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EXPERIMENTAL INVESTIGATION ON PERFORMANCE OF CASHEW NUT SHELL PYROLYSED OIL BLEND WITH BIO DIESEL AND DEISEL

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ABSTRACT

The project work focus as on the Pyrolysis process of thermal degradation of carbonaceous materials extracting oil from solid waste biomass like Cashew nut shell in the absence of oxygen. In this process temperatures are fixed between 150°C and 650°C. The oil obtained from cashew nut shell biomass was then blended with Bio diesel (Jatropha) and Diesel in five different ratios. Bio oil blends CPO10 (10%CPO oil +10% Bio diesel+80% Diesel), CPO20 (20%CPO oil +10% Bio diesel+70% Diesel), CPO30 (30%CPO oil +10% Bio diesel+60% Diesel), CPO40 (40% CPO oil +10% Bio diesel+50% Diesel) and CPO50 (50%CPO oil +10% Bio diesel+40% Diesel) are prepared with the given volume. Blending of oil is mixing from mechanical stirrer at a speed of 800 rpm for 10 min. The properties of these blends were analyzed such as flash point, fire point, density, viscosity, calorific value and the FTIR analysis was done using all these blends. The performance and emission characteristics of the blends were analyzed by running in IC engine. Among the five samples, the best sample CSO10 was very close to the properties of diesel fuel. The performance shows, that brake thermal efficiency is slightly increased to CSO10 fuel and increased specific fuel consumption and lower exhaust gas temperature. Emissions show that considerable reductions for the smoke, and CO emissions, HC emissions and Nox are slightly increased when compared to diesel fuel. To overcome the usage of diesel fuel these CSO blends of pyro oil can be used without any modification in the diesel engine.

Key words: Bio diesel, Cashew nut shell biomass, pyrolysis oil, Diesel engine, Fast pyrolysis, Performance, Emission.

INTRODUCTION

Alternative fuel for compression ignition engine finds very attractive and has greater scope especially in developing and undeveloped countries due to the fast depletion, cost and environmental pollution from fossil fuels[1]. Different techniques such as gasification,

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anaerobic digestion, pyrolysis and liquefaction are adopted for producing energy from biomass[2-5]. Among these techniques, pyrolysis finds simple and very attractive in extracting oil from biomass[6]. From pyrolysis process of biomass yields solid, liquid and gaseous products such as char, pyro oil and pyro gas[6]. A number of researches have been carried out all over the world on pyrolysis of different materials such as biomass, plastic waste, engine oil, tyre pyrolysis etc. to produce bio oil and used as fuel in diesel engines[7-10]. Investigation reported that blends of pyrolysis oil obtained from pyrolysis process of biomass with diesel resulted in comparable thermal efficiency and emissions with diesel[11-13]. It was found that the mixture of 10%, 20%, 30%, 40% and 50% by volume of CPO, respectively with 90%, 80%, 70%, 60% and 50% by volume of diesel and 10% by volume of biodiesel were found stable and homogeneous for a long period of time (one week). Beyond 50%, separation was noticed and hence the quantity of CPO used was limited up to 50%. Experiments were performed on a single cylinder diesel engine using them CPO10 (10%CPO oil +10% Bio diesel+80% Diesel), CPO20 (20% CPO oil +10% Bio diesel+70% Diesel), CPO30 (30%CPO oil +10% Bio diesel+60% Diesel), CPO40 (40%CPO oil +10% Bio diesel+50% Diesel) and CPO50 (50%CPO oil +10% Bio diesel+40% Diesel) are prepared with the volume of CPO to study the performance behavior of the engine. Results were compared with conventional diesel (BD) and analyzed.

