EXPERIMENTAL STUDIES ON EFFECT OF EXHAUST GAS RECIRCULATION (EGR) ON CARDANOL BIODIESEL BLEND WITH COBALT OXIDE AS NANO ADDITIVE

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***Abstract**: The use of Nano additives in alternate fuels have been emerging day by day which results in lowering the emissions and thereby increasing performance characteristics. In the present study Cardanol oil is used as alternative fuel with cobalt oxide (Co_3O_4) as nano additive to achieve better performance and lower emissions. In this current investigation Cardanol bio diesel blends (B10, B20 and B30) are used with Cobalt oxide (Co_3O_4) as nano additive has been tested for performance and emission characteristics of Compression ignition engine. Biodiesel emits higher amounts of NOx Emission. In order to reduce NO_x Emission Exhaust gas recirculation (EGR) of 5%, 10%, 15% is employed. Finally the performance and emissions like NO_x, HC, CO, CO_2 with Exhaust gas recirculation are compared.*

Keywords - Cardanol, Biodiesel, and Exhaust gas recirculation.

I. INTRODUCTION

Compression Ignition engines are extensively used for transportation because of its fuel economy and torque. The incremental usage of automobiles resulted in an +and find better replacement for diesel fuel due to their low emission characteristics and equivalent energy, but the biodiesel fuels emit higher NOx emissions. According to biodiesel characteristics the use of pure biodiesel in C. I engines is undesirable because of its high density and viscosity erode the engine rings, tubing, clog nozzles, increase carbon deposition. Biodiesel in pure form has high gelling point compared to other fuels. This means it thickens when the temperature falls below the freezing point. Fuels with high viscosity could not mix with air properly which leads to incomplete combustion. So oils cannot be used directly in C. I engines. Viscosity can be reduced by so many methods. Among them transesterification is most commonly used. In transesterification process triglycerides of vegetable oils are transformed into esters in the presence of base catalyst such as potassium hydroxide (KOH), sodium hydroxide (NaOH) and methanol. In the current study cardanol oil is used as alternate fuel which is derived from cashew nut shell liquid (CNSL) by transesterification process.

Mohd Hafizil Mat Ysain investigated on effects of exhaust gas recirculation (EGR) on palm oil and reported that decrease in exhaust gas temperature is obtained when EGR is employed. NO_x emission is reduced significantly when EGR is used with increase in carbon monoxide and unburnt hydro carbons. The presence of lower oxygen while using EGR results in increase of 19.5% in Brake specific fuel consumption (BSFC) and decrease of 1.6% in exhaust gas temperature. In case of emissions there is a decrease of 22% in NO_x, increase of 24.5% in CO.

Karthikeyan.S investigated that the addition of nano particles to fuel improves physical and chemical properties. Additives are the major source to increase the calorific value of the fuel. Oxygen present in cobalt oxide makes ignition cleaner, increasing the amount of cobalt oxide in ppm results in increase of brake thermal efficiency, lower emissions.

II. MATERIALS AND METHODS OF PRODUCTION

2.1. Extraction of cardanol oil

Cardanol oil is acquired from cashew nut shell liquid (CNSL) which is the origin of cashew nut. The cashew tree is a tropical evergreen impervious to sandy soil which raises up to 12 meters high, spread up to 25 meters. India is one of the significant makers of cashews it was first present in goa from where it spread to different states of the nation at the outset it was principally utilized for soil authoritative to check erosion of soil. The significant cashew nut generating states in India are Goa, Maharashtra, Andhra Pradesh, Orissa, Kerala, Karnataka, Tamil Nadu and West Bengal. The nut is connected to the lower part of the cashew apple which is narrowly molded. The cashew nut (seed) hangs at the base of the apple, and is c-formed. The cashew seed has inside the external shell the eatable piece or nut. In its curded structure the cashew portion is delicate, white and substantial. At that point when cooked it changes shading and taste. Cashew apples and cashew nuts are rich in nutrients and minerals. The cashew nut is a kidney shaped structure and it comprises principally of a nutshell and a kernel, which is the primary result of cashew. The nutshell a dull rosy earthy colored thick fluid which is harmful natural tar, known as cashew nut shell liquid (CNSL) and a hard and fragile inward shell which ensures the kernel. CNSL is a valuable source of natural phenols. Cashew nutshell oil is utilized as fuel for thermal power generation plants in cold areas -42 degrees, in addition it is utilized to make cardinal as added substance in industries and business applications such as paints, water proof coatings, to adhere one substance to another as adhesives, in glues. Cardanol also have applications in lamination industry, surface coating, paints and brake linings.

