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Experimental Investigation of Improvement of Engine Performance using Cotton Seed Biodiesel with Ethanol Blending and EGR

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Abstract - *Biodiesel is an alternative diesel fuel that can be produced from different kinds of vegetable oils. It is an oxygenated, non-toxic, biodegradable, and renewable fuel and can be used in diesel engines without significant modification. However, the performance, emissions and combustion characteristics will be different for the same biodiesel used in different types of engine. In this study, the biodiesel produced from cottonseed oil was prepared by a method of transesterification and its blends of 20%, 40%, 60%,80% and 100% in volume,with ethanol and different percentage of exhaust gas recirculation (EGR) for analyzing the emission characteristics. The effects of biodiesel addition to diesel fuel on the performance, emissions and combustion characteristics of a single cylinder, DI, water-cooled, four strokes engine were examined. Biodiesel has different properties from diesel fuel. A significant increase in brake thermal efficiency (BTE), exhaust gas temperature (EGT) and decrease in specific fuel consumption for biodiesel and its blends were observed compared with diesel fuel. The significant improvement in reduction of Hydro carbon (HC) were found for biodiesel and its blends at high engine loads. It is observed that the increase in EGR percentage in fresh mixture which results reduction in oxides of nitrogen emissions. The maximum percentage reduction in oxides of nitrogen, nitrogen oxides (NOx) were slightly higher for biodiesel and its blend. By using an ethanol for reduction in emission of hydrocarbons, carbon monoxide for various EGR rate. Biodiesel and its blends exhibited similar combustion stages to diesel fuel. The use of transesterified cottonseed oil can be partially substituted for the diesel fuel at most operating conditions in terms of the performance parameters and emissions without any engine modification.*

Keywords *— Biodiesel, EGR, emission.*

1. INTRODUCTION

Biodiesel is a mixture of oil extracted from plant oil, vegetables, farm wastage, waste cooking oil, animal fats, etc. Biodiesel is a good substitution of diesel fuel. All these things mainly used for producing biodiesel. Biodiesel is generally blending of diesel and oil extracted from various sources. It is very important to consider the percentage of oil for preparing the blends because it causes vital effects on exhaust emissions. Generally, biodiesel is formed by chemical processes by adding methyl esters and acid. Viscosity is the major specifications of biodiesel that needs to observe carefully. Biodiesel is an eco-friendly, economical and harmless fuel and it can be usable in IC engine without making any changes into the machine. Biodiesel is very efficient for environment that leads to reduce carbon particles, hydrocarbons and particulate matters.

Bio-fuel will help to reduce expense on crude oil as well as it also helpful in reduction of emission of harmful gasses like carbon dioxide, carbon monoxide, hydrocarbon, Sulphur, smoke and small particles in the exhaust of the engines. For production of biodiesel in India cotton seeds are available in large extent, as cotton most cultivated crop in many states across the India. Using cottonseed biodiesel production is more suitable. In the world, India is the second biggest producer of cotton after the china. From the cotton plant we get three major parameters such as cotton fiber, cotton seed, and cotton seed's cake as diet to cattle for better milk. India cottonseed biodiesel production is easy and due to high rate of production of cottonseed thus it will be economical and hence more usable also.

2. EXPERIMENTAL SET-UP

This project Experimental investigations were conducted on a Kirloskar make single cylinder water cooled naturally aspirated 5.2kW at 1500 rpm and at constant pressure 180 bar. Cottonseed biodiesel and diesel were fuel considered in experimentation. Experimental setup is prepared for EGR to reduce the concentration of NOx in the exhaust gas. The experiments were conducted for pure biodiesel without EGR, 5%, 10%, and with EGR and pure diesel on normal engine. The performance, and emission characteristics without EGR and with EGR using cottonseed biodiesel are evaluated and the results compared with that of pure diesel.

The variable tests are conducted for 0, 1, 2, 3, 4, and 5 kW at a constant speed of 1500 rpm with constant injection pressure of 180 bar and EGR (Exhaust Gas Recirculation) at 5% and 10%.

The performance characteristics of the engine are evaluated in terms of brake thermal efficiency (BTHE), specific fuel consumption (SFC), exhaust gas temperature (EGT) and volumetric efficiency, then emission characteristics of the engine are evaluated in terms of carbon monoxide (CO), carbon dioxide (CO2), oxide of nitrogen (NOX), and hydro carbon (HC), and combustion characteristics are evaluated in terms of pressure, crank angle, cumulative heat release rate, and net heat release rate. These characteristics are compared with the results of diesel fuel.

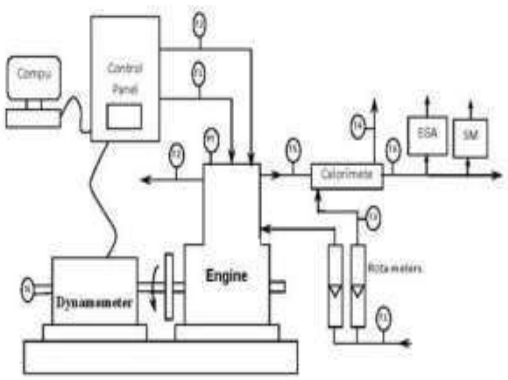

Fig -1: Experimental setup with EGR

Table -1: Specifications of the Kirloskar Diesel Engine

Parameters	specifications
Manufacturer	Kirloskar Oil Engine Ltd., India
Model	TV – SR II, naturally Aspirated
Engine	Single cylinder, DI, water- cooled, four strokes
Bore/Stroke	87.5 mm/110 mm
Compression ratio	17.5:1
Speed	1500 r/min, constant
Rated Power	5.2 kw
Injection pressure	240 bar/230 BTDC
Type sensor	Piezo electric
Response time	4 micro seconds
Make and model	Neptune equipment's, India, OPAX200 II/DX200P
Crank angle sensor	1 – degree crank angle