EXPERIMENTAL

Pyrolysis setup

The pyrolysis setup consists of a thermal reactor made of rectangular box copper material with a wall thickness of 10 mm. The reactor has an inlet and outlet for supplying nitrogen gas (0.5 kg/cm^2) at inlet and transferring volatile gases at the outlet. The stainless steel condenser used for the pyrolysis process is of a counter flow type and is connected to the gas liquid separator. The outlet of the reactor was directly connected with the help of an alloy gasket to the condenser using a stainless steel tube, which can withstand high temperatures. The flow of water was directed against the direction of pyrolysis gas flow in the condenser. The condensate was allowed to drip into the gas liquid separator. The non-condensable gases were allowed to pass through the exhaust tube to gas burner. Achromel-alumel thermocouple connected with a digital temperature indicator was used to measure the temperature inside the reactor. A nitrogen cylinder was used to supply the nitrogen gas into the reactor to remove the oxygen present in the reactor to reduce combustion. Initially the cashew shells were cut into small pieces to reduce the size and dried in the sunlight. The dried seeds were fed into the reactor through lid of the reactor for pyrolysis. The pyrolysis reaction was carried out at the temperature of 650°C. During this process, the vapour coming out from the reactor was allowed to pass through the condenser which acts as counted flow type heat exchanger and condensed by circulating water. The CPO oil was then collected in a container. The extracted bio oil was then purified and analyzed for its physical and chemical properties to use as fuel.

Preparation of CSO Oil

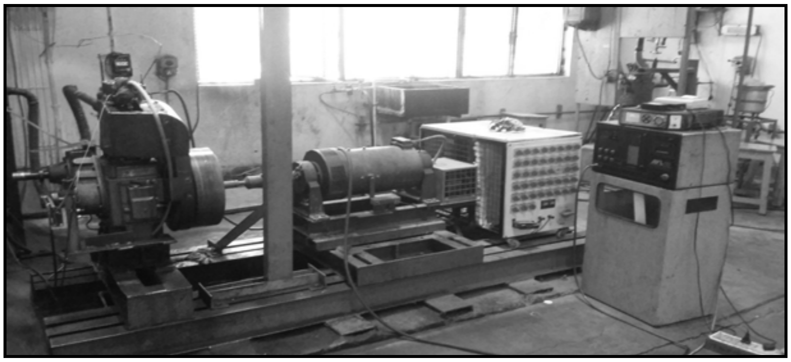
CPO oil can be prepared by mixing the bio diesel with cashew shell pyro oil and diesel fuel. For preparing themCPO10 (10%CPO oil +10% Bio diesel+80% Diesel), CPO20 (20%CPO oil +10% Bio diesel+70% Diesel), CPO30 (30%CPO oil +10% Bio diesel+60% Diesel), CPO40 (40%CPO oil +10% Bio diesel+50% Diesel) and CPO50 (50%CPO oil +10% Bio diesel+40% Diesel) were taken in a container. The mixture was stirred vigorously until a homogenous mixture was formed. The stirrer speed was maintained as 1500 rpm. Stable oil preparations were obtained by stirring the mixture for 15 to 20 minutes and the stability of the blend was found as stable for one week. The blending of oil was mixed with help of a mechanical stirrer, and it is found that up to 50% of CPO bio oil blend diesel fuels, without any separation for long time. CPO10, CPO 20, CPO 30, CPO 40 and CPO50 blends of pyro oil have comparable low properties compared to diesel fuel. All the below properties of blend CPO are closer to that of diesel fuel.

Table 1: Property of different blending pyro fuels

S. No.	Properties	Diesel	CPO	CPO10	CPO20	CPO30	CPO40	CPO50
1	Density (kg/m^3)	836	934	854	863	872	886	891
2	Flash point (^{o}C)	51	64	58	60	62	68	72
3	Fire point (^{o}C)	56	85	63	65	67	73	79
4	Calorific value (Mj/Kg)	43.5	45.0	42.34	41.25	40.56	39.45	38.25
5	Viscosity (Cst)	3.2	9.3	4.2	5.1	5.9	6.6	7.8
6	Water content	0	8.5	1.0	1.8	2.4	2.8	3.2
7	pH Value	5.6	5.3	5.2	5.3	5.4	5.6	5.9

