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Influence of Nano Metallic Additive on Jamun Oil and Habitude in Compression Ignition Engine

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***Abstract:** An experimental investigation has been carried out to validate the effects of cupric oxide and zirconium oxide Nano metallic additive in jamun seed oil and habitude in CI engine. Jamun seed oil is refined by wellknown trans esterification process and Nano biodiesel fuels were prepared by adding cupric oxide and zirconium oxide nanoparticles additives. These nanoparticles were blended with jamun seed oil (jamun) in the mass fractions of 25 ppm, 50 ppm with aid of ultrasonicator. Physicochemical characteristics of Nano biodiesels were measured and correlated with diesel fuel. Engine tests have been conducted to get the comparable measures of Brake Specific Fuel Consumption (BSFC), Brake Thermal Efficiency (η) and Emission components like CO, HC, NOX & O2 are evaluated to study the behavior of B20 added with 25ppm, 50ppm Cupric oxide (CuO) nanoparticles and 25ppm, 50ppm, Zirconium oxide (ZrO2) nanoparticles at various loading conditions with standard diesel operation.*

It is revealed that there is increase in the Brake specific fuel consumption for the fuel B20 with 50 ppm CuO and Zirconium oxide at full load condition. The brake thermal efficiency is matching than that of diesel operation at full load condition. A significant improvement in Emission factors CO, CO2 & HC has been observed when the engine is fed with B20 with 50 ppm CuO and Zirconium oxide at Full Load conditions. In spite of, NOX emissions had increased. Keeping in view of performance and emission analysis the fuel blend 20 with 50 ppm CuO and Zirconium oxide Nano particles is the best combination.

***Keywords:** Nano metallic additive, Jamun oil, Cupric oxide, Zirconium oxide, Brake Specific fuel consumption, Performance & Emission*

I. INTRODUCTION

1) *K.M. Nitish Kumar (2017)* studies that jatropha oil cannot be used directly in a diesel engine due to its higher viscosity and transesterification is carried out to reduce the visocity levels. Nanoparticles such as cerium oxide, titanium dioxide and cupric oxide are added in weight basis (0.02%) (0.03% and (0.04%)to jatropha oil and its performance and emission test were conducted for B20 (20% jatropha and 80% diesel. [1]
2) *Sreesha MBhat et.el.,* discussed different fuel opportunity encrich the engine performance by using various edible and non-edible oil as an alternative fuels. Stabilization of calcium oxide nano particle with castor were examined with SEM, XRD and FTIR spectrum rays tests.[2]
3) *A. Rajalingam et.al.* analyzed the physiochemical properties such as kinematic viscosity, specific gravity, cetane number, gross calorific value and flash point of neem oil biodiesel with cerium oxide blends and properties compared to ASTM standards.[3]
4) *S.M. Abdul Razek et.al,. examined the effect of aluminumoxide nano particle in B20 biodiesel blends and concluded* that overall BSFC is reduced by about 12.5%, engine thermal efficiency is increased up to 12%, and exhaust gas temperature is reduced by 13%. Along with percentage reduction of smoke opacity by 20 %, unburned hydrocarbon by 10 %, carbon monoxide by 29 % and nitrogen oxides by 13%.[4]

II. LITERATURE REVIEW

1) *J.Tharun et.al,.* Studied the performance and emission levels of jamun seed powder blend of 20 % and 30 % in twin cylinder diesel engine in order to reduce the oxides of emission. There has been high increase in the oxide formation levels however the unexpected reduced emissions of HC Hexane has captured the importance of jamun seed. The blends proved to have high fuel power and brake thermal efficiency in parallel with the reduction of Fuel consumption there by compensating the fuel economy by the above two factors. [5]

2) *Visnusarathy et. el,* investigate the performance and exhaust emission of various blends of jamun seed oil methyl ester (JOME) in a small - unmodified single cylinder diesel engine and to compare them with that of a reference diesel fuel (D100). The B30 blend yields 3.5% more brake thermal efficiency than diesel and the specific fuel consumption decreases by 8.8%. In emission characteristics B30 blend shows considerable reduction in CO, CO2, HC, Smoke density particularly NOX emission of B30 decreases by 32% when compared to diesel. [6]
3) *S.Vinodraj et. el,*. Establish the effects of combustion catalyst cupric oxide and Zirconium oxide nano particle on cashew nut shell biodiesel (cardanol) and habitude in diesel engine. It is noticed that there is slight rise in the specific fuel consumption for the fuel B20 with 100ppm cupric oxide (CuO) and Zirconium oxide (ZrO2) at full load operation. The brake thermal efficiency is identical than that of diesel operation at full load condition. A convincing improvement in Emission components CO, CO2 & HC has been observed when the engine is fed with B20 with 100ppm CuO and ZrO2 at both 3/4th Full Load and Full Load conditions. However, NOX emissions had increased. Reckon with performance and emission analysis the fuel blend 20 with 100 ppm CuO and Zirconium oxide Nano particles is the best combination.[7]
4) *MD Imitaz et.el.,* investigate the mechanical properties and performance characteristics of bio diesel extracted from jamun seed oil. the results of JB10 and JB30 shows better Brake thermal efficiency and specific fuel consumption compare to diesel. The Emissions like CO2,NOX and smoke opacity are reduced compare to diesel. HC and CO are highly increased. Further we add 5% of Diethyl Ether to JB10 HC and CO decreased compare to diesel and slightly increased in NOX and shows better efficiency.[8]

III. EXPERIMENTAL STUDY

The experimental study was conducted in a single cylinder, four stroke, air cooled, direct injection diesel engine that has a rated output of 4.4 kW at constant speed of 1500 rpm. An electrical dynamometer was coupled to the engine was used as a loading device. The load and speed can be increased or decreased on the engine by using dynamometer, by switching on or off the load resistances. Carbon monoxide (CO), carbon dioxide (CO_2), nitrous oxide (NO_x) and unburned hydrocarbon(UBHC) emissions were measured by AVL exhaust gasanalyzer. Fuel consumption was measured by a U-tube manometer. Smoke number was measured by smoke meter. The schematic diagram of the experimental set-upis shown in with all measuring points and measuring instruments. The technical specifications of the engine are given below respectively. The engine was started with diesel fuel and warmed and thenfuel consumption and exhaust emissions NOx, HC, CO, CO2 and smoke were measured. Similar procedure was repeated for biodiesel (B20, B60, and B100) and biodiesel (B20 jamun) with nano fuel additives of CuO and ZrO_2 in various level ppm.