Table -2: Properties of cotton seed Biodiesel, Ethanol and pure Diesel

Properties	Diesel	Cotton seed	Ethanol
Viscosity, cSt (at 40°C)	5.032	7.5	6.04
Calorific Value, kJ/kg	42707	39605	27800
Sp. Gr. At 25°C	0.834	0.874	0.79
Density, kg/m^3	834	904.8	780.8
Flash point, °C	78	204	14
Fire point, °C	85	230	26

3.RESULTS AND DISSCUSSIONS

3.1 Performance characteristics:

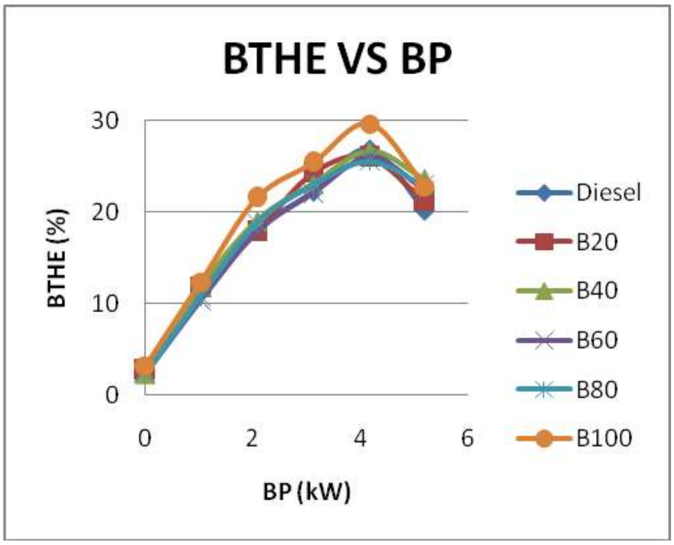

Fig -1: variation of brake thermal efficiency vs brake power for diesel and different blends.

Fig .1 shows the brake thermal efficiency of cotton seed biodiesel and its blends with respect to the brake power. It shows that the brake thermal efficiencies of all blends are lower at almost all load levels. Among the blends B100% found to have maximum thermal efficiency of 29.65% and B40% blend is 26.66% while for diesel it is 26.9%. The decrease in brake thermal efficiency with increase in cotton seed biodiesel concentration is due to poor atomization of the blends due to their high viscosity. The B40% and B100% blends are more close to pure diesel brake thermal efficiency.

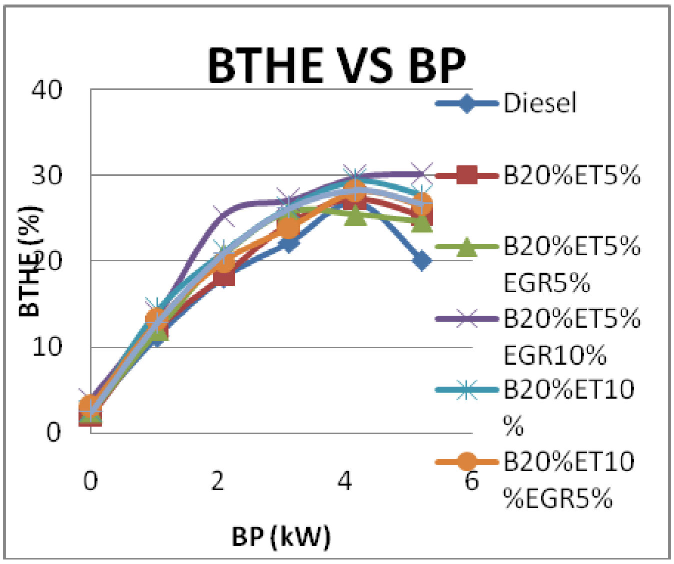

Fig -2: Variation of brake thermal efficiency with brake power for blend B20% with ethanol 5% and 10% without EGR, with EGR 5% and 10%.

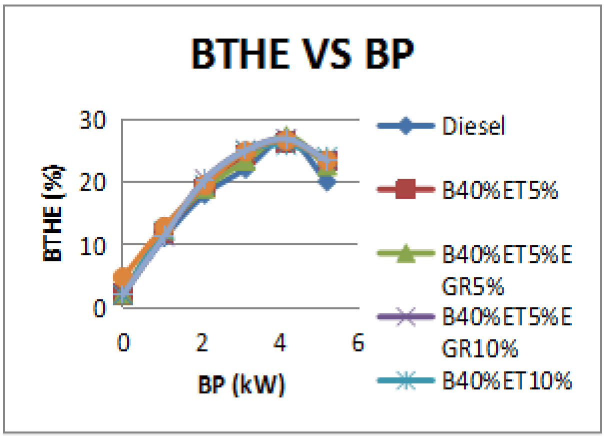

Fig -3: Variation of brake thermal efficiency with brake power for blends B40% with ethanol 5% and 10% without EGR, with EGR 5% and 10% .

Fig.2 & 3. shows the comparison of brake thermal efficiency with brake power for B20% and B40% blends of cotton seed biodiesel with ethanol 5%,10% and EGR 5%,10% and pure diesel. At constant pressure 180 bar, as the load on the engine increases the brake thermal efficiency because brake thermal efficiency is the function of brake power. The maximum brake thermal efficiency of blends B20% and B40% with ethanol 5% without EGR the values found to be 27.31%and 26.42% respectively, at maximum load, the brake thermal efficiency of B20% and B40% with ethanol 5% with EGR 5% the values found to be 28.14% and 27.41% respectively, the brake thermal efficiency of blends B20% and B40% ethanol 5% with EGR 10% the values found to be 30.27% and 26.94% respectively against diesel of 26.9%.

