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Karanja (pongamia pinnata) biodiesel as an alternative fuel for DICI engine: A review

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Abstract

The use of vegetable oil as an alternative fuels has been known for 100 yrs when the inventor of the diesel engine Rudolph Diesel first tested peanut oil in his compression ignition engine. Over the last few decades due to industrial development and rapid increase in vehicle production the demand of fossil fuels increases continuously. But these fossil fuels are limited available and the emissions like CO, HC, NO_x coming by the burning of these fuels affects negatively on the environment. This forces scientist to work toward alternative fuels. .Vegetable oils and tree born oil seeds are the potential alternative for fossil fuels. These fuels are termed as biodiesel. Biodiesel could be an answer for the alternative fuel, which is renewable, biodegradable, non-toxic and less polluting. This paper reviews the performance, emission and combustion characteristics of karanja biodiesel as an alternative fuel for the single cylinder, four strokes, direct injection and water cooled diesel engine.

Keywords: Biodiesel, emission, renewable energy , performance

1. Introduction

In last few years interest and activity has grown up around the globe to find a substitute for the fossil fuels. With the increase in population, number of automobiles day by day the demand and consumption of petroleum based fuels increases. Being a fifth largest primary energy consumer and fourth largest petroleum consumer in the world the demand of petroleum based fuel like diesel increases continuously in India and hence it is necessary to find the alternative solution. There are various sources of alternative energy have been discovered in which biodiesel is one of the most potential alternatives to cut down the dependency on fossil fuels by replacing it fully or partially. Using vegetable oil for diesel engine is not a new idea. *Rudolf diesel,* the inventor of diesel engine had used peanut oil as fuel for the demonstration of his diesel engine in 1900. But the use of vegetable oil to produce biodiesel is not feasible solution as far as the country like India is concerned due the big gap in demand and supply of such oil. So it is necessary to go for non-edible vegetable oil like Jatropha, karanja, Mahua. The seeds of these plants contain 27-50% of oil and hence they are the potential alternative for fossil petroleum based fuels [8]. Karanja (Pongamia Pinnata) is the species of tree in pea family and grows in parts of India, China, Japan, Malaysia, Australia and Pacific islands. It is often planted as an ornamental and shade tree but now-a-days it is considered as alternative source for Bio-Diesel. It is legume tree that grows to about 15-25 meters in height with a large canopy which spreads equally wide. It may be deciduous for short period. The leaves are soft, shiny, burgundy in early summer and mature to a glossy, deep green as the season progresses. Flowering starts in general after 3-4 years. Cropping of pods and single almond sized seeds can occur by 4-6 years. The tree is well suited to intense heat and sunlight and its dense network of lateral roots and its thick, long taproot make it drought-tolerant.

2. Fuel Properties

Density, viscosity, heating value and cetane number, etc. are considered as the most important properties of a fuel for its application in engine. In order to define limit of these properties different types of standard like ASME, EN, ISO, etc are used from which ASME is most widely used standard [12]. These properties define the quality of fuel on which engine performance and emission depends. It's very difficult to use pure vegetable oil as a fuel directly in available diesel engine due to its higher viscosity, lower cetane number and lower calorific value. Transesterification is the process used which converts this pure vegetable oil into methyl or ethyl ester. Which have improved properties than pure vegetable oil. Now-a-days, blending is widely being used to improve biodiesel fuel properties. Table 1 shows the fuel properties of different Karanja biodiesel blends and diesel.

Table 1 Properties of different karanja biodiesel blends and diesel [2].

Property	Unit	K100	K50	K20	K10	K5	Diesel
Density	g/m3	0.881	0.856	0.841	0.836	0833	0.831
Viscosity	cSt	4.42	3.51	3.11	3.04	2.91	2.78
Calorific value	MJ/kg	37.98	40.8	42.57	43.18	43.48	43.79

3. Performance and Emission

Different researchers have performed number of experiments to find sustainability of different biodiesel fuels as an alternative fuel for diesel engine. In this study majorly use of Karanja biodiesel as an alternative fuel is reviewed.