A. Preparation of nanoparticles

The stabilization is the process of making the nanoparticles stable with the biodiesel without getting deposit at the bottom. The stability of fuel is very essential, because by making the fuel stability it helps for good combustion inside the engine cylinder. The process of adding nanoparticles to the fuel is done with the aid of an ultrasonicator.

The ultrasonicator technique is the best suited method to disperse the nanoparticles in the base fuel, as it facilitates possible agglomerate nanoparticles back to nanometer range. . It helps to maintain stability of nanoparticles with biodiesel for a period of time. In this experiment cupric oxide (CuO) and zirconium oxide (ZrO_2) nanoparticles are weighed to a predefined mass fraction say 25ppm, 50ppm dispersed in the biodiesel with the aid of ultrasonicator set at a frequency of 20 kHz for 60 minutes. The resulting nanoparticles blended biodiesel is named as B20+25ppm, 50ppm CuO and ZrO_2. For analyzing the stability characteristics of nanoparticles blended biodiesel, the blends were kept in conical flask under static conditions.

B. Procedure for stabilization process

1) First the nanoparticles of 25, 50 ppm cupric oxide and zirconium oxide are measured and kept in the separate air tight container.
2) The biodiesel obtained from the jamun oil is poured into the conical flash of 500 ml.
3) The distilled water is poured in to the ultrasonicator.
4) In the conical flask the biodiesel (jamun) are mixed with nanoparticles of 25 ppm of CuO and keep the conical flask inside the ultrasonicator.
5) The stabilization time is set for 60 minutes in the ultrasonic bath so that the nanoparticles and biodiesel (jamun) get stabilized.
6) After 60 minutes the nanoparticles get stabilized in the biodiesel (jamun).
7) The same procedure is repeated is for all the levels of nanoparticles.

C. Engine performance and emission tests

Table 1 Specifications of Test engine

Make	Kirloskar
No. of Cylinder	One
Stroke	Four Stroke
Type of Cooling	Air Cooled
Ignition	Compression Ignition
Fueling	Diesel
Bore	87.5 mm
Stroke	110 mm
Compression Ratio	17.5:1
Speed	1500 rpm
Brake Power	4.4 kW
Injection Pressure	200 bar
Static Fuel Injection Timing	23 bTDC

Fig 1 Experimental set-up

IV. RESULTS AND DISCUSSIONS

The following section illustrates the results obtained from the performance and emission characteristics of the CI engine for diesel and biodiesel blends B20, B60, B100,B20+25,50 ppm CuO and B20+25,50ppm ZrO_2.

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A. Performance characteristics of blend percentage of B20, B60, B100 of jamun oil:

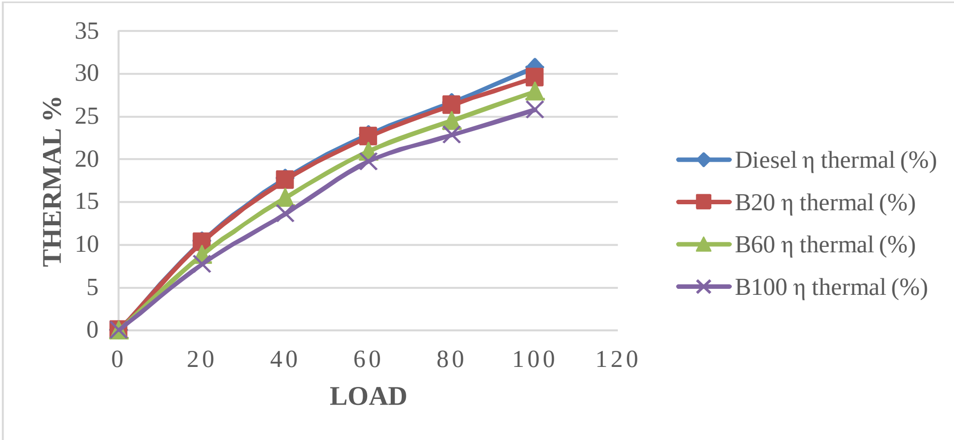

Fig: 2 Load vs Thermal η %

The variation of the thermal efficiency with respect to the load is shown in the Fig 2. The thermal of the jamun blends (B20, B60, and B100) was lower than the diesel. This is due to the lower calorific value, higher viscosity and density present in the jamun oil.