The maximum brake thermal efficiency of blends B20% and B40% with ethanol 10% without EGR the values found to be 29.3%and 25.92% respectively, at maximum load, the brake thermal efficiency of B20% and B40% with ethanol 10% with EGR 5% the values found to be 28.14% and 26.7% respectively, the brake thermal efficiency of blends B20% and B40% ethanol 10% with EGR 10% the values found to be 28.31% and 26.94% respectively against diesel of 26.9%.

As comparison the blend B20% with ethanol 5% with EGR 10% value which is more higher to the diesel value for higher blends may be due to better air fuel mixing, proper spray property. The BTHE of cotton seed biodiesel blends were higher than that of the diesel.

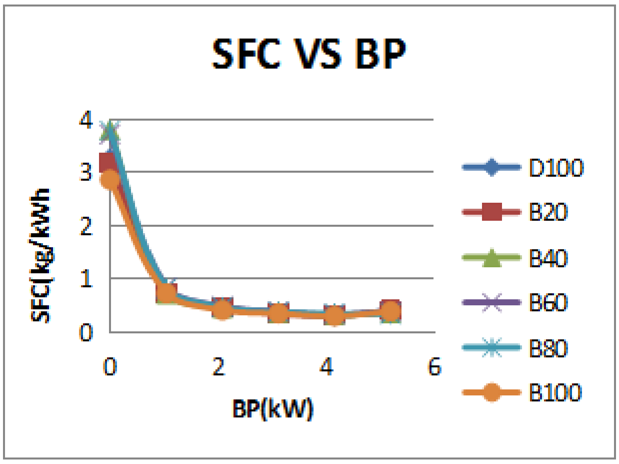

Fig -4: variation specific fuel consumption vs brake power for diesel and different blends.

Figure 4 shows the specific fuel consumption of cotton seed biodiesel and its blends with respect to brake power. By increasing the cotton seed biodiesel portion blend which increases the viscosity of the fuel, which increases the specific fuel consumption due to poor atomization of fuel. However, the variations are appreciable at part load conditions for all the blends. SFC of cotton seed was lower at full load then that of the diesel. The calorific value of cotton seed is decreases then that of diesel with increase in biodiesel percentage in blends. From the graph it is found that the B80% blend is very close to the diesel at full load. The SFC of D100 is 0.42kg/hr and B40% is 0.37 kg/hr,B80 is 0.35kg/hr. Hence the B80% is the best blend for low fuelconsumption.

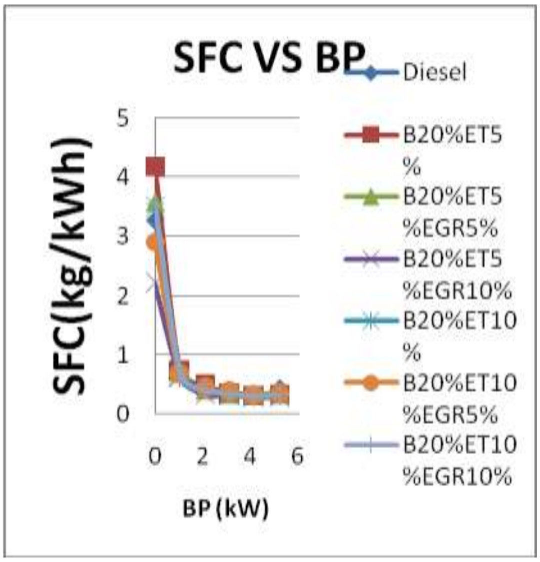

Fig -5: Variation of specific fuel consumption with brake power for blend B20% with ethanol 5%,10% without EGR, with EGR 5% and 10%.

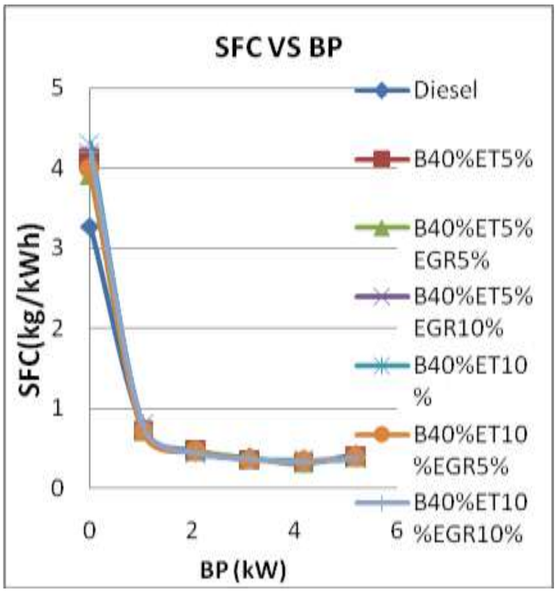

Fig -6: Variation of specific fuel consumption with brake power for blend B40% with ethanol 5%,10% without EGR, with EGR 5% and10%.

Fig.5 and 6. shows the comparison of specific fuel consumption with brake power for B20% and B40% blends of cotton seed biodiesel with ethanol 5%,10% and EGR 5%, 10% and pure diesel. Specific fuel consumption of blends B20% and B40% without EGR with ethanol 5% under full load was found to be 0.34 kg/kW-hr and 0.38kg/kW-hr respectively, the blends of B20% and B40% with 5% ethanol and with EGR 5% the specific fuel consumption found to be 0.34 kg/kW-hr and 0.39 kg/kW-hr respectively, as increase in the cotton seed biodiesel portion the specific fuel consumption increases due to increasing the viscosity of the fuel specific consumption of B20% and B40% with 5% ethanol with EGR 10% it is found to be 0.29 kg/kW-hr and 0.38 kg/kW-hr respectively and pure diesel found to be 0.42kg/kW-hr due to its lower heating value, greater density and hence higher bulk modulus.

