PERFORMANCE AND EMISSION ANALYSIS OF CI ENGINE USING COTTONSEED OIL

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Abstract— In a modern day world alternative source of energy are given importance due to gradual depletion of fossil fuels reserves vegetable oils can be used as an alternative to diesel in CI engines. The use of vegetable oils in CI engine results in low CO and HC emissions compared to conventional diesel fuel. The present study covers the various aspects of biodiesels fuel derived from cottonseed oil and performance emissions study on four stroke compression ignition engine with cottonseed oil. Cottonseed oil is converted to cottonseed oil methyl esters by transesterification process. In the initial stage the tests are conducted on the four stroke single cylinder water cooled direct injection diesel engine with constant speed by using diesel and base line data is generated by varying loads with constant loads. In second stage, experimental investigation has been carried out on the same engine with same operating parameters by using the cottonseed oil methyl esters in different proportions as C10, C20and C30 to find out the performance and emission. The performance and emission parameters obtained by the above are compared with the base line data obtained earlier by using diesel and optimum cottonseed oil blend is obtained. The performance and emissions parameters obtained by the above tests are to be compared with diesel base line data and optimum blend is C20.Finally results show engine performance and emissions have been to justify the potentiality of the cottonseed oil methyl esters of as alternative fuel for compression ignition engine fuel.

Keywords: Combustion characteristics, Diesel-Biodiesel blends, Transesterification process, performance

1. INTRODUCTION

Cottonseed oil is extracted from the seeds of cotton plant of various species, mainly Gossypium hirsutum and Gossypium herbaceum. Cotton grown for oil extraction is one of the big four genetically modified crops grown around the world, next to soya, corn, and rapeseed (canola), mostly Monsanto products.

The cottonseed has a similar structure to other oilseeds such as sunflower seed, having an oil bearing kernel surrounded by a hard outer hull; in processing, the oil is extracted from the kernel. Cottonseed oil is used for salad oil, mayonnaise, salad dressing, and similar products because of its flavor stability. The cottonseed oil undergoes intensive treatment after extraction to reduce the level of gossypol found in untreated cottonseed oil, the consumption of which may produce undesirable side-effects.

Its fatty acid profile generally consists of 70% unsaturated fatty acids (18% monounsaturated, and 52% polyunsaturated) and 26% saturated fat. When it is fully hydrogenated, its profile is 94% saturated fat and 2% unsaturated fatty (1.5% monounsaturated, and 0.5% polyunsaturated).

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The cottonseed oil industry claims that cottonseed oil does not need to be hydrogenated as much as other polyunsaturated oils to achieve similar results. The three key steps of refining, bleaching and deodorization that are involved in producing finished oil act to reduce the gossypol level. Ferric is often used to decolorize cotton seed oil. Once processed, cottonseed oil has a mild taste and appears generally clear with a light golden color, the amount of color depending on the amount of refining. Cottonseed oil has a relatively high smoke point as a frying medium. Like other long-chain fatty acid oils, cottonseed oil has a smoke point of about 450 °F (232 °C).

Table 1. Oil Properties

Vegetable oil	Kinematic viscosity at 38°C (cSt)	Cetane No.	Heating value (MJ/kg)	Pour point (°C)	Flash point (°C)	Density (g/cc)
Diesel	3.06	50	43.8	–16	76	0.855
Corn	34.9	37.6	39.5	- 40.0	277	0.909
Cotton	**33.5**	**41.8**	**39.5**	**-15.0**	**234**	**0.915**
Crambe	53.6	44.6	40.5	- 12.2	274	0.905
Linseed	27.2	34.6	39.3	-15.0	241	0.924
Peanut	39.6	41.8	39.8	-6.7	271	0.903
Rapeseed	37.0	37.6	39.7	-31.7	246	0.912
Safflowe	31.3	41.3	39.5	-6.7	260	0.914

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Sesame	35.5	40.2	39.3	-9.4	260	0.913
Soya bean	32.6	37.9	39.6	-12.2	254	0.914
Sunflower	33.9	37.1	39.6	-15.0	274	0.916
Palm	39.6	42.0	–		267	0.918