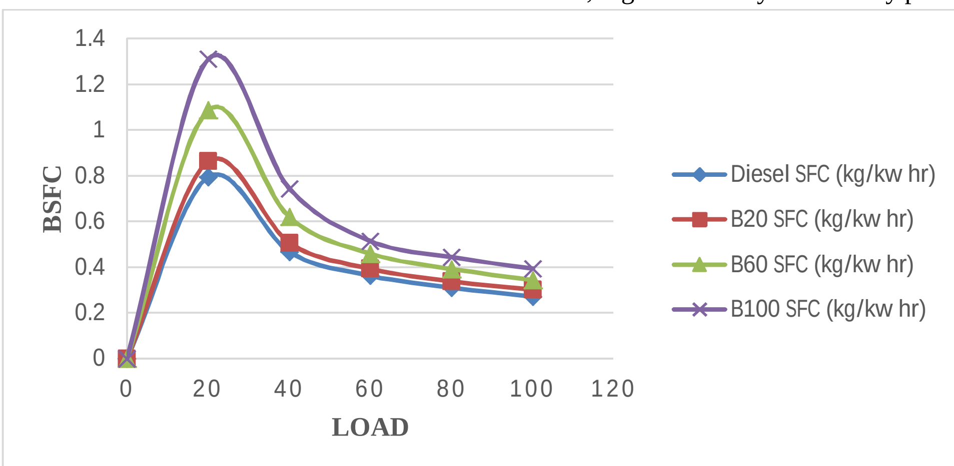

Fig: 3 Load vs BSFC

The variation of the specific fuel consumption with engine loads, for different blends jamun (B20, B60, and B100)) and diesel are shown in Figure 3. The specific fuel consumption decreases with an increase in the engine loads. Lower SFC is observed for B100 jamun biodiesel this occurs due to the enhanced surface area to volume ratio during the combustion of fuel inside the engine cylinder.

Table 2 - Physico chemical properties of jamun biodiesel

Properties	Units	Diesel	Jamun biodiesel	ASTM standards
Specific gravity @ 20˚C	kg/m^3	0.835	0.932	-
Density @20˚C	Kg/m^3	0.85	0.916	0.86-0.9
Flash point	˚C	80	153	>130
Cloud point	˚C	-	-	-
Viscosity @40˚C	Cst	2.8	5.7	1.9-6
Fire point	˚C	88	163	-
Calorific value	kj/kg	42000	36550	-
Cetane number	-	50		Min 47
Iodine value	G12/110g	-	97.12	Max 120
Carbon residue	Mol/mol	-		Max 0.05

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B. Emission Curve

1) *B20, B60, B100 jamun biodiesel:* The major pollutants emitted at the exhaust of the engine are CO, CO2, NOx, HC, and Smoke. Among them, the most problematic gas emission is Nitric Oxide (NO).

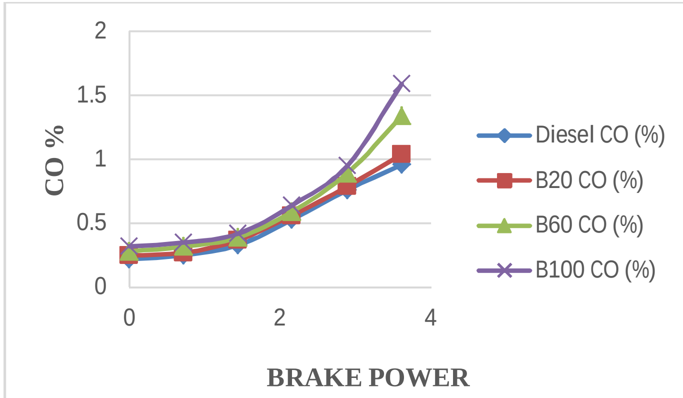

Fig: 4 Brake power vs CO

The graph plotted between brake power and CO% shown in Fig:4 indicates CO emission for jamun biodiesel are higher than that of diesel fuel for varying proportion (B20, B60, B100).This is due to the poor combustion of jamunbiodiesel compared to diesel fuel and it also lowers the thermal efficiency of an engine and reduces the CO_2emission as shown in the fig: 5

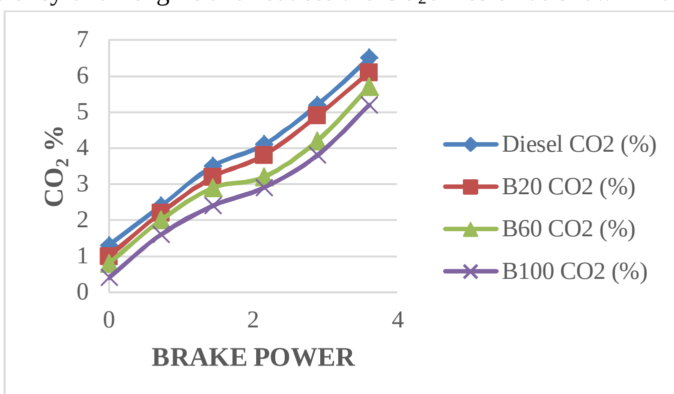

Fig: 5 Brake power vs CO_2

In fig:5 shows as CO% is higher than of diesel fuel. It indicates the poor CO_2 emission compared to diesel fuel and low CO_2 emission gives raise to higher unburnt hydrocarbon HC shown in fig:6

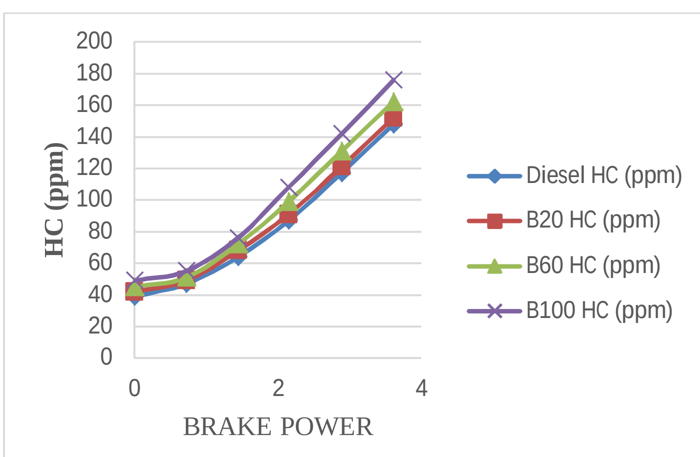

Fig:6 Brake Power vs HC(ppm)

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The un-burnt HC emission variations for diesel, jamun biodiesel blends of (B20, B60, and B100) B20 are shown in Fig 6. The HC emission for B20, B60, and B100operation was higher when compared to diesel fuel. This is due to its lower thermal efficiency of jamun biodiesel resulting for incomplete combustion.

