because of poor atomization, evaporation and combustion resulting from high viscosity and lower heat content of the fuel [12]. Overall it is absorved that usage of Jatropha based biodiesel and it blends increases the NOx emissions and decreases the unburnt HC and CO.

V. Mathan Raj et. al. in an experiment on single cylinder four stroke diesel engine with blends of cotton seed oil and isobutanol with diesel by volume, found that brake thermal efficiency increases with decrease in specific fuel consumption lower exhaust temperatures with addition of cotton seed oil [7]. Basavaraj M. Sirigiri et. al. in their experimentation with cotton seed oil methyl ester on single cylinder four stroke direct injection system found that brake thermal efficiency at the peak loads is reduced by 5.91% and specific fuel consumption increased by 28.57%. it was also found that there is an increase in NOx emission, with slight increase in CO, smoke and HC emissions [8]. R. Senthilraja et. al. in their experimental setup of dual fuel engine on different blends of cottonseed oil Methyl Ester, diesel and CNG found that the brake thermal efficiency increases with increase in Ethanol and Cottonseed oil Methyl Ester blends, this is because of presence of higher oxygen content which makes more complete combustion. On the other side brake specific fuel consumption increases with increase in the percentages of ethanol and Cottonseed oil Methyl Ester blends, this is because of lower heating value of these blends. Increase in cottonseed oil Methyl Ester blend increases the exhaust gas temperature because of complete combustion due to presence of oxygen content. Regarding emissions, the emission of CO is little higher in lower and medium loads, whereas the emission decreases at higher loads. Because of higher density, viscosity, atomisation and inbuilt interatomic molecular oxygen the HC and NOx emissions increases with percentage increase in cottonseed oil Methyl Ester blends [11]. M. R. Subbarayan et. al. in their work on diesel engine with cottonseed oil Methyl Ester and blends along with petro-diesel found that the specific fuel consumption increases with the increased concentration of the blends because of their lower calorific value. The percentage increase in brake thermal efficiency of the engine for the neat diesel is greater than the blend but at full load condition the brake thermal efficiency of the blends is 0.63% greater than the neat diesel [13]. Pankaj S. Shelke et. al. in an experimental study on base diesel and cottonseed oil biodiesel (B5, B10, B15 and B20) as fuel found that ignition delay of cottonseed oil biodiesel blends decreases in comparative to the diesel which is because of the higher cetane number of these biodiesel blends. Because of lower calorific value of these blends the brake thermal efficiency decreases and there is an increase in NOx emission because of increase of premix combustion of these biodiesel blends which also increases combustion duration [14]. Over all the specific fuel consumption increases because of their lower heat content, only at full load condition the brake thermal efficiency will be better than the neat diesel, regarding emissions with the percentage increase in the blends the HC and NOx emissions also increases.

Ahmed Syed et. al. in their work on direct injection engine with dual fuel mode operating on hydrogen and Mahua Methyl Ester found that brake thermal efficiency improved by 28% with injection opening pressure of 250 bar and 75% of engine load. It was also found that brake specific fuel consumption decreases with increase in injection opening pressure for these blends. With the presence of hydrogen as fuel in dual fuel mode the HC emissions are reduced by 87% and CO emissions reduced by 86% than the pure diesel [15]. C. Solaimuthu et. al. in their work on selective catalytic reducer for direct injection diesel engine with Mahua blends found that the specific fuel consumption is very low for the blends B0 and B25 at no load and full load conditions. Along with this these blends show very low CO emissions but the HC emissions are little higher for B0 compared to other blends [23]. M. Senthil Kumar et. al. in their work on effect of high octane fuel induction on combustion behaviour with Mahua oil based dual fuel engine found a reduction in combustion duration was in dual fuel mode with Eucalyptus oil with comparatively better brake thermal efficiency [24]. Deepesh Sonar et. al. in their work on varying injection pressure on raw Mahua (Pre-heated) and Mahua Methyl Ester observed that brake thermal efficiency increases for almost all the blends with injection opening pressure, the brake specific fuel consumption for the Mahua oil blends is greater. In case of emission characteristics, it's found that CO and HC emissions are less but on the other hand because of increase in inlet temperature NOx emissions also increases [25].