2. EXPERIMENTAL SET UP AND PROCEDURE

2.1 Experimental Set Up: The engine shown in plate.1 is a 4 stroke, vertical, single cylinder, water cooled, constant speed diesel engine which is coupled to rope brake drum arrangement to absorb the power produced. The engine crank started. Necessary dead weights and spring balance are included to apply load on brake drum. Suitable cooling water arrangement for the brake drum is provided. Separate cooling water lines fitted with temperature measuring thermocouples are provided for engine cooling. A measuring system for fuel consumption consisting of a fuel tank, burette, and a 3- way cock mounted on stand and stop watch are provided. Air intake is measured using an air tank fitted with an orifice meter and a water U- tube differential manometer. Also digital temperature indicator with selector switch for temperature measurement and a digital rpm indicator for speed measurement are provided on the panel board. A governor is provided to maintain the constant speed

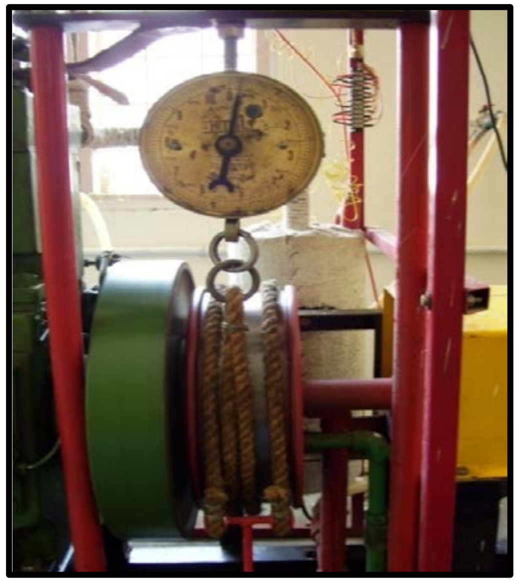

Plate 1 Diesel Engine Test Rig

Table 2 Specifications of the Test Engine

Particulars	Specifications
Make	Kirloskar
Rated Power	3.7 kw(5hp)
Bore	80 mm
Stroke Length	110 mm
Swept volume	562 cc
Compression ratio 16.5:1	Compression ratio 16.5:1

2.2 Test Fuels: For experimental investigations, biodiesel derived from cotton seed was mixed with diesel in varying proportions 10%, 20% and 30% by volume respectively to all the blends.

2.3 Experimental Procedure:

Calculate full load (W) that can be applied on the engine from the engine specifications. Clean the fuel filter and remove the air lock. Check for fuel, lubricating oil and cooling water supply. Start the engine using decompression lever ensuring that no load on the engine and supply the cooling water Allow the engine for 10 minutes on no load to get stabilization. Note down the total dead weight, spring balance reading, time taken for 20cc of fuel consumption and the manometer readings. Repeat the above step for different loads up to full load. Connect the exhaust pipe to the smoke meter and exhaust gas analyzer and corresponding readings are tabulated. Allow the engine to stabilize on every load change and then take the readings. Before stopping the engine remove the loads and make the engine stabilized Stop the engine pulling the governor lever towards the engine cranking side. Check that there is no load on engine while stopping.

3 RESULTS AND DISCUSSION

The performance and emission characteristics of a high speed diesel engine at various loads from no load to full load fuelled with cottonseed oil blends compared with diesel are discussed below as per the results obtained.

3.1 Performance Analysis

3.1.1 Brake Thermal Efficiency

The brake thermal efficiencies which are obtained from calculations was plotted against brake power and compared the results for different blends of fuels as shown in Figure 3.1.1 for C10,C20,C30,D100.From the Plot it is observed that BTH at full load conditions for D100, C10, C20 and C30 are 32.82%, 30.48%, 35.62%, 35.35% respectively. The maximum BTH is observed for C20 blend. As the blend mixture strength is increasing the calorific value decreases. So there will be variation in the Brake Thermal Efficiency. From graph it is clear that BTH is more for the blends when load reaches the maximum. The Fig 3.1.1 shows the Brake thermal efficiency for diesel and its blends. But only slight improvement in BTH has been observed for C20 at full load as 35.62% and for D100 it is 32.82%. So the percentage of increase in BTH compared to D100 by C20 is 4.7%.Only small increase in brake thermal efficiency due to the fact that with the increase in load, both the BP and fuel flow rate increase and there is reduction in heat loss at higher load. However the rate at which BP increases with load is higher than the rate of increase of fuel flow rate. It was also observed that the brake thermal efficiencies were closer to each other.

