Performance and Emission of Vegetable Shell Pyrolysed oil blended with Diesel fuel in a DI Diesel Engine

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ABSTRACT

The main aim of the work is to performance and emission of Vegetable Shell Pyrolysed oil blended with Diesel fuel in a diesel engine. This process is used to extract the pyro oil from the cashew nut shell bio mass materials. The biomass used a cashew nut shell at the reaction temperature of 350-750ºC to obtain pyro oil through fast pyrolysis. Property studies were made on the pyro oil called CNPO, CNPO50D50 and CNPO40D50DEE10 to property characterize it as fuel for diesel engines. Blending of CNPO (namely CNPO50D50 and CNPO40D50DEE10) was prepared by mixing respectively diesel by volume. All the fuels were tested in a single cylinder diesel engine for their performance was compared to diesel fuel. Engine test results showed comparable performance for all CNPO50D50 and CNPO40D50DEE10with diesel fuel. At the full load condition the power output the brake thermal efficiency was found as 31.43% respectively with CNPO40D50DEE10 and where as it was 29.5% with BD. There is a considerable reduction in Smoke and NOx emissions with CNPO40D50DEE10 compared to BD at all power outputs.

KEY WORDS: Cashew nut shell, Fast pyrolysis, Engine, combustion, heat release rate.

1. INTRODUCTION

Diesel engines are popular prime movers which are used in industrial, transport and agricultural applications due to their high efficiency and reliability. However, suffer from high smoke and nitric oxide emissions. The increasing in the cost of diesel fuel, reduced availability, more stringent governmental regulations on exhaust emissions and the fast depletion of world-wide petroleum reserves provide a strong encouragement to the search for alternative fuels. The commonly accepted that clean combustion in diesel fuel can be achieved only if engine development with fuel reformulation and the use of alternative fuels are implemented.There are many number of alternative fuels for diesel engines such as, vegetable oil esters, tyre pyrolysis oil, orange oil, kikar seeds oil, coconut shell oil etc. were introduced from the recent researches. Depletion of petroleum derivatives and increase in emission in diesel engine increases the research interest in the area of alternative fuels. Pyrolysis is the thermal degradation of carbonaceous materials at temperatures between 300˚C and 700˚C in the absence of oxygen. The process is endothermic and requires an external indirect input of energy typically through the walls of the reactor. The heat volatilizes and decomposes the organic matter to produce a pyrolysis gas and liquid and solid char in relative proportions depending on the process parameters of temperature and pressure. An oxygen-free atmosphere in the paralytic chamber is hard to achieve was reported by Howell heck. Therefore, an oxidation zone may exist. Oxygen bound in the refuse and from the air reacts with solid carbonized fuel, producing carbon monoxide.

Products of pyrolysis:

Gas: The gas is primarily of methane, hydrogen, carbon monoxide, water, and more complex of hydrocarbons, each as ethane, propane, oils and tars. The exact components in percent composition of these gases formed by pyrolysis of either MSW or any other feed stream cannot accurately be predicted in a real system.

Liquids: The pyrolysis oil consists of mainly of tar, light oil, and liquor. The tar contains from 17% to 26% olefins, 62% to 80% aromatics, and 4% to 15.5% paraffin's and naphthenes, and the remainder is organic compounds that have been identified as acids, bases, ketones, and aldehydes containing from one to eight carbon atoms. The major components of light oil are benzene and toluene.

Char: The solid char residues are a light weight char and the very stable but will not deteriorate, although it can absorb moisture. The use of the solid char residue as a fuel, a landfill cover. The solid char residue with high char content may allow it's used as a fuel in boilers furnaces, or it can be utilized as an external heating source in the pyrolysis process.

Working principle of pyrolysis: The Pyrolysis operating conditions are simple and this means that the furnace system is easier to apparatus and once apparatus, it is easier to run since it is not perturbed by high variations of the feed characteristics.