2.2. Transesterification of cashew nut shell liquid

For getting one liter of cardanol methyl Ester, cashew nut shell liquid of high viscosity is preheated at 70-80 degree centigrade and poured in a three way magnetic stirrer. Take a conical flask with 100ml methanol and 7.5grams of sodium hydroxide or potassium hydroxide as catalyst stir the mixture completely to get sodium or potassium methoxide gently pour the sodium methoxide or potassium methoxide in to the magnetic stirrer leave it for 2-3 hours. Pour the entire mixture in another flask and leave it for some time a separation of layer is obtained in which higher density molecules settled at bottom known as glycerine. Upper portion of the liquid is known as cardanol methyl Ester.

(a) (b)

Fig 2.1. (a)Magnetic Stirrer apparatus, (b) Heating of cardanol methyl Ester after washing

2.3. Cobalt oxide as nano particles

A group of researchers investigated and reported that the cobalt oxide (Co3O4) nanoparticles can be effectively used as additives for biodiesel fuels. The oxygen molecules can direct the ignition response much like cerium oxide. Subsequently the combustion was cleaner, better amount of oxygen is available when utilizing he cobalt oxide nano additive added substance and emission parameters like carbon monoxide and unburnt hydrocarbons were reduced. The cobalt oxide nano additive provides the diminishment of NOx creation which is high in biodiesel combustions. It is also known that biodiesel fuels emit high NOx emissions compared to diesel fuel. The amount of oxygen available in cobalt oxide is 26.57%

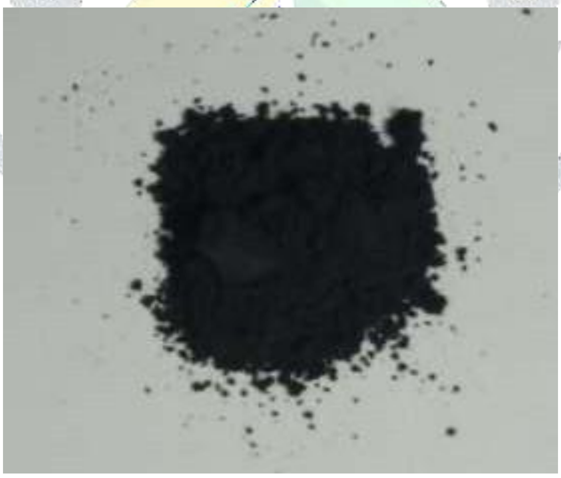


Figure 2.2. Cobalt oxide

Average Particle Size(APS)	Purity	Colour
30-50 nm	99.95 %	black

Table 2.1. Cobalt Oxide (CO_3O_4) Nano particle Specification

2.4. Ultra sonication of biodiesel dispersed with cobalt oxide nano particles

Ultra sonication is a powerful method of scattering nano particles in a fluid. The nano particles of 80ppm is measured and get dispersed in three different blends of B10,B20,B30 in which calorific value gets increased due to the presence of cobalt oxide. Ultrasonicator cycle was done at frequency of 50 kHz, 120w for 45min