3.1.2 Volumetric Efficiency

Volumetric efficiency is defined as the volume flow rate of air into the intake system divided by the rate at which the volume is displaced by the system. This is one of the very important parameters which decide the performance of 4-stroke engines, 4-stroke engines have distinct suction stroke and therefore the volumetric efficiency indicates the breathing ability of the engine. It is to be noted that utilization of the air is what going to determine the power output of the engine. Hence, an engine must be able to take in as much as air as possible. The Volumetric efficiencies which are obtained from calculations were plotted against brake power and compared the results for different blends of fuels as shown in Figure 3.1.2. From the plot it is observed that the volumetric efficiencies obtained at full loads for D100, C10, C20, C30 are 78.42%, 74.07%, 80.15%, 78.42% respectively. The results for all blends compared to D100 reveals the volumetric efficiency is not affected by all the blends. There is no considerable change in volumetric efficiency compared to utilization of D100 with all the blends.

3.1.3 Mechanical Efficiency

The Mechanical efficiencies which are obtained from calculations were plotted against brake power and compared the results for different blends of fuels as shown in Figure 3.1.3.From the plot it is observed that the mechanical efficiencies obtained at full loads for D100, C10, C20, C30 are 63.11%, 60.6%, 59.6%, 57.89% respectively. The variation of Mechanical efficiencies has been observed with various blends compared to Diesel. But considerable change in Mechanical efficiency has not observed since the fuel properties are not so different for pure diesel and other blends.

3.1.4 Brake Specific Fuel Consumption

The BSFC obtained from calculations was plotted against brake power and compared the results for different blends of fuels as shown in Figure 3.1.4.The plot reveals that the BSFCs obtained at full loads for D100 and C10, C20, C30 blends are 0.26 Kg/kW-hr, 0.27 Kg/kW-hr, 0.25 Kg/kW-hr, 0.25 Kg/kW-hr respectively. From the plot it is observed that BSFC is decreasing compared to D100 for C20 and C30 blends. As the mass flow rate of fuel is increasing the brake power also increasing and considerable decrease in BSFC has been observed for both C20 and C30 blends. The BSFC of the engine decreased with increase in load. The BSFC decreases with load because of higher rate of increase of BP compared to fuel consumption rate with load.BSFC for D100 is 0.26 Kg/kW-hr but for C20 and C30 are 0.25kg/kW-hr so percentage of decrease in BSFC for both these blends is 3.8%.

3.1.5 Indicated Specific Fuel Consumption

The ISFC obtained from calculations was plotted against brake power and compared the results for different blends of fuels as shown in Figure 3.1.5. From the plot it is observed as the load increases the ISFC also increases but considerable change in ISFC has not been observed for all the blends since as the percentage of blend is increasing mass flow rate of fuel also increasing and calorific value is decreasing.

3.1.6 Air Fuel Ratio

The relative properties of the fuel in the engine are very important from the stand point of combustion and the efficiency of the engine. This is expressed either as a ratio of the mass of the fuel to that of the air or vice-versa. A mixture that contains just enough air for complete combustion of all the fuel in the mixture is called a chemically correct or stoichometric fuel-air ratio. The A/F ratio that was obtained from calculations is plotted against brake power and compared the results for different blends of fuels as shown in Figure 3.1.6.From the Plot it is observed that A/F ratio at full load conditions for D100, C10, C20, C30 are 22.79, 19.85, 23.54, and 22.86 respectively. As the percentage of load increases the A/F ratio decreases at constant injection pressure which is used for Diesel. For the C20 blend the A/F ratio is slightly more by compared to diesel.