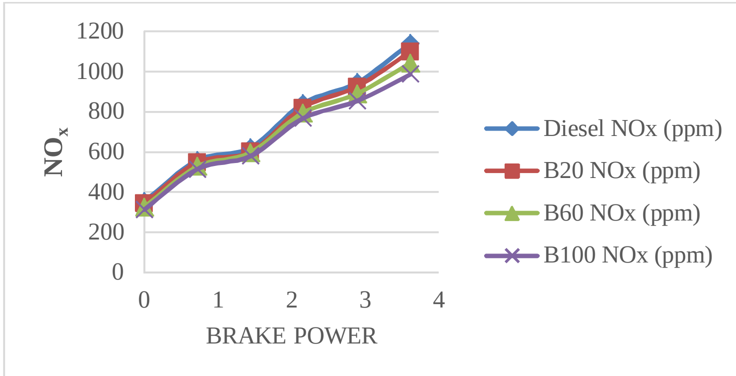

Fig: 7 Brake Power vsNO_x

The variations of NO_x emissions with respect to the load are shown in the Figure 7. The NO_x emissions found decreased with the increase in load. This is due to the lower in-cylinder pressure and the corresponding combustion temperature for all the fuel blends.

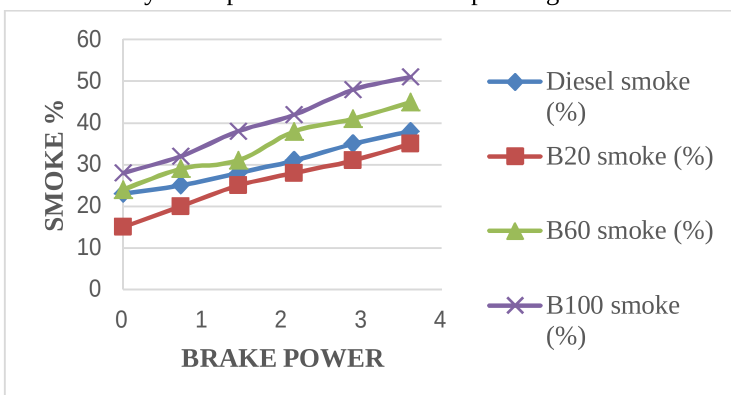

Fig: 8 Brake power vs Smoke

The smoke density variation for different blends is shown in Fig 8. Smoke density for jamun biodiesel (B20, B60, and B100) is noticed to be higher than the diesel fuel. This is due to the heavier molecular structure, poor atomization, presence of high carbon residue in the jamun biodiesel.

C. Performance Characteristics curve

1) Blend of B20 jamun biodiesel with 25, 50 ppm CuO:

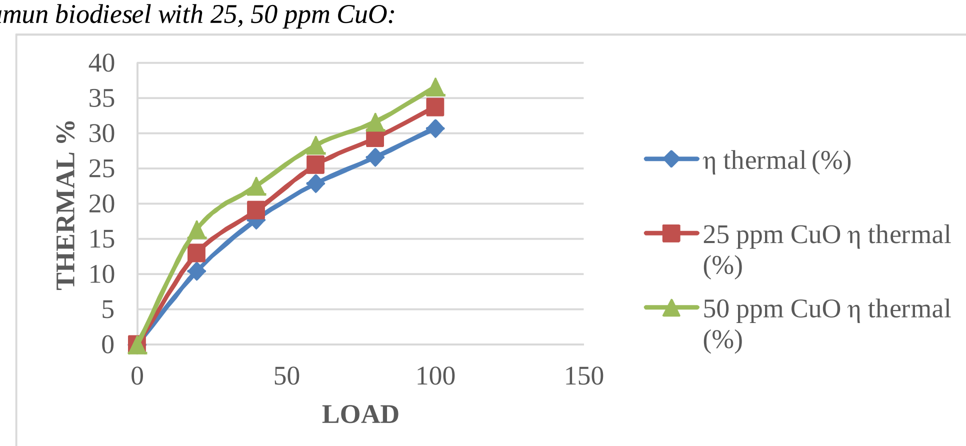

Fig: 9 Load vs Thermal

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The comparison of thermal efficiency (TE) of diesel, B20 +25, 50 ppm CuO at different load conditions is shown in Fig. 9. The results reveal that the addition of nanoparticles leads to an improvement in thermal efficiency compared to B20,B60, and B100 (jamun biodiesel). Nano-additives boost the combustion efficiency by reducing the evaporation time of the fuel and shortening the ignition delay and thus enhance the improvement in thermal efficiency. As the dosage level of nanoparticles increases, the thermal efficiency of the engine also improves due to lower fuel consumption.