S.No.	Fuel blends	Density (Kg/m3)	Kinematic Viscosity (Cst)	Calorific value (KJ/Kg)
1	Diesel	826	3.57	42000
2	B10+80ppm CO_3O_4	854	4.42	41520
3	B20+80ppm CO_3O_4	859	5.18	41200
4	B30+80ppm CO_3O_4	864	5.53	40800

Table: 2.2. Properties of various blends of cardanol oil

III. EXPERIMENTAL SETUP AND ARRANGEMENT

The current work is done to study the performance and emission characteristics of a C.I engine using cardanol biodiesel as fuel. A dynamometer is coupled with engine to determine the performance at rated rpm. Exhaust gas analyzer is used to evaluate the emission characteristics of the engine. Engine was started and made to run with diesel at no load condition speed was adjusted to 1500rpm and the engine was checked for any fuel or oil leaks. After running for certain period of time the diesel was cutoff and cardanol biodiesel blend is allowed to enter in to the combustion chamber. Now gradually apply the loads using dynamometer. The engine was run for few minutes and data were collected during last minutes. The performance and emission tests were carried for three different blends namely B10 80ppm Co_3O_4, B20 80ppm Co_3O_4, B30 80ppm Co_3O_4 at various loads. The exhaust gas sample is passed through AVL DI 444 exhaust gas analyzer for measurement of CO, HC, and NOx present in exhaust gases of Cardanol biodiesel blend.

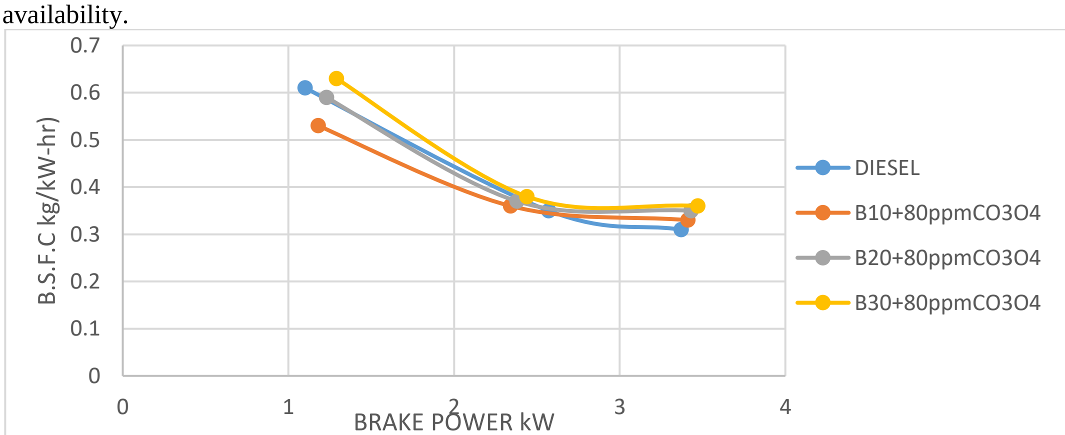
(a) (b)

Fig: 2.4. (a) 4-Stroke Single Cylinder VCR engine with EGR (b) Exhaust Gas Analyzer