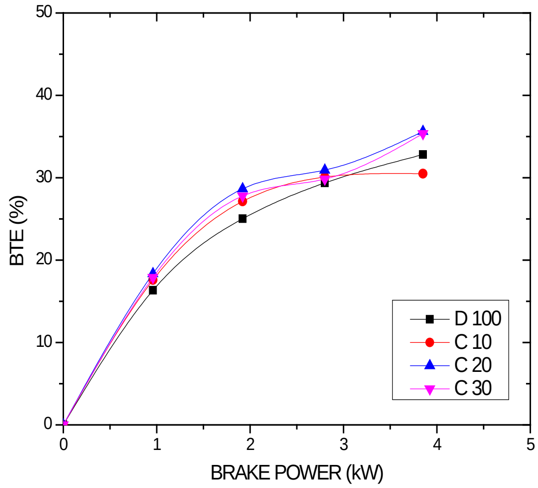

Fig 3.1.1 Variation of BTE with brake power using COME blends

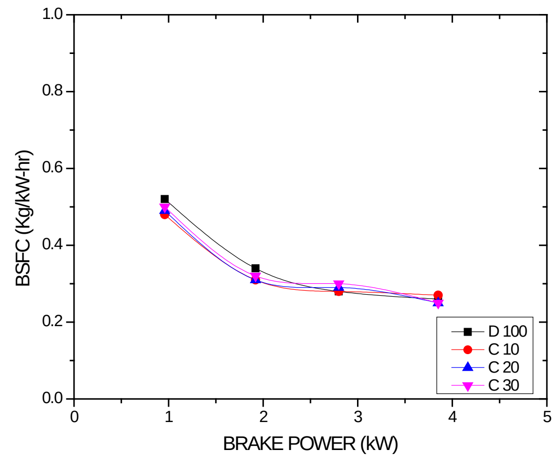

Fig 3.1.4 Variation of BSFC with brake power using COME blends

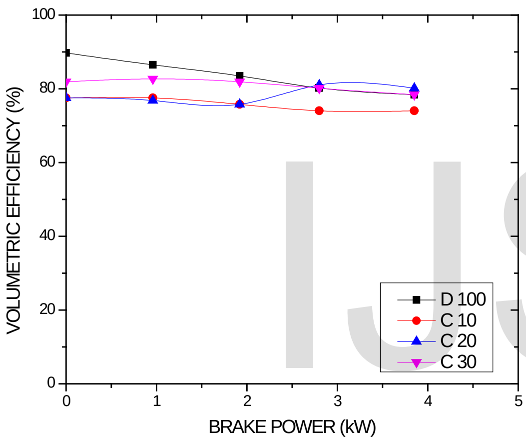

Fig 3.1.2 Variation of Volumetric Efficiency with Brake Power using COME Blends

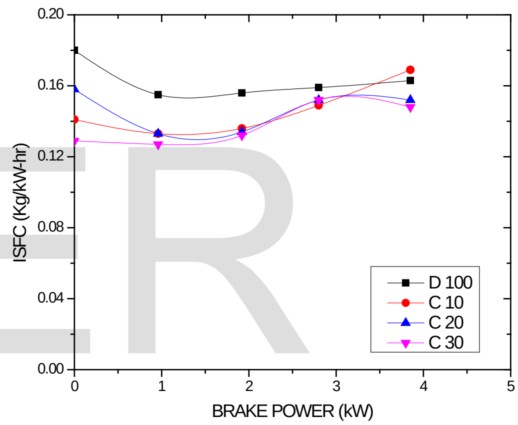

Fig 3.1.5 Variation of ISFC with Brake Power using COME Blends

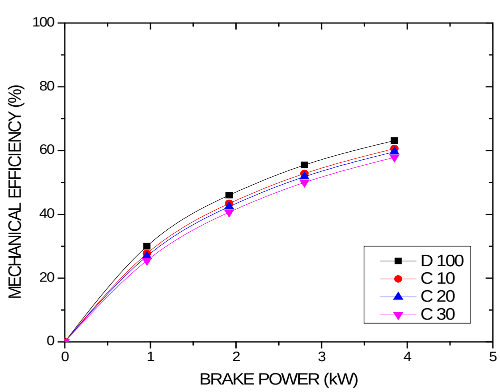

Fig 3.1.3 Variation of Mechanical Efficiency with Brake Power using COME Blends

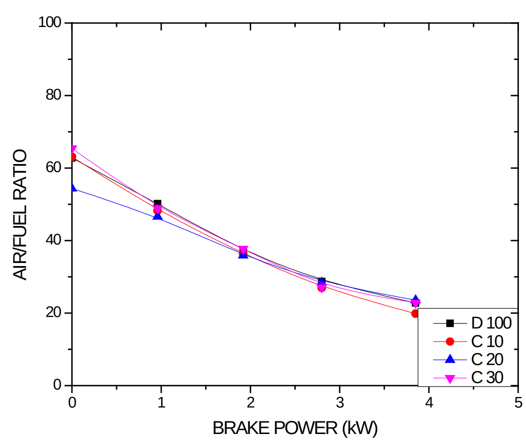

Fig 3.1.6 Variation of A/F Ratio with Brake Power using COME Blends

3.2 Emission Analysis

The experiments are conducted on the four stroke single cylinder water cooled diesel engine at constant speed (1500 rpm) with varying loads. Various emission parameters in the sense of smoke density, unburned hydrocarbons, carbon monoxide, unused oxygen and oxides of nitrogen are discussed below

3.2.1 Smoke Density

The variation of smoke density with brake power of the engine for D100, C10, C20, C30 by volume of concentrations are shown in Figure 3.2.1. It was observed that the smoke density of all the blends is lower than that of diesel at maximum load. The smoke density is lower for C10 and C20 compared to C30 and D100 as shown in Fig. The maximum smoke density recorded for the diesel was 79.6 HSU and 60.33 HSU for C10 and 54.67 HSU for C20 at maximum brake power. Because of the oxygen enrichment contained by C10 and C20 improves fuel evaporation during diffusion combustion which subsequently reduces the smoke density. The decrease in smoke density by percentage compared to D100 for C10 and C20 is 24% and 22.6% respectively. But for the C30 blend Smoke density slightly increased because of increased viscosity and incomplete combustion.

3.2.2 Carbon Monoxide