Specific fuel consumption of blends B20% and B40% without EGR with ethanol 10% under full load was found to be 0.32 kg/kW-hr and 0.37kg/kW-hr respectively, the blends of B20% and B40% with 5% ethanol and with EGR 5% the specific fuel consumption found to be 0.33 kg/kW-hr and 0.38 kg/kW-hr respectively, as increase in the cotton seed biodiesel portion the specific fuel consumption increases due to increasing the viscosity of the fuel specific consumption of B20% and B40% with 10% ethanol with EGR 10% it is found to be 0.33 kg/kW-hr and 0.38 kg/kW-hr respectively. B20% with ethanol 5% with EGR 10% has low SFC at higher load due to the fuel consumpti on is less compared to other blends because of its high latent heat vaporization. As compare to other blends are high fuel consumption. As compared to all the blends B20% with ethanol 5% with EGR 10% is the best blend for low fuel consumption.

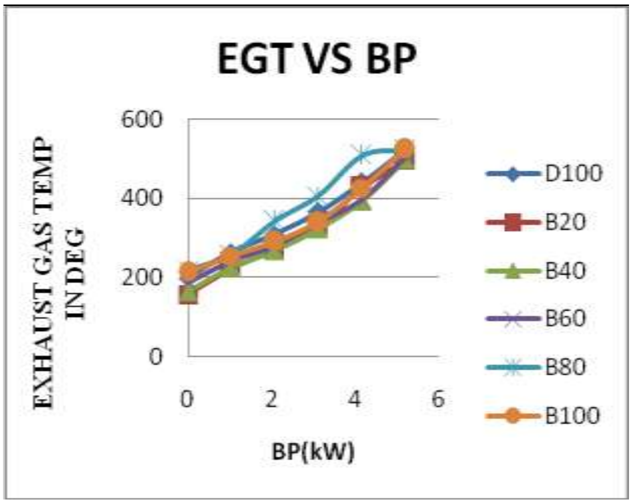

Fig -7: variation of exhaust gas temperature vs brake power for diesel and different blends.

The variation of exhaust emission temperature with brake power for diesel, and other blends of cotton seed biodiesel are shown in figure 7, the exhaust emission temperature of all the biodiesel shows lower than the diesel except B80 as it is obtained from the graph. The exhaust gas temperature for D100% and other blends for varying loads can be observed and stated as they are slightly parallel to each other. The exhaust gas temperature of all blends and 100% diesel increase as load increases. It is observed from graph, the exhaust gas temperature is maximum at full load, this is because at full load the chemically the ratio will be correct for air and fuel which is used, due to correct ratio of air and fuel, the high heat generated inside the cylinder.

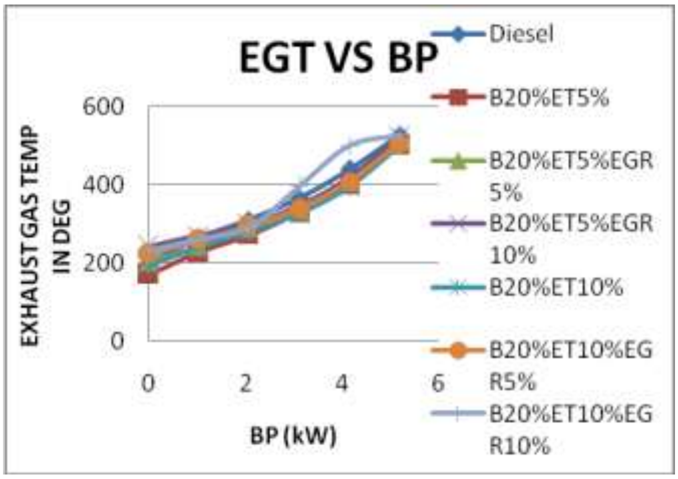

Fig -8: Variation of exhaust gas temperature with brake power for blend B20% with ethanol 5%,10% without EGR, with EGR 5% and 10%.

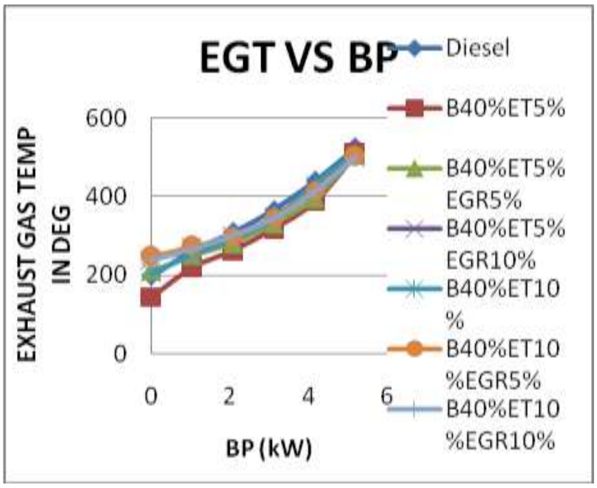

Fig -9: Variation of exhaust gas temperature with brake power for blend B40% with ethanol 5%,10% without EGR, with EGR 5% and 10%.

Fig.8 and 9 shows the comparison of exhaust gas temperature with brake power for B20% and B40% blends of cotton seed biodiesel with ethanol 5%, 10% and EGR 5%, 10% and pure diesel. The exhaust gas temperature of B20% and B40% with ethanol 5% and without EGR at full load was 500.76 °C and 508.45 °C respectively at constant pressure 180bar and the exhaust temperature of B20% and B40% with ethanol 5% with EGR 5% at full load, it can be observed that 513.11 °C and 506.35 °C respectively. The exhaust temperature of B20% and B40% blends with ethanol 5% with EGR 10% at full load values can be found to be 521.31 °C and 500.29 °C respectively at constant pressure 180 bar, the pure diesel exhaust temperature found to be 525.38 °C.