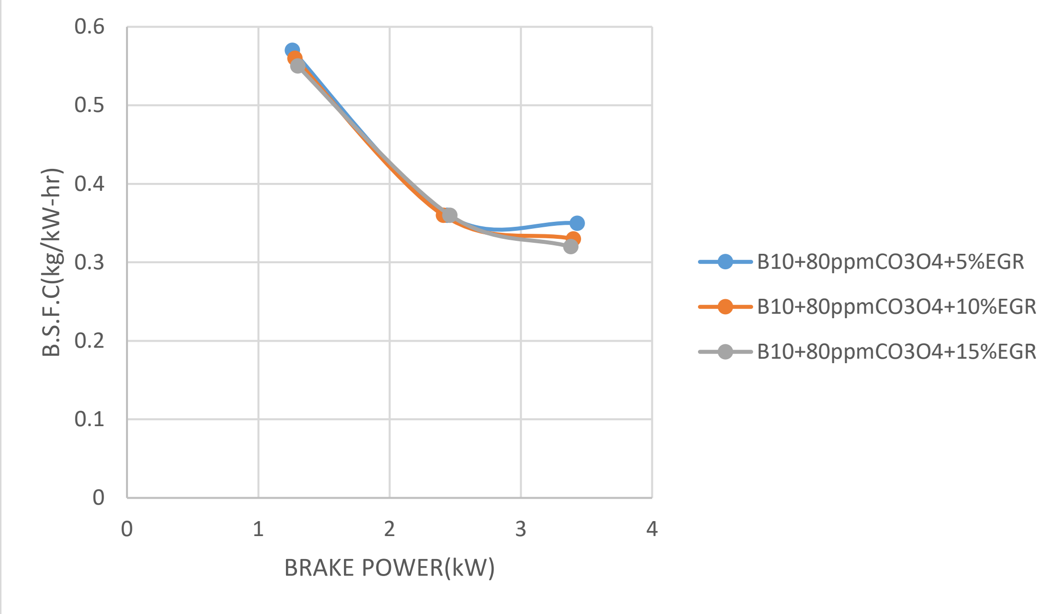
IV. RESULTS AND DISCUSSIONS

Brake specific fuel consumption

Brake specific fuel consumption for various cardanol blends with respect to brake power are compared. It is observed that specific fuel consumption is high at lower loads for diesel and further by increasing the loads specific fuel consumption has been decreased. By increasing the blend percentage brake specific fuel consumption decreases with increase in load, due to presence of cobalt oxide which acts as oxygen buffer leads to better atomization, and improved combustion. When Exhaust gas recirculation (EGR) is used at lower loads brake specific fuel consumption is lower, at higher loads it will be similar to without EGR due to decrease in oxygen availability.



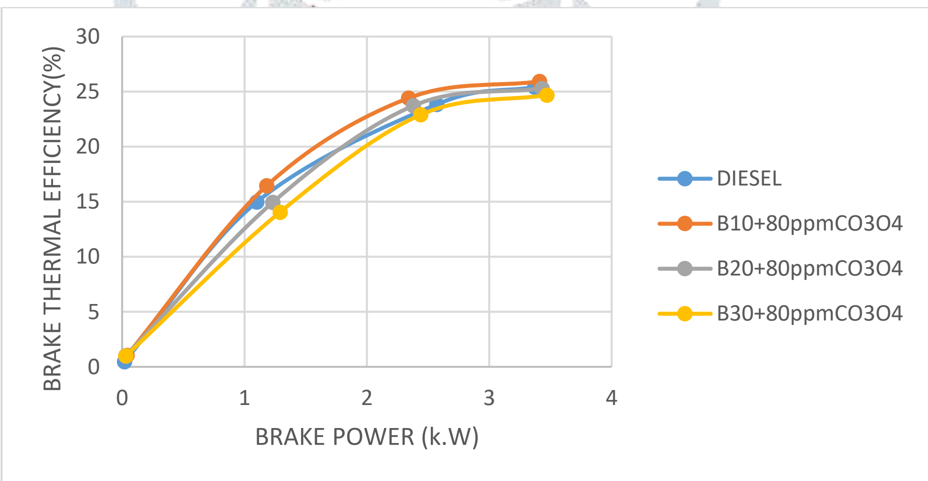
Graph. 4.1. Variation of BSFC with Brake power for blends B10, B20 and B30 with 80ppm CO_3O_4