CO emission depending on many parameters such as air–fuel ratio and the engine temperature are the causes of exhaust gas emissions in the internal combustion engine. It is one of the toxic products of combustion due to the improper burning of hydrocarbon (HC).Figure 3.2.2 shows the variation of CO emissions for D100 with other blends. From the plot it is observed that the CO emissions at full load for D100, C10, C20, and C30 are 0.07%, 0.05%, 0.04%, 0.06% respectively. It is clear from the plot that CO emissions decrease with C10, C20 blends produces significantly lower CO emissions than that of diesel fuel because of Oxygen availability from this blend for complete combustion.

3.2.3 Unburned Hydrocarbons

The variation of HC with brake power of the engine for D100 and C10, C20, C30 blends are shown in Figure 3.2.3. Because of the oxygen enrichment contained by C20 and C30 improves fuel evaporation during diffusion combustion which slightly reduced the unburned Hydrocarbons. For D100, HC content is 58ppm but for C30 it is reduced to 42ppm. These reductions indicate a more complete combustion of the fuel. The presence of oxygen in the fuel was thought to promote complete combustion. But for blends like C10, HC content is more (75ppm) means incomplete combustion. It requires changes in injection pressure and combustion chamber design. Unburned hydrocarbons are reduced by 4.6% using the blends C20 and C30 as compared with diesel.

3.2.4 Carbon Dioxide

The variation of CO_2 with brake power of the engine for D100 and C10, C20, C30 blends are shown in figure 3.2.4.From the plot it is observed that the CO_2 content for D100, C10, C20, C30 blends at full load conditions are 8.5%, 8.4%, 8.7%, 8.7% respectively. But there is no considerable change in CO_2 only slight decrease in CO_2 occurred for C10 blend compared to D100. Since enough amount of oxygen is available for complete combustion. The CO_2 emissions from a diesel engine indicate how efficiently the fuel is burnt inside the combustion chamber. As discussed earlier, the ester-based fuel burns more efficiently than diesel.