M.Srinivasa Rao et al. have carried out the test to find eco friendly alternative for diesel. The experiment was carried out to determine effect of catalyst in biodiesel production process. The catalyst used were NaOH and KOH and oil used was pongamia pinnata. Also the working characteristics of biodiesel and biodiesel water emulsion were compared with neat diesel. The engine used were single cylinder, four stroke, naturally aspirated, DICI engine with AC alternator for loading. In the performance analysis it was found that BSFC decreases with increase in bmep (brake mean effective pressure) for all fuels. BSFC water emulsion biodiesel was higher than neat biodiesel which is higher than neat diesel. This may be due to prolonged ignition delay decreases cetane number of water emulsion biodiesel. BTE increases with bmep and it is maximum for neat diesel among the all other test fuel. The decrease in BTE for biodiesel could possibly be due to combined effect of their lower calorific value and higher viscosity. In emission analysis it was found observed that HC and CO emission for biodiesel were less than that of diesel due to more oxygen molecules present in diesel. But water emulsified biodiesel shows more HC and CO emission than neat biodiesel. This is due to adverse effect of water addition which leads to incomplete combustion. NO emission was high for biodiesel compare to diesel due to more oxygen content and peak combustion temperature. Smoke opacity of biodiesel is less compare to neat diesel because of more oxygen content.

Atul Dhar et al. states that one of the emission from diesel which have adverse effect on human body and on environment is PM (Particulate Matter). It is very important to have control on PM emission from diesel engine as it leads to many respiratory problems. So newer emission legislation about emission of PM are now globally accepted. Author have investigated effect of karanja biodiesel and its blends on particulate size, number distribution at different engine speed and loads in a transportation DICI sport utility vehicle engine. From experimental investigation it was found that number concentration of accumulation mode particles was lower for lower biodiesel blends at all engine loads. From the experiment it was found that number concentration of particulates increases with increase in engine load. This may be due to at higher engine load higher fuel quantity is injected and more fuel is combusted in diffusion combustion mode, hence more number of particles are formed. Maximum PM emission was observed at B100.

Chit Wityi Oo et al. were carried out research to find the ignition and combustion characteristics of various biodiesel blends in diesel engine. The fuels used were diesel, Jatropha methyl ester (JME), coconut methyl ester (CME), soybean methyl ester (SME) and palm methyl ester (PME).In the study it was observed that temperature has great effect on ignition delay period. Ignition delay period of all the biodiesel is shorter than that of diesel and CME shows minimum ignition delay for the temperature range of 600k to 1200k. This may be due to its lower viscosity and distillation temperature. Ignition delay also decreases when temperature and pressure increases. Also evaporation and mixing process of all fuels is affected by physical properties such as density, viscosity and distillation temperature. CME shows faster evaporation and ignite in short time than other biodiesel fuels and minimum at B10. So blending up to B20 of karanja biodiesel was useful.

P. Thennarasu et al. have carried out experimental investigation to analyse combustion characteristics of VCR diesel engine fuelled with karanja biodiesel blend. The blends taken were B10, B20, B30, B50 and B75. They also have varied the compression ratio as 16.5, 17.5 and 18.5. It was observed that ignition delay for biodiesel blends was lower than diesel and decreases with increase in biodiesel proportion. Increase in peak pressure with load was observed. Maximum peak pressure was observed for diesel than biodiesel blends. This may be due to slow combustion rate in initial stage of combustion for biodiesel. Rate of pressure rise for biodiesel blends was observed less than neat diesel. So from combustion analysis they have concluded that B10 is the best alternative fuel for diesel engine at slightly higher compression ratio without any modification in existing engine

K. Gopal et al. have tested pongamia pinnata (karanja) biodiesel for emission and combustion characteristics of DICI engine. The blends taken were B20, B40, B60 and B80. BSFC of all blends was found more than pure diesel at all loads. BTE of diesel was observed higher than biodiesel blends. This may be due to lower heating value of diesel. CO and HC emissions for biodiesel blends observed were less than pure diesel but NOx emissions were more. This may be due to more oxygen content and higher combustion temperature of biodiesel. In combustion analysis it was found that in cylinder pressure rise for diesel and biodiesel blends follow same pattern and it increases with increase in load. Peak pressure rise observed near to TDC but as load increases peak pressure rise was slightly after TDC. This may be due prolonged delay period which extends premixed combustion phase. Peak heat release rate for biodiesel was observed less than diesel. This may be due to shorter delay period and lower calorific value of biodiesel. From all three analysis they have concluded that karanja biodiesel can be used as a alternative fuel for diesel engine