Engine setup

A single cylinder diesel engine four Stroke, air cooled, direct injection diesel engine develops a power output of 4.4 kW at 1500 rpm. Eddy current dynamometer water cooled was used for loading the engine. The test engine setup can be seen in design 1. The fuel flow rate was measured on the volumetric basis using a burette and stop watch. An infrared AVL five gas exhaust analyzer was used for measuring HC, CO and NO in the exhaust. Black carbon smoke levels were measured by using a standard AVL smoke meter. Tests were conducted for four different loads such as 25%, 50%, 75% and 100% of the maximum power output with the fixed engine speed of 1500 rpm. All the tests were carried out with the injection timing of 27^o before TDC for all the tested fuels



Design 1: Engine set-up

RESULTS AND DISCUSSION

Performance and emission characteristics

The experiments were done at different load 25%, 50%, 75% and 100%. Static injection timing 27^o bTDC at the rated injection opening pressure are 160 kg/cm^2. The specific fuel consumption (SFC) and the brake thermal efficiency (BTE) can be calculated by the engine speed, torque and mass consumption rate of the fuel. Fig. 1 and Fig. 2 shows the SFC and the BTE variations under different brake power for 1500 rpm.

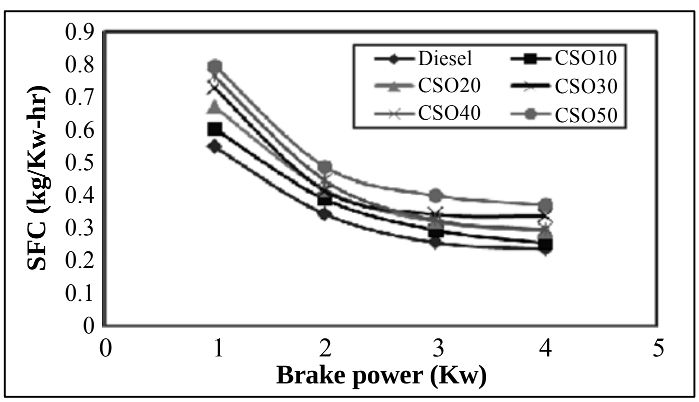


Fig. 1: Variation of specific fuel consumption

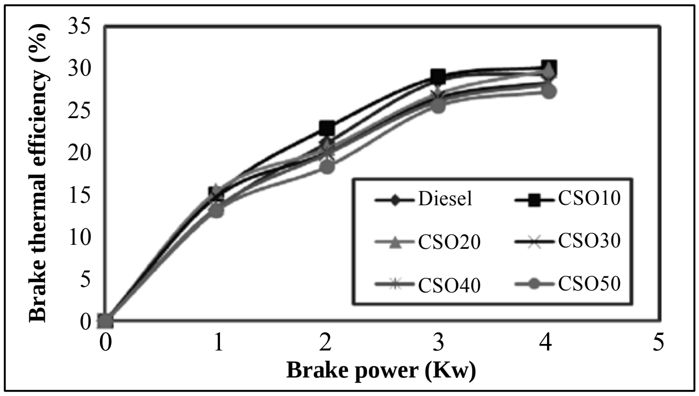


Fig. 2: Variation of brake thermal efficiency

The SFC of the CSO blended pyro oil is slightly increased than that of diesel fuel. This is due to the effect of viscosity and density and mixture formation of CSO blends of pyro oil. The increase in blend percentage of pyro oil the calorific value decreases. Hence CSO10 blend gives less SFC compare to CSO50. SFC consumption of the higher percentage of pyrolysis blends increases compared to that of diesel.

In all the cases of BTE has the tendency to increase with increase in brake power. The BTE of all blends of pyro oil is lower than that of diesel fuel. This is due to high viscosity and density of CSO blends. CSO10 blend gives the higher BTE compare to other fuel namely diesel, CPO 20, CPO 30, CPO 40 and CPO50. Hence because an account of calorific value and better mixture formation.

The exhaust gas temperature as shown in Fig. 3 is lower for all the blends of pyro oil as compared to BD operation at all power outputs. The CSO10 blend increase in exhaust gas temperature with these fuels is due to the combustion occurring slightly more in the diffusion stage and resulted in late burning to be more as a result of slow burning nature of pyro oils.