3.2.5 Oxides of Nitrogen

NOx emissions are very important in polluted air. Diesel engines operate with an excess air ratio on full load and higher values on lower loads. Diesel engine combustion generates large amounts of NOx because of high flame temperatures (>1800 K) in the presence of abundant oxygen and nitrogen in the combustion chamber. To reduce NOx, the temperature in the cylinder should be reduced. The NOx emissions increased with the engine load, due to a higher combustion temperature. This proves that the most important factor for the emissions of NOx is the combustion temperature in the engine cylinder and the local stoichiometry of the mixture. The reduction of NOx emissions is possibly due to the smaller calorific value of the blends. Cetane number is also effective in NOx emissions. Cetane number of the sesame oil is smaller than that of the diesel fuel. The smaller the cetane number, the longer the ignition delay and the burning. This causes lower temperatures inside the cylinder and low NOx emissions in the exhaust gases. Exhaust gas temperatures of the blend are lower than those of the diesel fuel due to the lower heating value of the blend. It is proved that the lower temperature causes low NOx emissions when compared with diesel fuel. The variation of NOx emissions for D100 and COME blends with B.P is shown in Figure 3.2.5. NOx content is reduced for C20 and C30 blends compared with D100 which is 1236ppm to 1220ppm and 1218ppm respectively.

3.2.6 Unused Oxygen

The small decrease of O_2 emissions for D100 and COME blends with B.P is shown in Figure 3.2.6. From the plot it is observed that the O_2 content for D100, C10, C20, C30 blends are 18.62%, 14.14%, 14.71%, 14.55% respectively at full loads.O_2 content is slightly reduced for COME blends compared with D100. Since Cetane number of the Cottonseed oil is smaller than that of the diesel fuel. The smaller the cetane number, the longer the ignition delay and the burning. This causes effective utilization of O_2 for all the COME blends compared with D100.