The exhaust gas temperature of B20% and B40% with ethanol 10% and without EGR at full load was 502.08 °C and 510.56 °C respectively at constant pressure 180bar and the exhaust temperature of B20% and B40% with ethanol 10% with EGR 5% at full load, it can be observed that 507.14 °C and 501.96 °C respectively. The exhaust temperature of B20% and B40% blends with ethanol 10% with EGR 10% at full load values can be found to be 527.49 °C and 500.29 °C respectively. At constant pressure 180 bar, the pure diesel exhaust temperature found to be 525.38 °C. As a result of increased combustion duration, a higher exhaust gas temperature is recorded for B20% with ethanol 10% with EGR 10% blend exhaust gas temperature was higher in biodiesel compare with diesel at all load conditions. The possible reason for this temperature increased may be relatively higher availability of oxygen in biodiesel for combustion and because at full load the chemically correct ratio of air and fuel is used, because of chemically correct ratio of air and fuel, there is a generation of high heat inside the cylinder.

Emission characteristics:

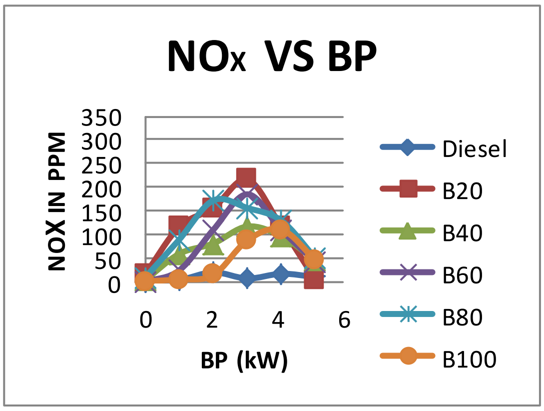

Fig -13: variation of oxides of nitrogen vs brake power for diesel and different blends.

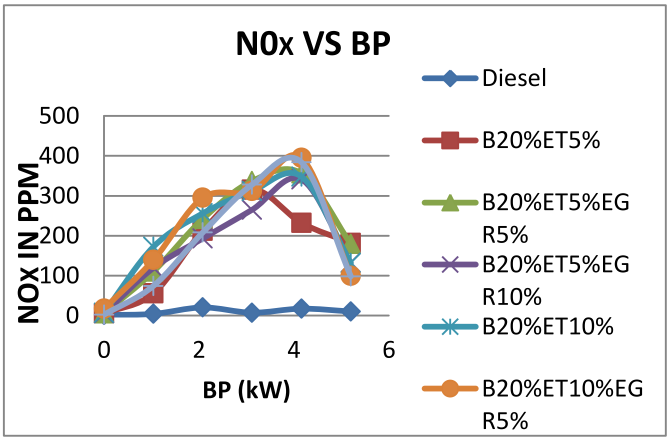

Fig -14: Variation of emission of oxides of nitrogen with brake power for blend B20% with ethanol 5%,10% without EGR, with EGR 5% and 10%.

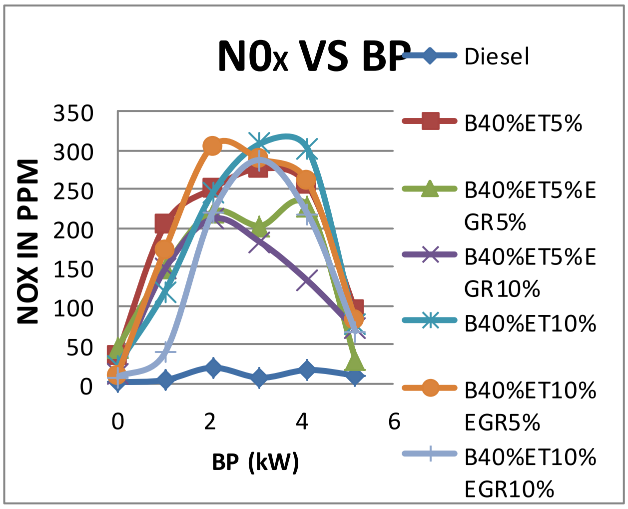

Fig -15: Variation of emission of oxides of nitrogen with brake power for blend B40% with ethanol 5%,10% without EGR, with EGR 5% and 10%.

Fig.14 and 15 shows comparison of NOx with brake power for B20% and B40% blends of cotton seed biodiesel with ethanol 5%, 10% and EGR 5%, 10% and pure diesel. At constant pressure 180 bar. It is observed that the NOx emissions increased with increase in load and increase in nozzle opening pressures. The NOx emissions for the blends B20% and B40% with ethanol 5% without EGR at full load the values found to be 182 ppm and 94 ppm respectively. The blends B20% and B40% with ethanol 5% with EGR 5% at full load the values found to be 179 ppm and 31 ppm respectively. The blends of B20% and B40% with ethanol 5% with EGR 10% at full load the values found to be 132 ppm and 70 ppm respectively. The pure diesel found to be 10 ppm at full load.

The NOx emissions for the blends B20% and B40% with ethanol 10% without EGR at full load the values found to be 131 ppm and 76 ppm respectively. The blends B20% and B40% with ethanol 10% with EGR 5% at full load the values found to be 99 ppm and 82 ppm respectively. The blends of B20% and B40% with ethanol 10% with EGR 10% at full load the values found to be 98 ppm and 67 ppm respectively. The pure diesel found to be 10 ppm at full load.

The increase in NOx emission may be due to more oxygen present in the biodiesel, resulting in increased peak combustion temperature. It is observed that the lower NOx emissions are 31 ppm at a blend of B40% with ethanol 5% with EGR 5%, with increase in EGR the NOx level was reduced..