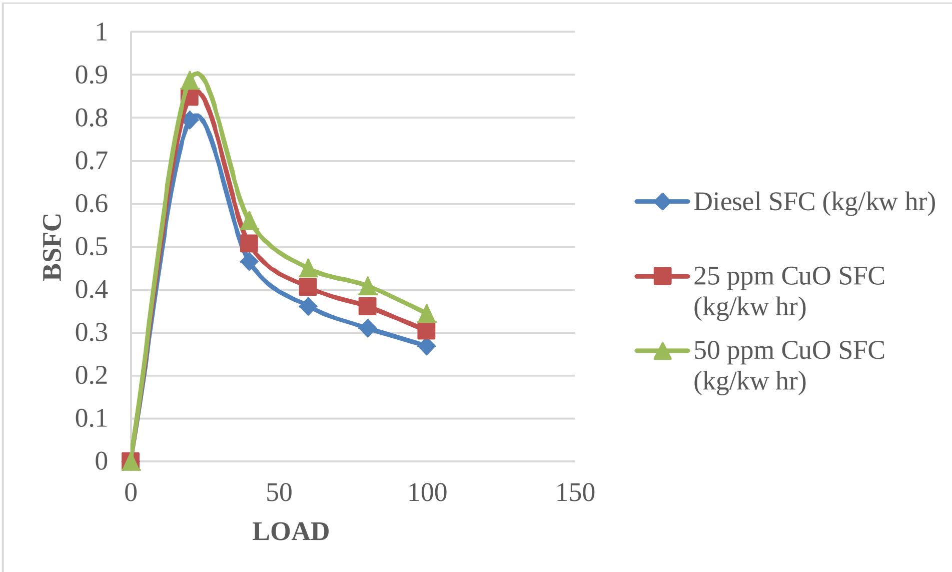

Fig: 10 Load vs BSFC

Fig: 10 shows the variation of brake specific fuel consumption (BSFC) with load. The BSFC is defined as the ratio of fuel mass flow rate to engine output power. It has been observed that by the addition of nanoparticles to B20(jamun biodiesel), the BSFC decreased efficiently. The addition of nanoparticles improves the properties of the fuel and shortens the ignition delay. At each engine load condition, the BSFC reduces more with increasing the proportion of nanoparticle in the base fuel.

D. Emission curve

1) *B20 (jamun) blended with 25ppm,50ppm CuO:* The nanoparticle cupric oxide is added to the biodiesel (cardanol) at the levels of 25, 50 parts per million (ppm).The cupric oxide is added to reduce the exhaust gas emission. The below graph show the emission characteristics of the CuO added to the biodiesel (jamun biodiesel) B20.As the jamun shows some unsteady combustion and increase in emission levels to avoid the toxic and to save the engine life an combustion catalysts is introduced in the form of nano particles to enhance the steady combustion in engine cylinder.

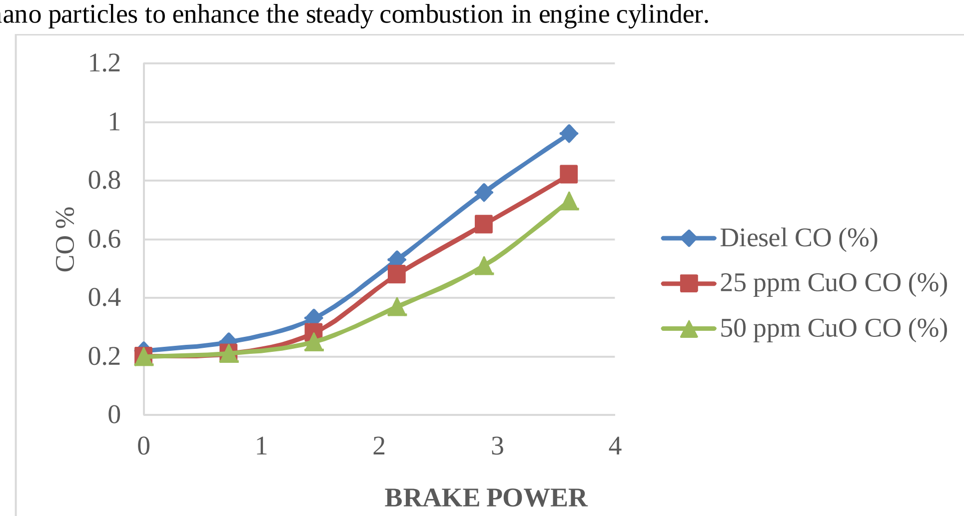

Fig: 11 Brake power vs CO%

The variation of the carbon monoxide (CO) emissions with brake power are shown in the Fig. 11. Carbon monoxide isformed because of poor mixing of fuel and oxidant and incomplete combustion, lack of oxygen, temperature inside the engine. As seen from the fig: 11, the addition of both nanoparticles reduces the CO emission compared to the diesel fuel. The reason is that nanoparticles act as an oxidationcatalyst to accelerate the combustion rate leading to shortened ignition delay. With the decreased ignition delay, the degree of mixing between fuel and oxidant and uniform combustion have been improved and resulted in enhanced complete combustion and hence lower CO emissions. Increasing the mass fraction of nanoparticles in the jamun biodiesel led to more reduction of CO.

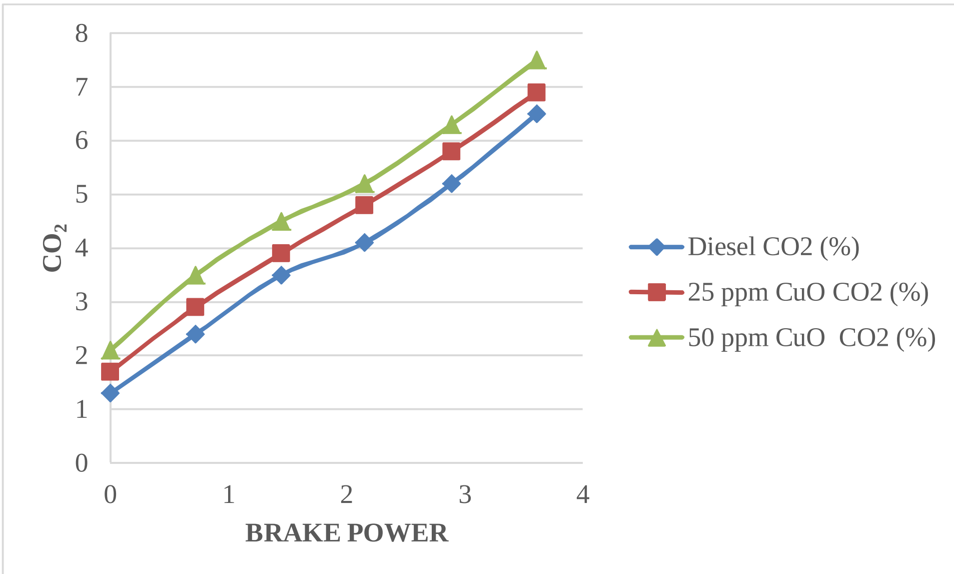

Fig: 12 Brake Power vs CO_2

The above fig 12 shows the variation of CO_2 with brake power. The CO_2 emission for jamun biodiesel (B20) blended with nanoparticles are comparatively higher than that of diesel fuel. This is due to the nano particles act as the catalysts which decrease the ignition delay and improve the combustion of the engine. The increase in emission of CO_2 is good for the engine.