Fig.1. Pictorial view of the apparatus used for the oil extraction

The reactor is placed on the floor with temperature indicator. The outlet of the pyrolysis reactor is directly coupled to the volatile condenser using a stainless steel tube which can withstand high temperature. Another one of the inlet is connected to the reactor from the nitrogen cylinder. The condenser is firmly connected with the help of alloy gasket. Counter flow condensation was selected. The flow of water is directed against the direction of Pyrolysis gases. The condensate drips into the gas liquid separator. The non-condensable gases are connected to the neck of other tube and pass through the exhaust tube to gas burner. To indicate the temperature outside the reactor thermocouple is connected to the digital temperature indicator. The apparatus button set the temperature level. While the specified temperature is attained at the apparatus, it's automatically off the supply to the reactor. When the temperature is tend to reduce, it's automatically gets switched on and power supply were applied. In this Pyrolysis apparatus, chipped material is filled in the reactor initially, and then reactor closed with the help of bolt. The steel wooden gasket was used to prevent leakage. Then supply nitrogen gas from the cylinder to reactor for the time period of 3 to 4 min, after it's closed. Switch on the electrical current, the initially set the temperature up to 750^{0}C in the temperature controller. For condenser water is supplied from inlet to outlet. Gases are collected in the balloon. Finally time taken was noted that to reach the temperature up to 750^{0}C. Cooling time of the pyrolysis reactor is 16 to 18 hours. Finally we have collected the Pyrolysis oil, char and syngas's. The pictorial diagram of the apparatus was shown in the above figure1.

Fuel preparation:

CNPO50D50 Preparation and CNPO40D50DEE10: Cashew nut shell pyro Oil is made blend in to diesel fuel at the various proportions and finally output found at around 50% volume maximum stability was attained. The CNPO50D50 blends was prepare in the laboratory with 50% by volume of cashew nut shell pyro oil and 50% of neat diesel. And cashew nut shell pyro oil 40% by volume and 50% diesel by volume and 10% mixing with the oxygen additives di ethyl ether add and the blending preparation maximum stability was attained. Its properties were measured in the Table.1. The literature review it is found that Calorific value of the CNPO is around 45 MJ/kg.

Table.1. Property of Diesel and CNPO50D50 and CNPO40D50DEE10

Properties	Diesel	CNPO50D50	CNPO40D50DEE10
Kinematic Viscosity at 40^{o}C (cst)	3.62	7.2	6.3
Flash Point (^{o}C)	51	68	64
Fire Point (^{o} C)	56	73	68
Density at 30^{o}C (kg/m^3)	830	920	896

Engine set- up: A computerized kirloskar diesel engine of AV l model, four stroke direct injection. Naturally aspirated air cooled Engine was utilized to investigate this study. The engine specifications are listed in table 3.1. The engine was directly coupled with an eddy current dynamometer and a data acquisition system, so that the data can be saved. AVL five gas analyzer was used to measure the emissions characteristics; smoke opacity has been measured using the AVL smoke meter. The engine was operated on diesel first and then blended pyrolysis oil CNPO50D50 and CNPO40D50DEE10.

Table.2. Specification of the Diesel Engine

No. of Cylinders	01
Bore	87.9mm
Stroke	110mm
Compression ratio	17.5:1
Rated power	4.4 KW
Injection pressure	200 bar
Rated speed	1500 rpm
Injection timing	25˚ BTDC

Fig.2. Photographic view of Engine set up.

2. RESULTS AND DISCUSSION

Results of Brake thermal efficiency: The different variations of the brake thermal efficiencies at different load for various combinations have been shown. The thermal efficiency is 31.43% at full load for CNPO40D50DEE10. It can also be observed that the efficiency for CNPO50D50 and CNPO40D50DEE10 are 25.87% and 31.43% respectively. The thermal efficiency of CNPO40D50DEE10 is higher compares then diesel fuel. The increase in the thermal efficiency for CNPO40D50DEE10 may be attributed to better fuel atomization due to lower viscosity and increases the volatility. The efficiency of CNPO50D50 blends are slightly lower compared to diesel fuel. The thermal efficiency is 29.56% at full load for Diesel fuel.