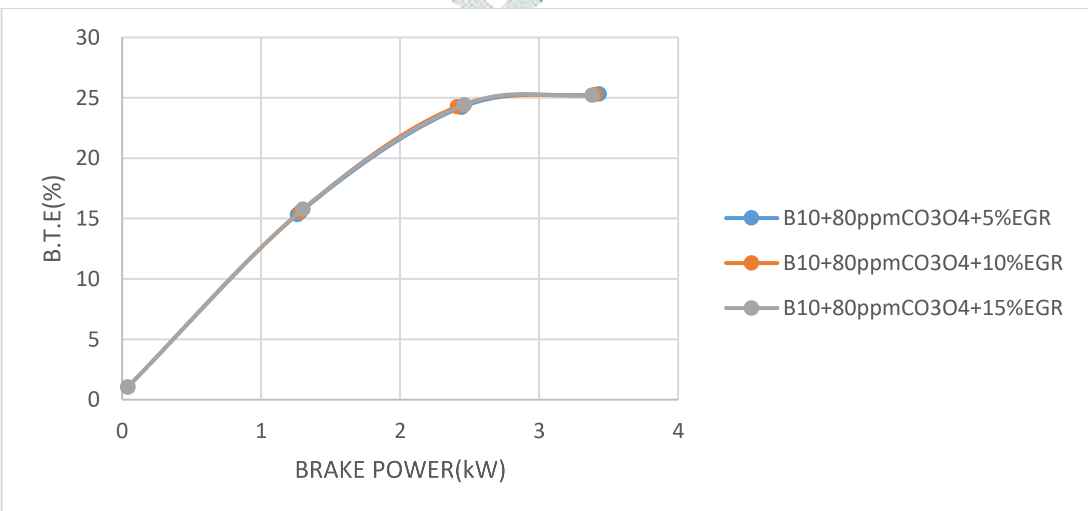
Graph. 4.2. Variation of BSFC with Brake power for blends B10+80ppmCO_3O_4 with 5%, 10%, 15% EGR

Brake thermal efficiency

Brake thermal efficiency for various cardanol blends with respect to brake power are compared. It is reported that by increasing the blend percentage brake thermal efficiency increases with increase in load, due to high evaporation rate, and secondary atomization. When exhaust gas recirculation is used at lower loads there is a slight increase in brake thermal efficiency due to reburning of hydrocarbons that enters combustion chamber with recirculated gas. At higher loads it remains unaffected due to increase in co_2, decrease in maximum temperature present in the combustion chamber. A slight increase in BTE of 1.96%was observed with the addition of cobalt oxide nanoparticles to biodiesel blend of B10+80ppm CO_3O_4 compared to diesel.



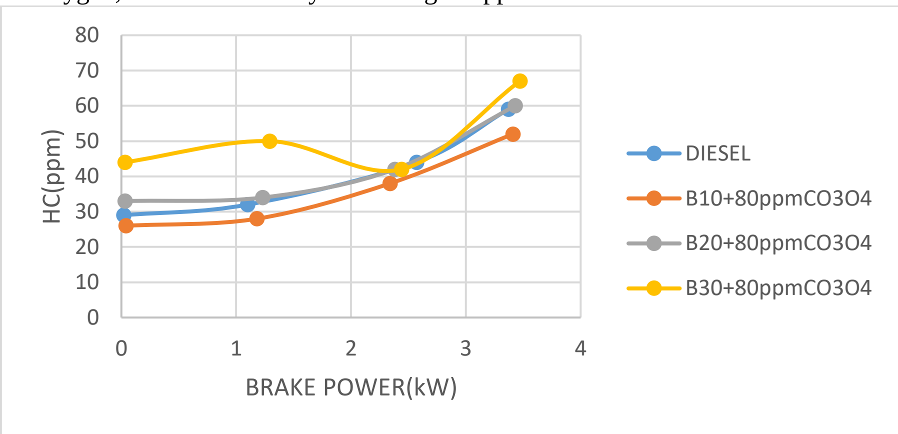
Graph. 4.3. Variation of BTE with Brake power for blends B10, B20 and B30 with 80ppm CO_3O_4