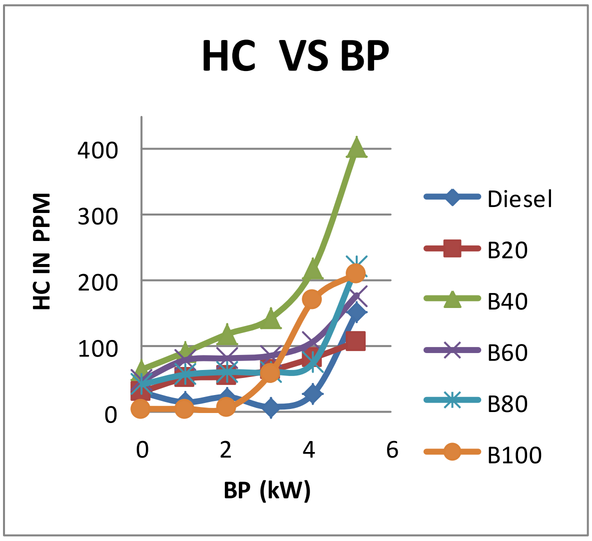

Fig -16: variation of emission of unburnt hydrocarbon vs brake power for diesel and different blends.

Figure 16 shows the variation of HC emissions against brake power variations. The exhaust of unburnt hydrocarbon is due to a incomplete combustion of carbon compounds in blends. The HC emission value increases with increase in biodiesel proportion in the fuel blends as in the graph it is observed that the 100% diesel at full load and part load condition the HC emission is more as compare to the other blends. High percentage of oxygen content and cetane number leads to less amount of HC, B20% the HC emission is less than that of the diesel

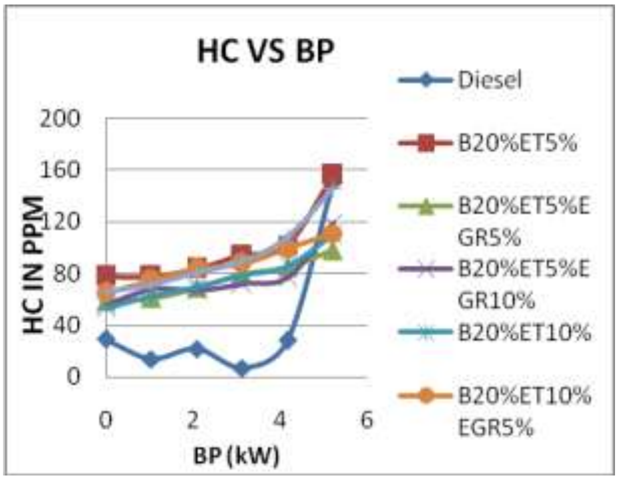

Fig -17: Variation emission of unburnt hydrocarbon with brake power for blend B20% with ethanol 5% ,10% without EGR, with EGR 5% and 10% .

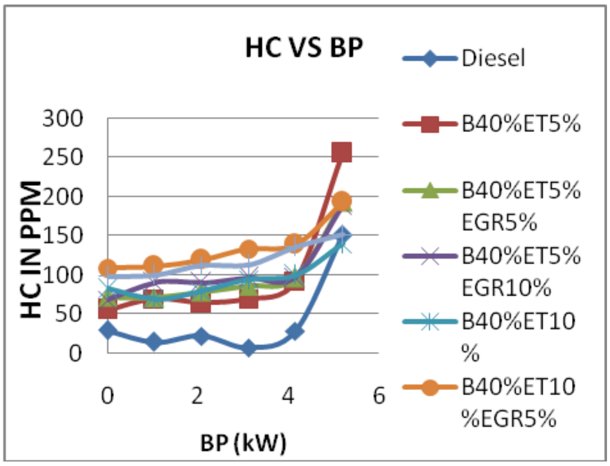

Fig -18: Variation emission of unburnt hydrocarbon with brake power for blend B40% with ethanol 5% ,10% without EGR, with EGR 5% and 10%.

Figure 17 and 18 shows comparison of Unburnt hydrocarbon with brake power for B20% and B40% blends of cotton seed biodiesel with ethanol 5%,10% and EGR 5%, 10% and pure diesel. The emissions of unburnt hydrocarbon for biodiesel are high as compared to the diesel in both the graphs. At higher load and 180 bar injection pressure. The blends B20% and B40% with ethanol 5% without EGR the values found to be 156 ppm and 256 ppm respectively, the blends B20% and B40% with ethanol 5% with EGR 5% the values found to be 98ppm and 193 ppm. The blends B20% and B40% with ethanol 5% with EGR 10% the values found to be 119 ppm and 189 ppm. The blends B20% and B40% with ethanol 10% without EGR the values found to be 110 ppm and 140 ppm respectively, the blends B20% and B40% with ethanol 10% with EGR 5% the values found to be 111ppm and 193 ppm. The blends B20% and B40% with ethanol 10% with

EGR 10% the values found to be 146 ppm and 151 ppm. The EGR widely used to reduce and control the oxides of nitrogen emission by lowering the oxygen concentration and flame temperature of working fluid in the combustion chamber this leads more emission of unburnt hydrocarbon to decrease a emission of unburnt hydrocarbon the 5% ethanol alcohol is used, which reduces some amount of unburnt hydrocarbon, as we can observed from the graphs the B20% with ethanol 5% with EGR 5% emits less emission of hydrocarbons at higher load.