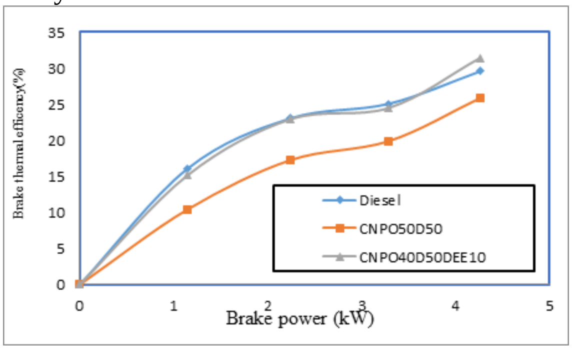

Fig.3. Brake power vs Brake thermal efficiency

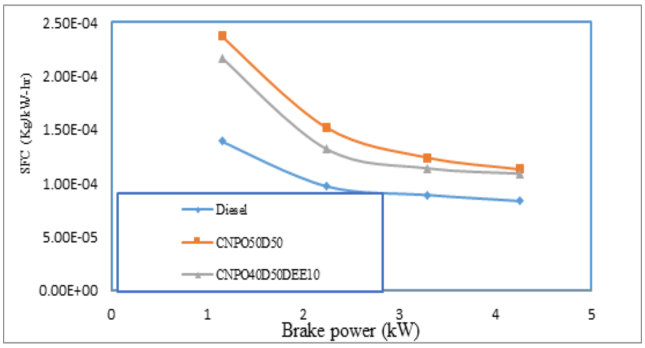

Fig.4. Brake power vs Specific fuel consumption

Specific fuel consumptions: The Specific fuel consumption is a very reliable factor to compare the three fuels as the Calorific value, viscosity and density of the blends are slightly different from that of diesel fuel. They can be observed that as the load increases and SFC decreases for all fuels. At the same time, it can be seen that SFC increases with lower load it consume more fuel with CNPO50D50 and CNPO40D50DEE10 blends the diesel fuel, this is due to the effect of density, viscosity and lower calorific values of fuel blends. It is show that CNPO50D50 and CNPO40D50DEE10 closer SFC values with diesel fuel.

Exhaust gas temperature: It can be observed that the EGT generally increases with increase in blend concentration and load. The CNPO50D50 blends show that lower gas temperature varies from 209˚ C to 546˚ C at maximum load for DF whereas it was varies from 199˚C at no load condition 450˚C at maximum load for CNPO40D50DEE10.

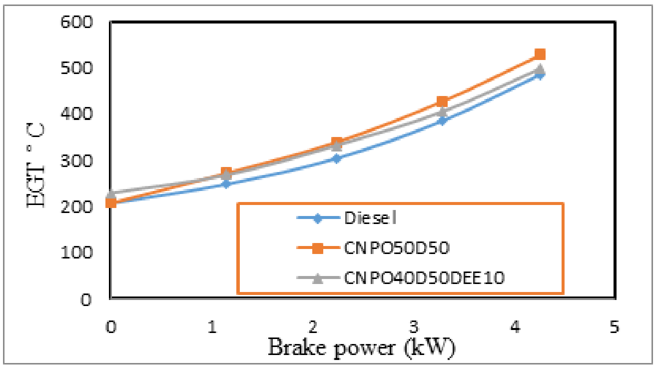

Fig.5. Brake power vs Exhaust gas temperature

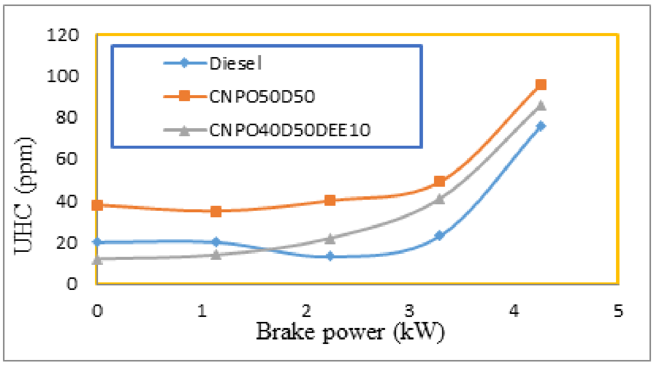

Fig.6. Brake power vs Hydrocarbon emission

The reason for lower EGT for CNPO40D50DEE10 blends are due to slightly lower viscosity which results a lesser penetration of the fuel, resulted in the combustion chamber due to the lesser amount of heat is developed.

Hydro carbon Emission: The variation of the hydrocarbon emission in the exhaust gas is shown in figure. The more amount of UHC emission is the direct result of incomplete combustion of fuel. The hydrocarbon emission is increasing with increasing load. From the graph UHC emissions19 ppm at no load condition and 86 ppm at the maximum load for the CNPO40D50DEE10. They vary 40 ppm at no load to 96 ppm at full load for CNPO50D50. UHC was higher at peak load for CNPO50D50 and CNPO40D50DEE10. This may be attributed to one of the reasons that the fuel spray does not propagate deeper into the combustion chamber and gaseous hydrocarbons remain along the cylinder wall and the crevice volume and left unburned. The unsaturated hydrocarbons present in the CNPO50D50 and CNPO40D50DEE10 which are unbreakable during the combustion process.