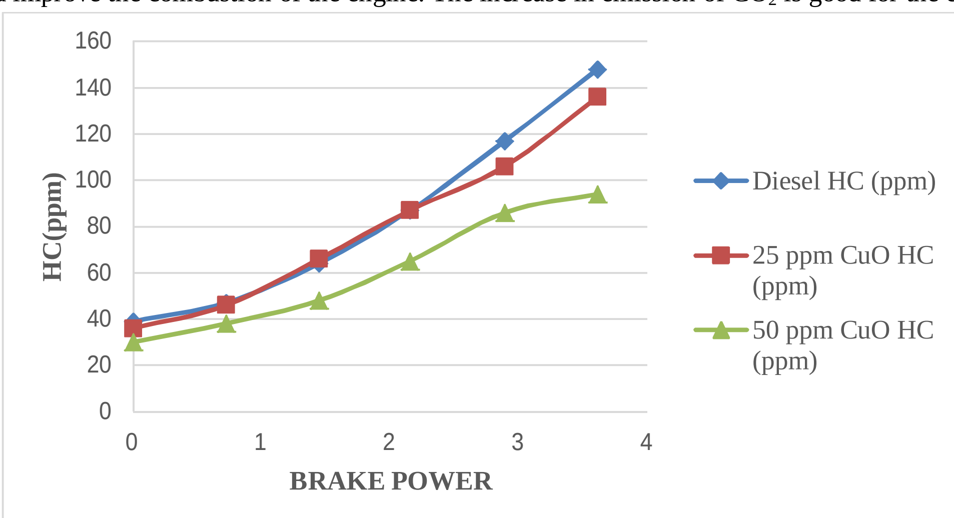

Fig: 13 Brake Power vs HC(ppm)

The un-burnt HC emission variations for Diesel, jamun biodiesel (B20) with cupric oxide nanoparticle blended fuels of B20 are shown in Figure 13. The HC emission for (B20, B60 and B100) operation was higher compared to diesel due to its lower thermal efficiency resulting from incomplete combustion. However HC emissions were marginally lower cupric oxide blended with (B20) jamun bio diesel compared to B20. This could be due to increased catalytic activity and improved combustion characteristics of oxide, copper oxide nanoparticles which lead to improved combustion.

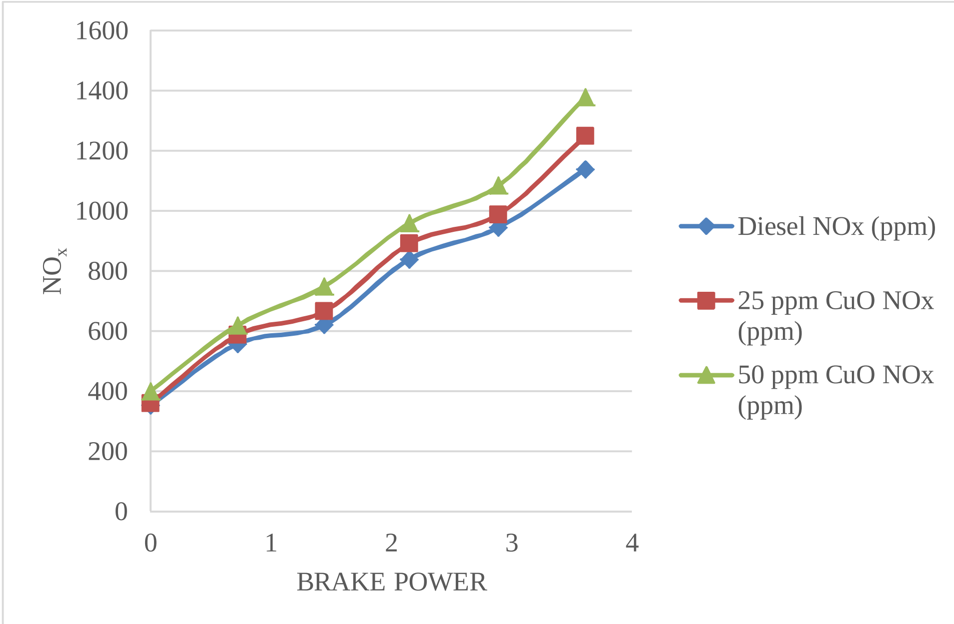

Fig: 14 Brake Power vsNO_x

The variations of NOx emissions with respect to the load are shown in the Figure 14. The NOx emissions found increased with the increase in load. The NO_x emissions are increasing with the load due to the more in-cylinder pressure and the corresponding combustion temperature for all the fuel blends. Similar trend was observed for diesel and B20 blended nano additives of cupric oxide at almost all loads. From the graph it is observed that addition of Nano-fuel additives resulted in an effective in NOx emission. This is due to that nanoparticles oxidize the nitrogen into nitric oxide at the elevated temperatures during the combustion process.