ISSN 2229-5518

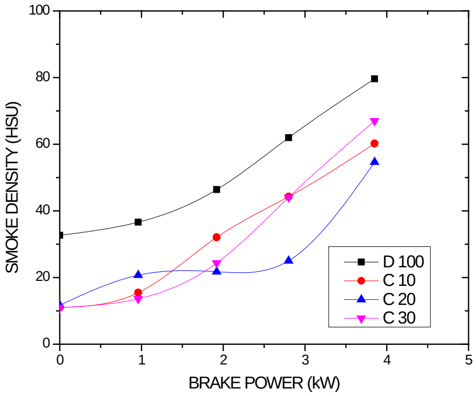

Fig 3.2.1 Variation of Smoke Density with Brake Power using COME Blends

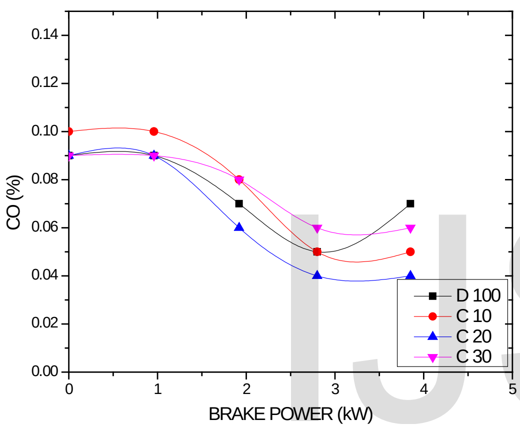

Fig 3.2.2 Variation of Carbon Monoxide with Brake Power using COME Blends

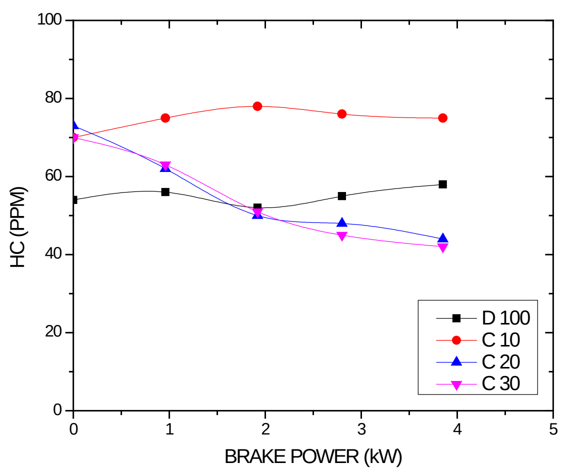

Fig 3.2.3 Variation of Unburned Hydrocarbons with Brake Power using COME Blends

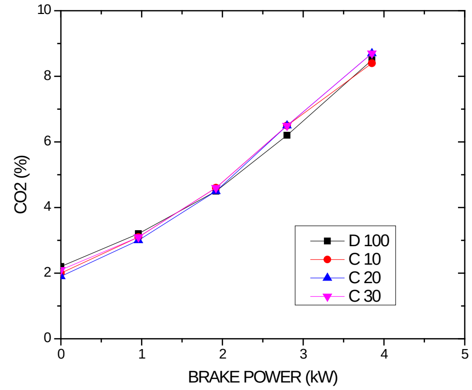

Fig 3.2.4 Variation of Carbon Dioxide with Brake Power using COME Blends

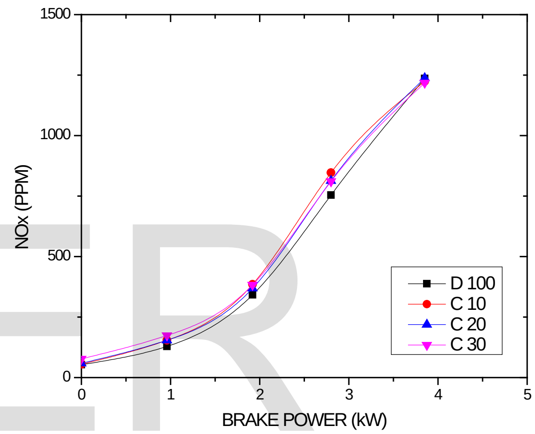

Fig 3.2.5 Variation of Oxides of Nitrogen with Brake Power Using COME Blends

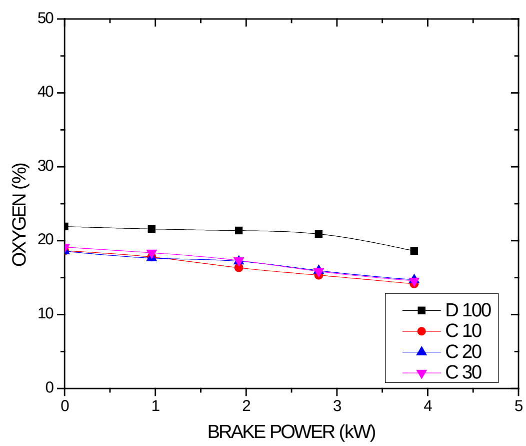

Fig 3.2.6 Variation of Unused Oxygen with Brake Power using COME Blends

4. CONCLUSION

From the above results the following conclusions are made

- BTH has been observed for C20 at full load as 35.62% and for D100 it is 32.82%. So the percentage of increase in BTH compared to D100 by C20 is 4.7% which is more than other blends.
- BSFC for D100 is 0.26 Kg/kW-hr but for C20 and C30 are 0.25kg/kW-hr so percentage of decrease in BSFC for both these blends is 3.8%.
- For the C20 blend the A/F ratio is slightly more compared to diesel which is also more compared to other blends
- The maximum smoke density recorded for the diesel was 79.6 HSU and 60.33 HSU for C10 and 54.67 HSU for C20 at maximum brake power. The decrease in smoke density by percentage compared to D100 for C10 and C20 is 24% and 22.6% respectively.
- Unburned hydrocarbons are reduced by 4.6% using the blends C20 and C30 as compared with diesel.
- NOx content is slightly reduced for C20 and C30 blends compared with D100 which is 1236ppm to 1220ppm and 1218ppm respectively.

Since from the above experimental results C20 is chosen as optimum blend for its great influence on to increased Brake thermal efficiency and decrease in Smoke density and NOx content and unburned hydrocarbons.

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