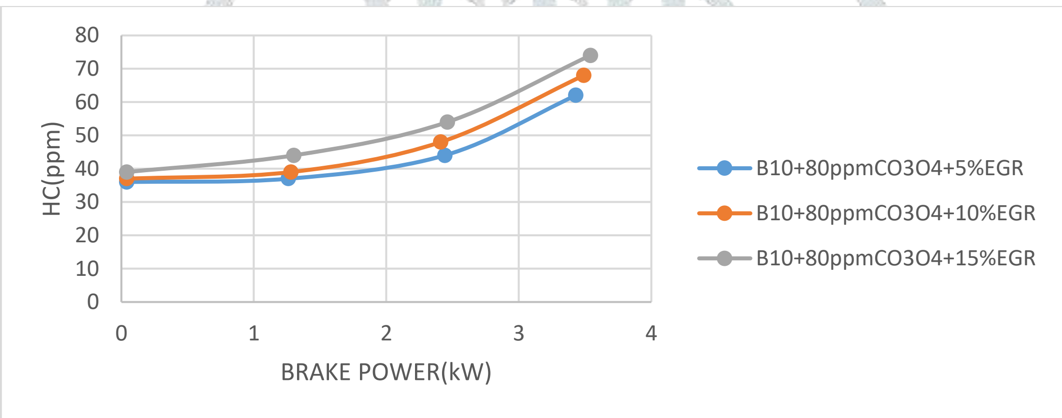
Graph. 4.4. Variation of BTE with Brake power for blends B10+80ppm $CO_3O_4$with 5%, 10%, 15% EGR

Emission parameters HC

The graph shows lower HC for lower loads. For high loads there is an increase in HC. Emission of HC depends on atomization, better air fuel mixture, ignition delay and physical properties of the fuel. Oxygen content present in nano additive leads to lower emission of HC. At high loads HC got reduced by 11.86% compared to diesel for B10+80ppm CO_3O_4. i.e. due to availability of oxygen present in biodiesel. When exhaust gas recirculation is used there will be an increase in HC due to lower concentration of oxygen, can be reduced by increasing the ppm of cobalt oxide nano additive.



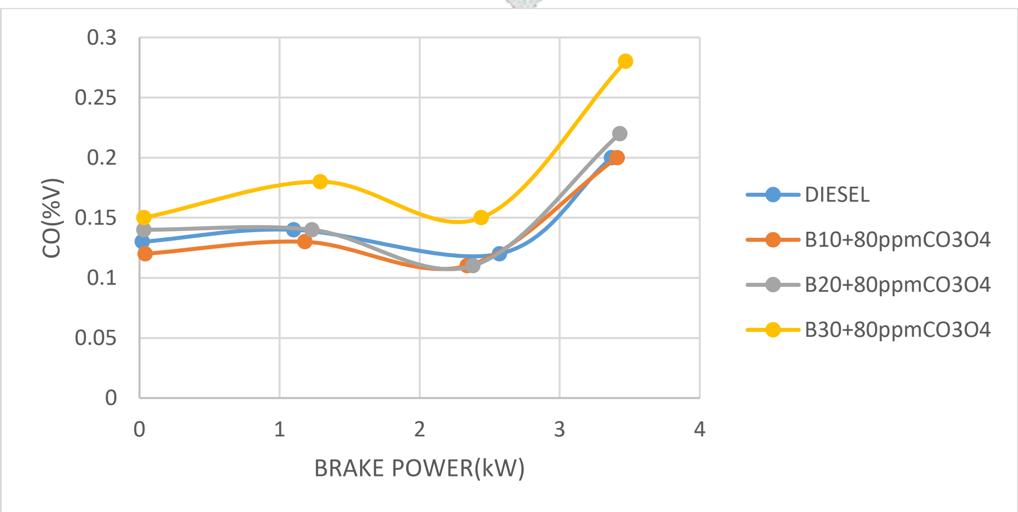
Graph. 4.5. Variation of HC with Brake power for blends B10, B20 and B30 with 80ppm CO_3O_4