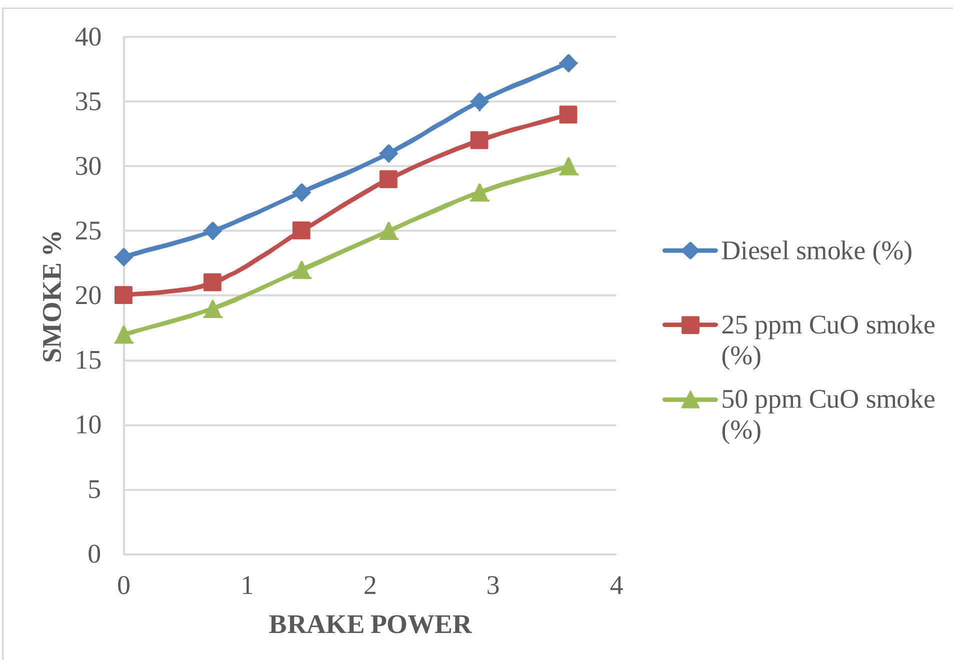

Fig: 15 Brake power vs Smoke

The smoke density variation with respect to brake power is shown Fig 15. Smoke density for jamun biodiesel blended with CuO nanoparticles is noticed to be lower than the diesel. This is due to the use of of oxygenate fuel (CuO) improves better combustion is the cause for reduction of smoke. It is observed the B20 jamun biodiesel with 100 ppm of CuO is very much lesser than diesel.

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E. Performance curve

1) *B20 blended with 25,50 ppm ZrO_2:* In this section we are adding the nanoparticles of zirconium (ZrO_2) at the levels of 25, 50, 75, 100 ppm. The below graphs shows the performance characteristics of the compression ignition engine by using the biodiesel (jamun biodiesel) with nanoparticles additives at various levels of proportion.

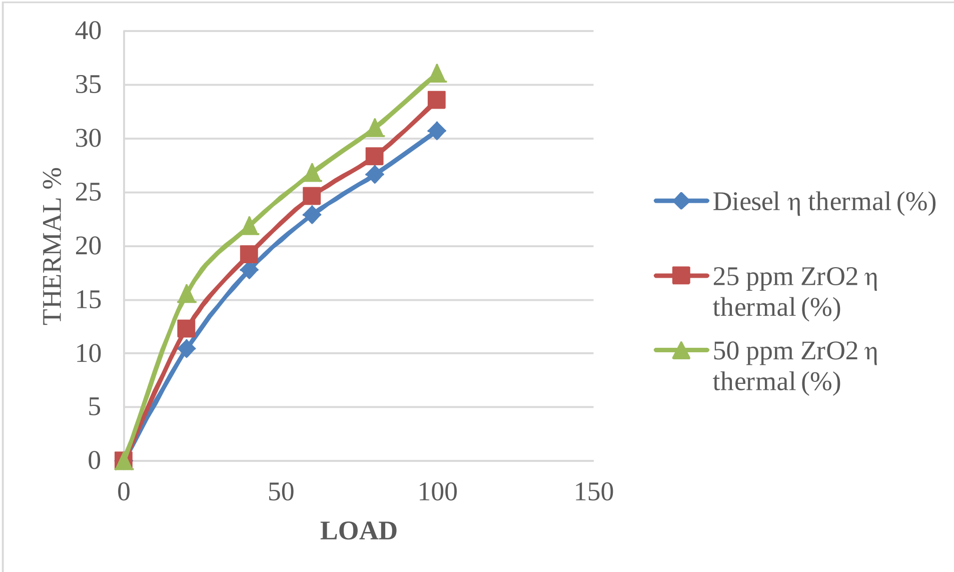

Fig: 16 Load vs η Thermal (%)

The variation of the thermal efficiency with respect to the load is shown in the Figure 16. The thermal efficiency of the jamun biodiesel was lower than the diesel due to the lower calorific value and also higher viscosity and density of the jamun biodiesel fuel. However, a small improvement in thermal efficiency was found when addition of nano particles to the biofuel. From the above graphs it is observed that the B20 (jamun biodiesel) added with nanoadditives(ZrO_2) increase in thermal Efficiency