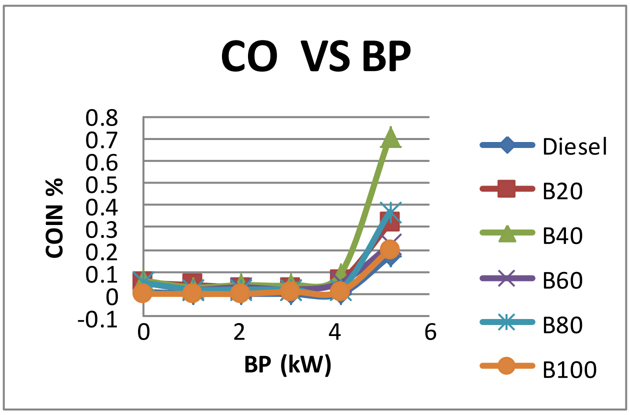

Fig -19: variation of emission of carbon monoxide vs brake power for diesel and different blends.

Fig. 19 shows variation of carbon monoxide with load for different blends, the CO emission increases with increasing the load. From the graph we can say that B40% of biodiesel the CO emission is more as compare to other blends this is because of high viscosity and poor atomization tendency of cotton seed biodiesel which leads poor combustion and higher carbon monoxide emission.CO emission increase as air-fuel ratio becomes greater than stoichiometric value. As compare to the biodiesel blends B40% emits more CO under all loading conditions. Biodiesel which has O2 itself which helps for complete combustion. B100% shows less emission of carbon monoxide.

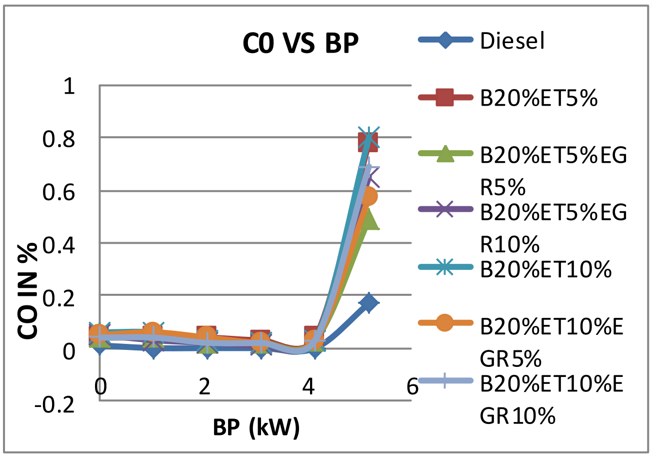

Fig -20: Variation emission of carbon monoxide with brake power for blend B20% with ethanol 5%,10% without EGR, with EGR 5% and 10%.

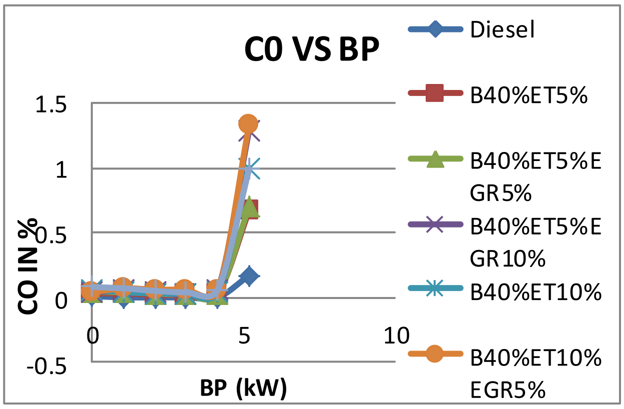

Fig -21: Variation emission of carbon monoxide with brake power for blend B40% with ethanol 5%,10% without EGR, with EGR 5% and 10%.

Fig.20 and 21 shows the comparison of CO emission with brake power for B20% and B40% blends of cotton seed biodiesel with ethanol 5%,10% and EGR 5%, 10% and pure diesel. The CO emissions with ethanol 5% without EGR were obtained from cotton seed biodiesel and its blends B20% and B40% at full load the CO emission is 0.78% and 0.67% respectively in 180 bar injection pressure and CO emission of B20% and B40% with ethanol 5% with EGR 5% is 0.49% and 0.7% respectively, the CO emission of B20% and B40% blends with ethanol 5% with EGR 10% the emission found to be 0.65% and 1.29% and pure diesel CO emission found to be 0.17% .

The CO emissions with ethanol 10% without EGR were obtained from cotton seed biodiesel and its blends B20% and B40% at full load the CO emission is 0.8% and 1% respectively in 180 bar injection pressure and CO emission of B20% and B40% with ethanol 10% with EGR 5% is 0.57% and 1.33% respectively, the CO emission of B20% and B40% blends with ethanol 10% with EGR 10% the emission found to be 0.69% and 0.99% and pure diesel CO emission found to be 0.17% , as comparison with other blends the B20% with ethanol 5% with EGR 5% shows less CO emission . This is due to using of ethanol alcohol which reduces the carbon monoxide percentage

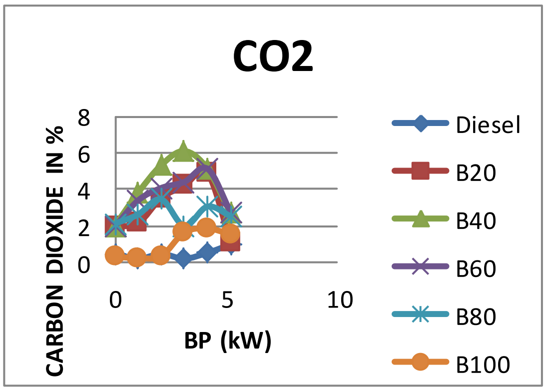

Fig -22: variation of emission of carbon dioxide vs brake power for diesel and different blends.