Nitrogen oxide: From the figure shows that NOx emission increases with increase the load, but lesser than that of diesel fuel. Two important parameters result in the formation of the NOx. One of the parameter is stoichiometric and the other parameter is cylinder temperature. The stoichiometry of the combustion is lean than lower NOx is formed. Due to the diffusible mixed of fuel and air occur along the spray envelope, the combustion takes place with near stoichiometric, forming higher NOx emission. The in cylinder temperature has a strong effect on the formation of NOx. If the combustion temperature is higher, then higher NOx is formed. In the case CNPO50D50 and CNPO40D50DEE10 blends, the lower in cylinder temperature is the reason for water content are present in the fuel, resulted in lower NOx levels than diesel fuel.

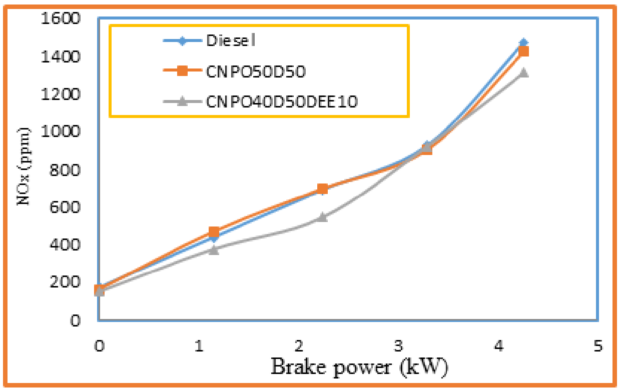

Fig.7. Brake power vs Nitrogen oxide emission

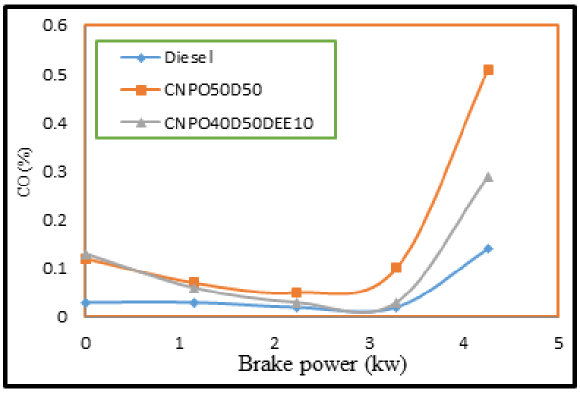

Fig.8. Brake power vs Carbon monooxide emission

Carbon Monoxide Emission: The comparisons of CO emission with load as shown in figure. CO is a product of incomplete combustion. The insufficient amount of air in the fuel or in sufficient time for complete combustion cycle CI engine operates. With lean mixtures the CO emission would be low. The CNPO50D50 resulted in higher CO emissions as compared to diesel at all power outputs. The maximum CO emission was found as 0.56%, 0.29 % and 0.14% respectively for CNPO50D50, CNPO40D50DEE10 and BD at the maximum load of 4.4 kW. It was noted as 0.14% with BD. The CO emission in diesel engine is due to the fuel richness which results in partial oxidization of carbon atoms in the fuel. It is already explained that the CNPO50D50 due to their poor energy content resulted in fuel richness which has lead to incomplete combustion of the fuel. It is seen that CNPO50D50 emitted highest CO emissions among all fuels.

Heat release rate analysis: The wall heat transfer was calculated by using Hohenberg's Convective heat transfer coefficient. It is clearly seen that BD resulted in maximum rate of the heat release and the fraction of fuel burned during the initial period (i.e. premixed combustion) of time whereas the premixed combustion rate was lower and the diffusion combustion rate was slightly higher for CNPO50D50 and CNPO40D50DEE10 as compared to diesel fuel. There was a delay in start of ignition (indicated clearly in the pressure crank angle diagram) with CNPO50D50 and it was increased further with CNPO40D50DEE10. The reduction in premixed combustion rate of the emulsions of CNPO50D50 can be explained by the high viscosity and density of the fuels which resulted in combustion to be more in the diffusion combustion phase. At medium engine load (i.e. 50% load) illustrated in Figure 4.7 the heat release pattern showed a sharp and short premixed combustion with all the tested fuels. CNPO50D50 and CNPO40D50DEE10showed lower peak values as compared to BD.