M.Mufijur et al. have reviewed the role of biodiesel on IC Engines Emission reduction and concluded that at full condition emissions like CO, smoke and NO_x are less biodiesel than diesel and suggested to use lower biodiesel blends. Also it is noted that there are about 22% of global GHG (greenhouse gas) emissions comes only from the transportation sector due to increasing demand of vehicles and biofuel have potential to reduce GHG emission more than 80%.Also in the study it is observed that Pongamia biodiesel reduces CO, smoke and engine noise only increase in NO_x emission.

E. Rajasekar et al. have reviewed the combustion characteristics of CI engine with biodiesel blend and neat biodiesel. Combustion parameters like cylinder pressure, peak pressure, rate of pressure rise. Start of combustion, ignition delay period, combustion duration, mass fraction burned, instantaneous heat release rate and cumulative heat release of biodiesel blend and diesel have been reviewed. They observed that results from different studies about performance, emission and combustion characteristics were not same. They depend upon engine type, operating and maintenance condition, testing method, injection system and on calibration. In spite of these results observed biodiesel and their blends shows similar characteristics in performance, emission and combustion as that of diesel. So from the review it can be concluded that biodiesel may be the potential alternative for diesel engine without any major modification.

S. Nayak et al. investigated experimentally performance and emission characteristics of diesel engine fuelled with Mahua Biodiesel with the addition of suitable additive like Dimethyl carbonate. Result shows that brake thermal efficiency increases and BSFC decreases with increase in additive percentage than pure biodiesel. This may be due to with the addition of additive better combustion will take place. With respect to load increase in Exhaust gas Temperature [EGR] was observed for all test fuels. For pure biodiesel due its high combustion temperature highest EGT was observed. EGT decreases with increase in percentage of additive. In emission analysis it was found that CO is more for pure biodiesel because of poor spray characteristics that results in improper combustion but with the increase in percentage of additive CO emission reduces this is due to good spray characteristics and proper combustion. However with increase in percentage of additive with respect to load HC emission increases because of low cylinder pressure and temperature causing comparatively lower burning rate. Decrease in smoke and NO_x emission was observed with increase in percentage of additive than pure biodiesel.

H. How et al. experimentally investigated the effect of using bioethanol as an additive to biodiesel-diesel blends on the engine performance, emission and combustion characteristics of a four cylinder, high pressure, common rail direct injection diesel engine. The blends used were B20 (20% coconut biodiesel+ 80% diesel) and B20E5 (20% coconut biodiesel + 5% ethanol + 75% diesel). These blends were compared with diesel and it is found that B20 and B20E5 show better BTE and less smoke, CO, NO_x emission than pure diesel

S. Savariraj et al. have carried out performance, emission and combustion analysis of fish-oil biodiesel. The blends used were B25, B50, B75 and B100. The results were compared with mineral diesel. In the performance analysis it was found that brake thermal efficiency and brake specific fuel consumption was higher for B100 than pure diesel. In combustion analysis it was found that peak pressure for all biodiesel blends were found less than diesel Start of combustion with the use of the biodiesels advanced more than 1^0 CA compared to diesel. Smoke density, NO_x, CO and HC emissions for all biodiesel blends were found more. This may be due to incomplete combustion of fish-oil biodiesel fuel caused by poor vaporisation and higher viscosity of biodiesel.

P. Naik et al. have carried out performance analysis of CI engine using Karanja biodiesel as an alternative fuel. Brake thermal efficiency of Karanja biodiesel found lower than that with diesel fuel. For all load conditions BSFC was found to increase with increase in blend proportion as compared to diesel fuel. Increase in NO_x emission and decrease in CO and HC emissions were found with increase in blend proportion than pure diesel. So they have concluded that blend B20 and less can be used in diesel engine without any major modifications.