The smoke emissions resulted from burning of BD and the pyro oil blends are indicated in Fig. 4, Smoke level increased with increases in engine power. This is due to the increase in amount of fuel injected with increase engine in power.

It is interesting to see that the smoke emission was found as lower for all pyro oil blends at all power outputs as compared to BD operation. The lowest smoke emission was found with CSO10 as 88 ppm followed by CSO20 as 83 ppm, CSO30 as 79 ppm, CSO40 as 73 ppm and CSO50 as 67 ppm. In diesel engines smoke is formed as 97 ppm. Pyro oil blends show that considerable reduction in NOx emissions as compared to BD at all loads as shown in Fig. 5, CSO50 resulted in lowest NOx emission of among the emulsions at all power outputs. At the maximum power output of 4.4 kW the NOx emission was found as 745 ppm, 736 ppm and 726 ppm, respectively with CSO20, CSO30 and CSO40 whereas it was 752 ppm with BD. CSO10 shows that slightly increased when compared with diesel fuel. The reduction in NOx emission with the pyro fuels blends is due to the lower air fuel ratio of the injected fuels and lower heating value for the given power output.

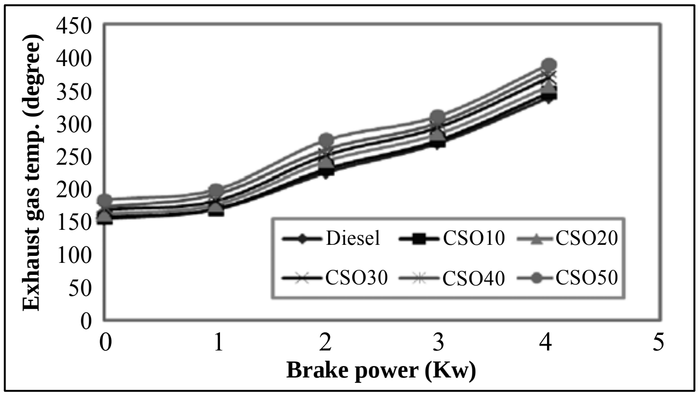


Fig. 3: Variation of exhaust gas temperature

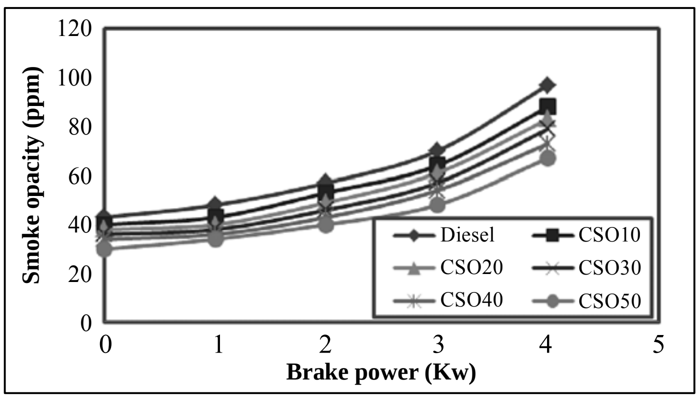


Fig. 4: Variation of smoke emissions

The variation of hydrocarbon emission with brake power for CSO10, CPO 20, CPO 30, CPO 40 and CPO50 is shown in the Fig. 3.6. It is seen that all the tested fuels resulted in higher hydrocarbon emissions at all operating conditions as compared to BD operation. At the 4.4 KW power output, the hydro carbon emission was found as 86 ppm, 90 ppm, 93 ppm, 99 ppm and 108 ppm, respectively CSO10, CPO 20, CPO 30, CPO 40 and CPO50. The main reason for the higher hydrocarbon emissions with the pro oil blends can be explained by the result of high latent heat of vaporization of water presented in the fuel. It was noted as 81 ppm with diesel fuel.