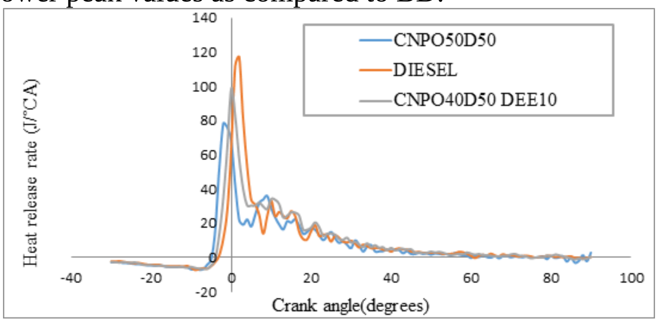

Fig.9. Variation of Heat Release Rate at Peak Power output

CONCLUSION

Engine test with CNPO50D50 and CNPO40D50DEE10 shows comparable performance with all power output of diesel fuel. All the fuels resulted in significant reduction in Exhaust gas temperature and NOx emissions from CNPO50D50 and CNPO40D50DEE10. HC and CO emissions were found to higher as compared to diesel fuel. This concludes that pyro oil obtained from pyrolysis of Cashewnut shell can be used as a partial substitute for diesel fuel. To use CNPO as soul fuel, the engines need further modifications.

REFERENCES

Adisakpattiya, Suntornsuttibak, Production of bio oil via fast pyrolysis of agricultural residues from cassava plantations in a fluidized bed reactor with a hot vapour filtration unit, Journal of analytical and applied pyrolysis, 95, 2012, 221-235.

Faisal Abnisa, Optimization and characterization studies on bio-oil production from palm shell by pyrolysis using response surface methodology, Biomass and Bioenergy, 23, 2002, 307 – 314.

Hohenberg GF, Advanced Approaches for Heat Transfer Calculations, Technical papers of Society of Automotive Engineers, 1979.

Hyeon Su Heo, The production and evaluation of bio-oils from the pyrolysis of sunflower-oil cake, Biomass and Bioenergy, 35, 2011, 3604 - 3616.

Kasiraman G, Nagalingam B, Balakrishnan M, Performance, emission and combustion improvements in a direct injection diesel engine using cashew nut shell oil as fuel with camphor oil blending, Energy, 47, 2012, 116-124.

Mani M, Nagarajan G, Sampath S, An experimental investigation on a DI diesel engine using waste plastic oil with exhaust gas recirculation, Journal of Fuel, 89, 2010, 1826–1832.

Murugan S, Ramaswamy M.C, Nagarajan G, Assesment of pyrolysis oil as an energy source for diesel engines, Fuel Processing technology, 90, 2009, 67-74.

Murugan S, Ramaswamy M.C, Nagarajan G, Performance, Emission and Combustion Studies of A DI Diesel Engine Using Distilled Tyre Pyrolysis Oil-Diesel Blends, Fuel processing technology, 89, 2008, 152-159.

Murugan S, Ramaswamy MC, Nagarajan G, Assessment of pyrolysis oil as an energy source for diesel engines, Fuel Processing technology, 90, 2009, 67-74.

Prabhahar M, Murali Manohar R, Sendilvelan S, Performance and Emission studies of a diesel engine with in pongamia methyl ester at different load conditions, IJERA, 2012, 2707-2713.

Saqib Sohail Toor, Lasse Rosendahl Andreas Rudolf, Hydrothermal liquefaction of biomass A review of subcritical water technologies, Energy, 36, 2011, 2328 - 2342.

Siva Kumar A, Maheswar D, Vijayakumar Reddy K, Comparision of Diesel Engine performance and Emissions from Neat and Transesterified Cotton seed oil, JJMIE, 2009, 190-197.

Venkatesan K, and Senthilkumar M, Performance and emission studies on a diesel engine using bio oil obtained from pyrolysis of prosopisjuliflora as fuel, JCHPS, 7, 2015, 245-248.

Yang S.I, Hsu T.C, Wu C.Y, Application of biomass fast pyrolysis part II: The effects that bio-pyrolysis oil has on the performance of diesel engines, Energy xxx, 2014, 1-9.