T.Pushparaj et al. have carried out combustion, performance and emission analysis of CNSL (Cashew nut shell liquid) biodiesel with ethanol and diethyl ether as a additives. The blends used were B20, B20+E10, B20+D10. The test was carried out on single cylinder, four stroke, naturally aspired, water cooled, 16.5:1 compression ratio DICI engine. In combustion analysis maximum peak pressure was observed for diesel than any other blend but in spite of higher viscosity than diesel biodiesel blends shows lower ignition delay than diesel. In performance analysis it was observed that BTE of diesel and all other blends increases with respect to load. This may be due increase in BP with load. BTE at full load condition of B20+D10 was 25.48% which was around 5% more than that of diesel. BSFC of all fuel blends decreases with increase in load. This may be due to higher energy required per kilowatt was higher than that of lower load. Exhaust gas temperature was observed more for all blends than diesel. In emission analysis it was found that CO emission reduces up to 80% load but after that it increases. The CO emission of B20+D10 blend was about 19% less than that of B20+E10 blends at full load condition. Max NO_x emission was observed for B20 than other blends. NO_x emission was found to be reduced by the addition of ethanol and diethyl ether to biodiesel. Average reduction of around 57% was observed with B20+E10 and 69% for B20+D10 blend when compared with B20 blend. HC emissions for B20+D10 were less than that of B20+E10. Also smoke opacity of B20+D10 gives better results at medium load than pure diesel. So 20% CNSL and 10% diethyl ether as additive can efficiently be used in diesel engines without any modifications.

M. Arbab et al. compared the fuel properties, engine performance and emission characteristics of commonly used different vegetable based biodiesel derived from experimental results at different conditions performed worldwide. There were total seven biodiesel considered namely Jatropha, palm, coconut, cottonseed, sunflower, soyabean and rapeseed. They have compared all these biodiesel and their blends with each other and with diesel and concluded that if we want to improve all the important properties of fuel like kinetic viscosity, cetane number, calorific value, flash point and fire point then blend of single biodiesel is not sufficient one has to go for blends of two or more biodiesel. In general biodiesel reduces CO, HC and smoke emission and increases NO_x emission but coconut biodiesel reduces NO_x emission along with all other emissions. So among these all seven biodiesel in emission point of view coconut biodiesel is better. Biodiesel in general increases BSFC and reduces BP and torque due to lower calorific value. But biodiesel blends up to 20% have shown lower BSFC.

S. lohan et al. have taken brief review on current status, future and path of development of biodiesel as an alternative fuel for diesel engine. As India being the fifth largest primary energy consumer (as per international energy annual) and the fourth largest petroleum consumer in the world will not meet the countries growing demand of fuel. Hence it is necessary to go for alternative fuel like biodiesel in which karanja, Jatropha, Mahua and Neem were some potential biodiesel fuel. As these biodiesel have shown properties very close to neat diesel hence very small or no modification were required in diesel engine. For lesser blend concentration all these biodiesel shows better performance characteristics. Also the emissions from these biodiesel were compatible with diesel and some policies related biodiesel if revised and cost of non-edible biodiesel is reduced then biodiesel may be the complete fuel in future.

M. Ali et al. carried out the test to study the aspects related to the production of biodiesel from Neem oil and to investigate its fuel properties. As in current scene it is necessary to reduce the dependency on fossil fuels and search the fuel which partially replace the fossil fuels and also have less pollution. Vegetable oils are the alternative fuels, but they can't be used directly due to their high density, high viscosity and lower calorific value. So it is necessary to convert these vegetable oils into biodiesel to make it consistent with fuel properties of diesel. Neem oil whose seeds contain 30-40% of oil can be converted into biodiesel by transesterification process. Biodiesel from Neem oil have shown fuel properties that are very close to diesel. The only challenge of using Neem oil biodiesel is its production cost. If it has to use commercially as a fuel its cost should be reduced.

4. CONCLUSION

In the performance and emission analysis it has found that Karanja biodiesel blend up to B20 shows better thermal efficiency, lower brake specific fuel consumption, lower HC and CO emissions. Only the NO_x emission observed were more due to more oxygen content and higher combustion temperature of biodiesel blend than diesel. In combustion analysis it was observed that biodiesel shows comparable heat release rate and peak pressure with diesel. From the study it can be concluded that Karanja biodiesel could be the future potential alternative for diesel engine and blend up to B20 can be used in diesel engine without any major modification.

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