Gvidonas Lebeckas et. al. in their work on off road vehicle direct injection system with Rapeseed oil found that the performance of engine with Rapeseed oil is on par with the diesel as fuel except with slightly higher brake specific fuel consumption at rated power and maximum torque [16]. M. Pexa et. al. in their work on Rapeseed oil Methyl Ester on IC engines for performance characteristics in comparison with Hydrogenated oil found that for better performance of the engine with Rapeseed oil Methyl Ester the fuel consumption will increase [17]. S. Duran et. al. in their experiment on Rapeseed biodiesel blend along with Karanja blends found that the brake thermal efficiency of the RB20 and RB50 Rapeseed blends are better than the pure diesel at full load conditions. The NOx emission is lower than the regular diesel this is because of the mean gas temperature of the RB20 and RB50 Rapeseed blends [18]. L. Labecki et. al. in their work on multi injection direct injection diesel engine found that results of pure Rapeseed oil and blends of Rapeseed oil show strong reduction in NOx emissions this is because of low inside pressure and temperatures. There is higher amount of HC and CO emissions in case of Rapeseed oil and Rapeseed oil blends because of incomplete combustion [19]. D. H. Qi et. al. in their work on direct injection diesel engine with Rapeseed oil with micro-emulsions as a fuel found that there is a lightly higher brake fuel consumption and there is a drastic decrease in smoke and NOx emissions due to presence of micro-emulsions. In another work on Rapeseed oil based hybrid fuel it was absorved that the smoke emissions were little lower at higher loads in comparative with diesel but there was a slight increase in HC and CO emissions at low loads. Yet in another experiment on dual cylinder agricultural diesel engine with Rapeseed oil blends found that CO and HC emissions were bit high because of unavailability of the localised oxygen, there is a bit lower in CO emissions at higher loads because of higher cylinder, better air-fuel mixture and better combustion [20, 21, 22].

V. Edwin Geo et. al. in their work on DEE port injection with Rubber seed oil found that the brake thermal efficiency of RSO (rubber seed oil) is less comparative to that of diesel which is because of poor mixture formation and regarding emission characteristics NOx, CO and smoke emissions are lowered whereas HC emission increased a little in comparative with diesel for neat Rubber seed oil [26]. M. Satyanarayana et. al. in their investigation on performance, emission and combustion characteristics of different bio oils found that the brake thermal efficiency of Rubber seed oil is around 30.5% whereas for diesel it is around 35%, HC emissions are less whereas CO and NOx are little higher [27]. Vishal V Patil et. al. in their work on influence of butanol on Rubber seed oil Methyl Ester blends found that emission of NOx reduced by 10% with increase in butanol content and emission of CO & HC are negligible, on the other hand brake thermal efficiency reduces with increase in butanol content [28]. S. Senthil Kumar et. al. in their work on their work on CI engines with various injection pressure using Rubber seed oil found that the break thermal efficiency of the engine increases by 25% at an injection pressure of 250 bar which is closer to diesel injection system at 200 bar on the other side the CO, HC and smoke decreased and NOx emission increased for that pressure of 250 bar. Yet in another experiment on B25 (25% Rubber seed oil Methyl Ester) on coated piston with Al_2O_3 found better engine performance in which the brake thermal efficiency is increased by 4% and the brake specific fuel consumption decreased by 9% in coated when compared to uncoated piston. The smoke, CO and HC emissions are also decreased [29, 30].

III. CONCLUSIONS

From the above literature review the study of performance, combustion and emission characteristics of the five-major biodiesel (Jatropha, Mahua, Cotton seed, Rubber seed and Rapeseed oil) blends the following observations are made;

The performance characteristics of Rapeseed oil blends is superior to that of other biodiesel blends and almost on par with the diesel

Emission of smoke, HC and CO is little more in case of Rapeseed oil in comparison with other biodiesel blends

The emission of NOx is less in case of Rapeseed oil blends than that of other biodiesels

But by making small modification in the engine like coating of the piston the emission characteristics like HC, smoke and CO can be regulated which makes Rapeseed oil blends as the superior and better alternative biodiesel.