Fig. 22 shows the variation of carbon dioxide with brake power different blends of cotton seed biodiesel and diesel. CO2 emission increases with increase in load, at full load CO2 emission is more B20% gives lower emission at full load condition as compare to other blends.. This is due to a complete combustion of fuel. The B20 blend gives lower emission with respect to other blends

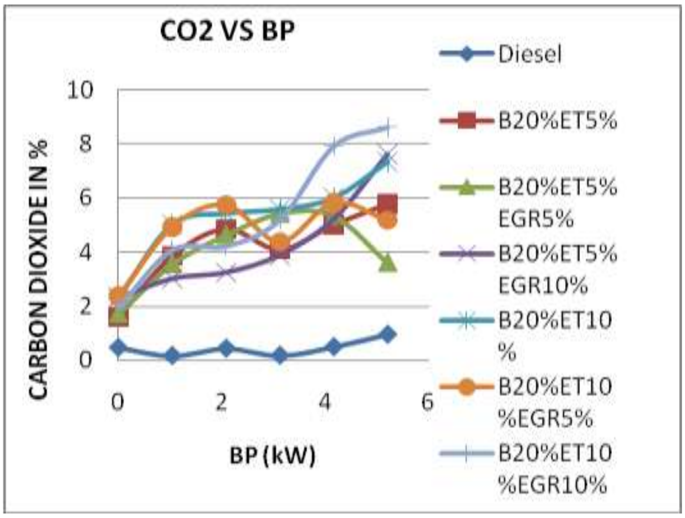

Fig -23: Variation emission of carbon dioxide with brake power for blend B20% with ethanol 5%,10% without EGR, with EGR 5% and 10%.

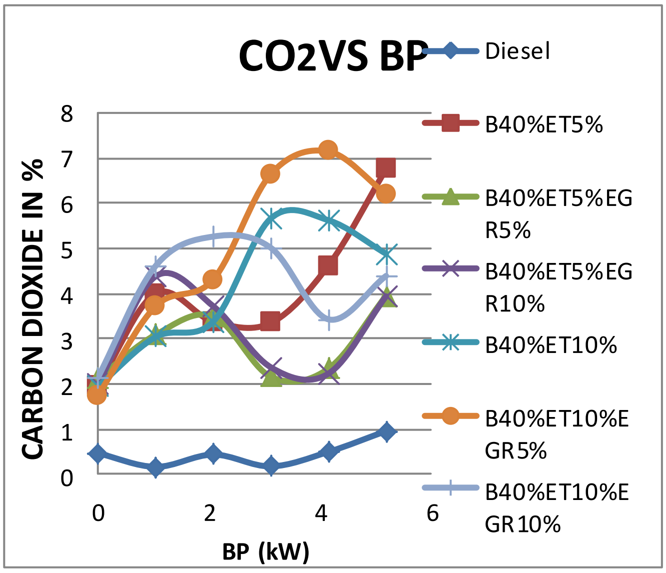

Fig -24: Variation emission of carbon dioxide with brake power for blend B40% with ethanol 5%,10% without EGR, with EGR 5% and 10%.

Fig.23 and 24 shows the comparison of CO2 emission with brake power for B20% and B40% blends of cotton seed biodiesel with ethanol 5%,10% and EGR 5%, 10% and pure diesel, at constant pressure 180 bar. The CO2 emission of blends B20% and B40% with ethanol 5% without EGR, at full load the values found to be 5.76% and 6.75% respectively. The CO2 emission of blends B20% and B40% with ethanol 5% with EGR 5%, at full load the emission value found to be 3.62% and 3.95% respectively. The CO2 emission of blends B20% and B40% with ethanol 5% with EGR 10%, at full load the emission value found to be 7.61% and 3.94% respectively. The CO2 emission of diesel found to be 0.96% at full load.

The CO2 emission of blends B20% and B40% with ethanol 10% without EGR, at full load the values found to be 7.34% and 4.88% respectively. The CO2 emission of blends B20% and B40% with ethanol 10% with EGR 5%, at full load the emission value found to be 5.17% and 6.2% respectively. The CO2 emission of blends B20% and B40% with ethanol 10% with EGR 10%, at full load the emission value found to be 8.6% and 4.39% respectively. The CO2 emission of diesel found to be 0.96% at full load. As compared to biodiesel the diesel emits less CO2 emission. In this biodiesel blends B20% with ethanol 5% EGR 5% shows less emission.

is observed that the heat release rate curves of the diesel, cotton seed biodiesel and their blends show similar patterns. The peak heat release rates of cotton seed biodiesel and their blends are higher than that of diesel.

4. CONCLUSIONS

The conclusion of this experiment is as follows.

- The biodiesel produced from neem oil by transesterification process reduces the viscosity of biodiesel found to be higher than that of diesel and the calorific value of biodiesel is lower than that of the diesel.
- The maximum brake thermal efficiency is obtained in the case of engine with EGR setup. The efficiency of biodiesel is lower than that of diesel fuel. However, the efficiency of the engine with EGR setup the biodiesel fuel is well within the expected limits.
- SFC is low for the 180 bar pressure with EGR because of its high latent heat vaporization. The blend B20% with ethanol 5% with EGR 10% is the best blend for low fuel consumption.
- The CO and HC emission is lower for Neem biodiesel without EGR than that of normal diesel engine for entire load of operation. The increase in EGR increases the CO and HC emissions.
- The NOx emission increases with increase in load and reaches maximum and then decreases. NOx emission is almost all comparable with diesel except a narrow band of part load. By increasing the EGR there is a considerable reduction in the NOx formation. NOx emission with 5%, 10% is respectively lower.
- Properties of 20% of biodiesel are very close to the diesel compared to other blends.

- It is concluded that neem biodiesel B20% with ethanol 5% with 10% EGR at 180 bar pressure can be used as, alternate fuel for DI diesel engine without any major modification.

The above study clearly reveals the possibility of using the biodiesel in DI diesel engine with EGR. The combustion, performance and emission characteristics shows the suitability of neem biodiesel in engine with EGR.

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