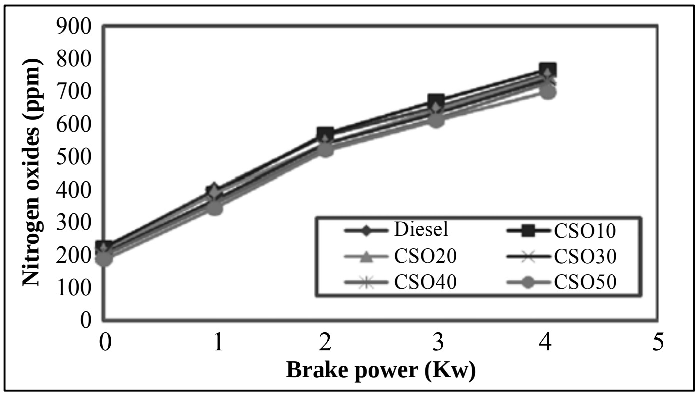


Fig. 5: Variation of nitrogen oxide

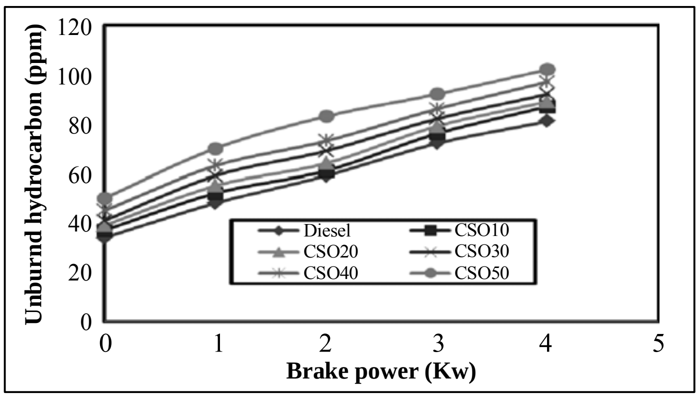


Fig. 6: Variation of hydrocarbon emission

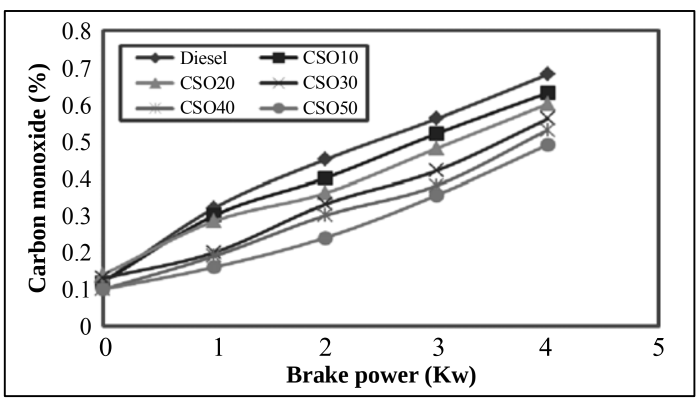


Fig. 7: Variation of carbon monoxide emissions

Fig. 7 indicates the results of CO emissions of CSO10, CPO 20, CPO 30, CPO 40 and CPO50 and BD at different power outputs. All the pyro oil blends resulted in lower CO emissions as compared to BD at all power outputs. The CO emission was found as 0.63%, 0.60%, 0.56%, 0.53% and 0.49%, respectively for of CSO10, CPO 20, CPO 30, CPO 40 and CPO50 at the maximum power out. It was noted as 0.67% with BD. The CO emission emitted from diesel engine is due to the fuel richness, which results in partial oxidization of carbon in the fuel.

CONCLUSION

All Blends of pyro oil with diesel blends are CSO10, CPO 20, CPO 30, CPO 40 and CPO50 resulted in comparable performance with slight reduction in BTE at all power outputs. CSO10 indicated slight increase of BTE as compared to other four blends. The significant reduction in exhaust gas temperature, smoke and CO emissions were achieved with all the blends. HC emission showed more reduction of smoke. Use of CSO blends can be used as alternative fuels in diesel fuel without engine modification and partial replacement of diesel by making CSO blends with diesel.

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