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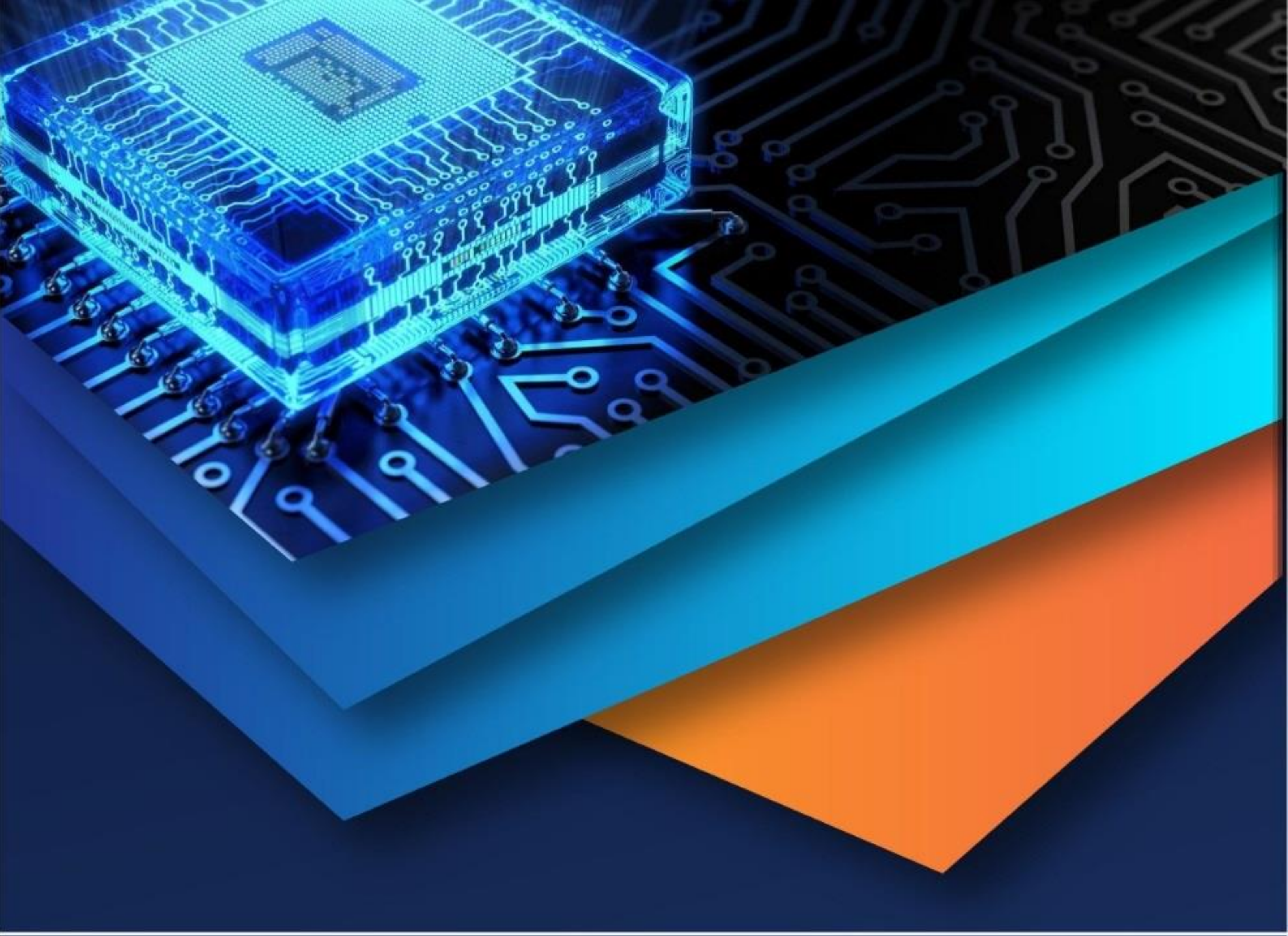

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