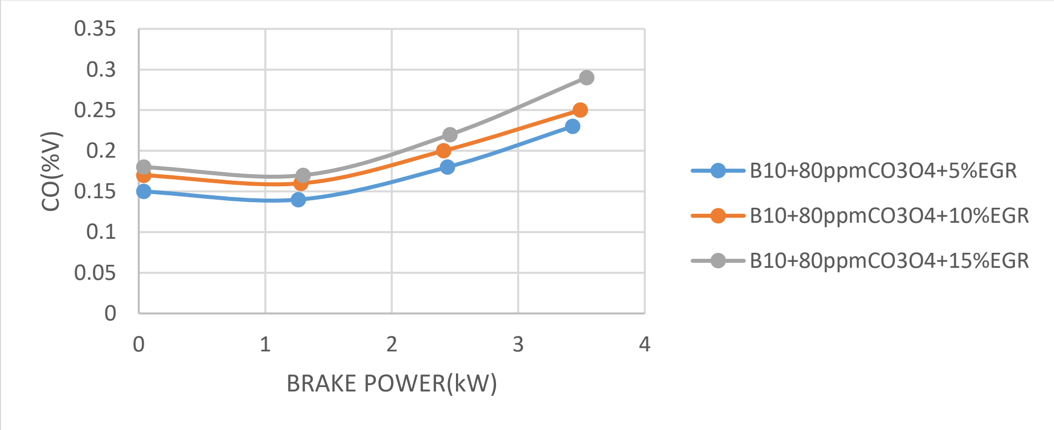
Graph. 4.6. Variation of HC with Brake power for blends B10+80ppm CO_3O_4 with 5%, 10%, 15%EGR

Emission parameters of CO

The below Fig. shows lower CO for lower loads and higher for higher loads due to presence of high air fuel mixture, it is observed that B30 shows increase of CO emissions due to high viscosity and poor atomization than that of other blends and diesel. At high loads CO got reduced by 8.3% compared to diesel, it is due to presence of cobalt oxide having higher oxygen atoms which can moderate combustion reactions and reduce emissions. When exhaust gas recirculation(EGR) is used there is an increase in CO due to lower concentration of oxygen which has to be recirculated into the combustion chamber.



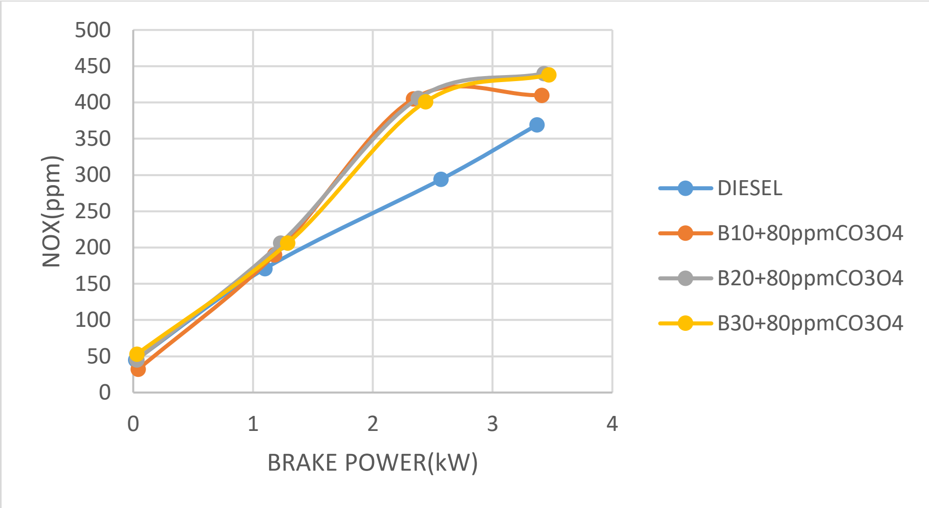
Graph. 4.7. Variation of CO with Brake power for blends B10, B20 and B30 with 80ppm CO_3O_4



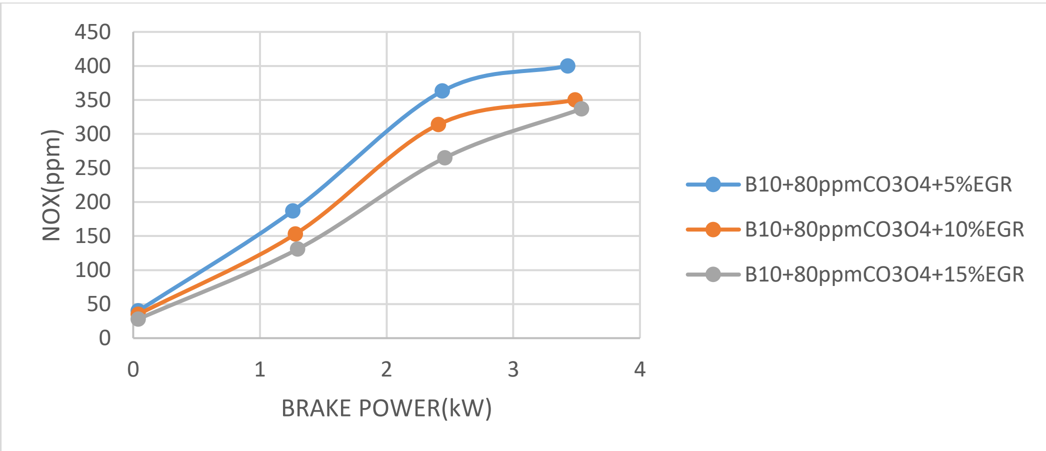
Graph. 4.8. Variation of CO with Brake power for blends B10+80ppm Co_3O_4 with 5%,10%,15%EGR

Emission parameters of NO_x

It is observed that with increase in percentage of blends there is increase in NO_X emission due to presence of inbuilt oxygen in the biodiesel which helps towards complete combustion and develops high exhaust temperatures which is favorable for getting NO_X The below Graph shows high increase in NO_X at higher loads due to presence of oxygen in cobalt oxide to decrease the NO_X exhaust gas recirculation is employed. An increase in NO_x of 11.11% is observed while using cobalt oxide, it is reduced with the help of exhaust gas recirculation. When EGR is used there is a decrease trend at lower loads for higher loads NO_X reduces drastically due to lower concentration of oxygen. At low loads exhaust gas recirculation reduces NOx without effecting the performance and emissions. At high loads Exhaust gas recirculation reduces NO_X affecting the performance and emissions. While using EGR of 5%, 10%, 15% at higher loads NO_x has been reduced drastically by 2.43%, 14.63%, 17.80% compared to B10+80ppm Co_3O_4.



Graph. 4.9. Variation of NO_X with Brake power for blends B10, B20 and B30 with 80ppm Co_3O_4



Graph. 4.10.Variation of CO with Brake power for blends B10+80ppm Co_3O_4 with 5%,10%,15%EGR

CONCLUSIONS

Cobalt oxide blended biodiesel showed an increase in calorific value. A slight increase in brake thermal efficiency is observed with the addition of cobalt oxide nano particles at full load. Cobalt oxide blended biodiesel reduce HC, CO emissions since cobalt oxide is having higher oxygen atoms which can moderate combustion reactions and reduce emissions. An increase in NO_X emissions is observed while using cobalt oxide it can be reduced while using exhaust gas recirculation. At higher loads NO_X has been reduced drastically with increase in HC and CO emissions which effect the performance.15% EGR is found to be effective to reduce NO_X without effecting the performance and emissions characteristics.

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