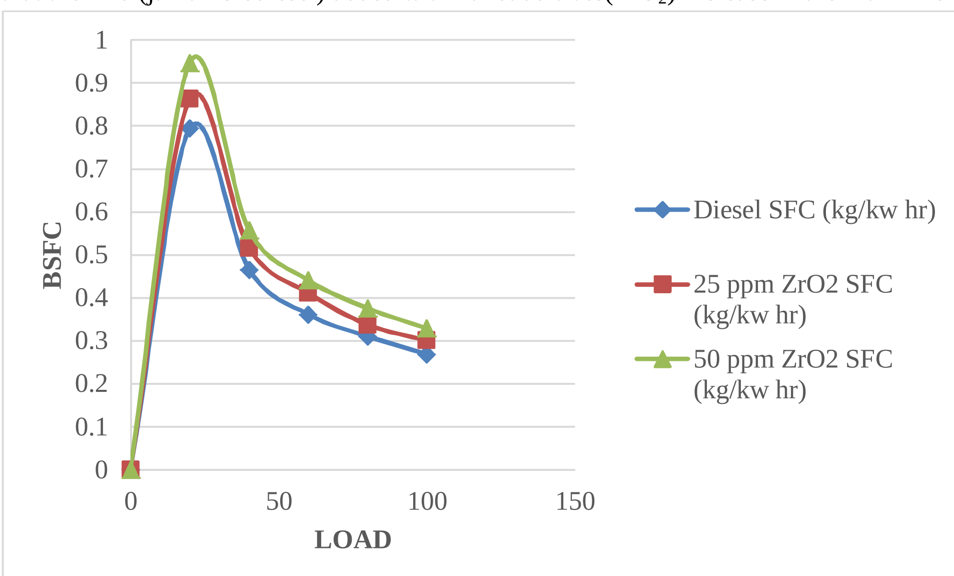

Fig: 17Load vs BSFC

The variation of the brake specific fuel consumption with engine loads, for different nano additives blends of jamun biodiesel (B20) and diesel are shown in Figure 17. The specific fuel consumption decreases with an increase in the engine loads. . Lower SFC is observed for B20 blended with (ZrO_2)nano additives this occurs due to the enhanced surface area to volume ratio by the catalytic effect during the combustion inside the engine cylinder and also due to the lower calorific value. From the above graphs it is concluded that B20+ 100 ppm ZrO_2 shows lesser specific fuel consumption than diesel due to the decrease in the calorific value.

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F. Emission curve

B20 blended with 25, 50 ppm ZrO_2

The emission of the engine were recorded at the five different load condition by adding the nanoparticles of 25, 50 ppm of zirconium oxide. The nanoparticles are added to reduce the exhaust gas emission. The following graph shows emission from singles cylinder compression ignition engine by adding the zirconium oxide.

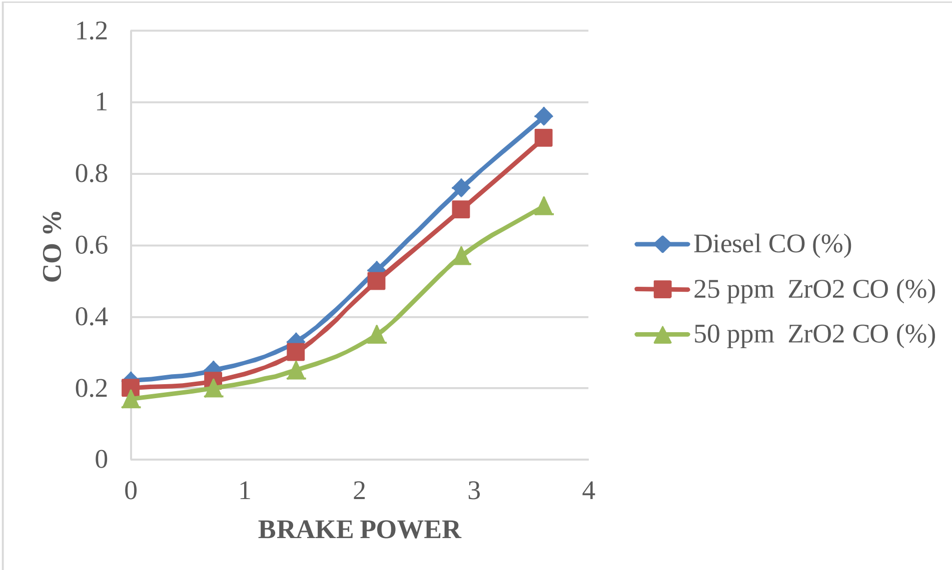

Fig: 18 Brake Power vs CO%

The CO emissions for diesel, jamun biodiesel (B20) with nanoparticles blended fuel are shown in Figure 18. The CO emission for B20, B60, and B100 blends operation was higher compared to diesel due to its lower thermal efficiency resulting in incomplete combustion. However CO emissions were marginally lower for the nanoparticles blended fuels than diesel. The higher catalytic activity and improved combustion characteristics of zirconium oxide nanoparticles lead to improved combustion. At B20 jamun biodiesel with Nano additive of 100 ppm ZrO_2there is a reduction of CO emission.

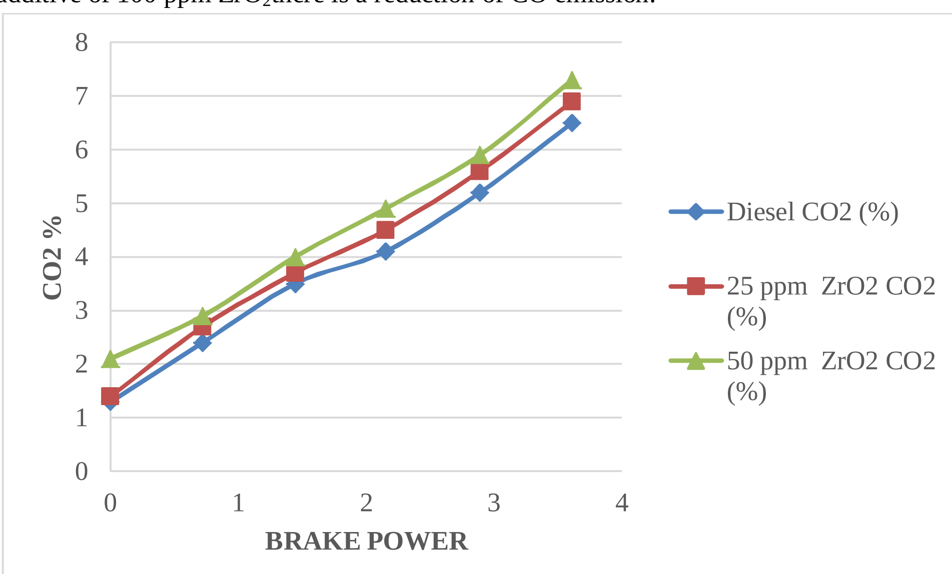

Fig: 19 Brake Power vs CO_2%

The CO_2 variation with brake power is shown in the above fig 19. The CO_2 emission for (jamun) biodiesel with Nano fuel additive ZrO_2 are comparatively higher than that of diesel fuel. This is due to the complete reaction of carbon and hydrogen with oxygen. This leads to superior combustion of the engine

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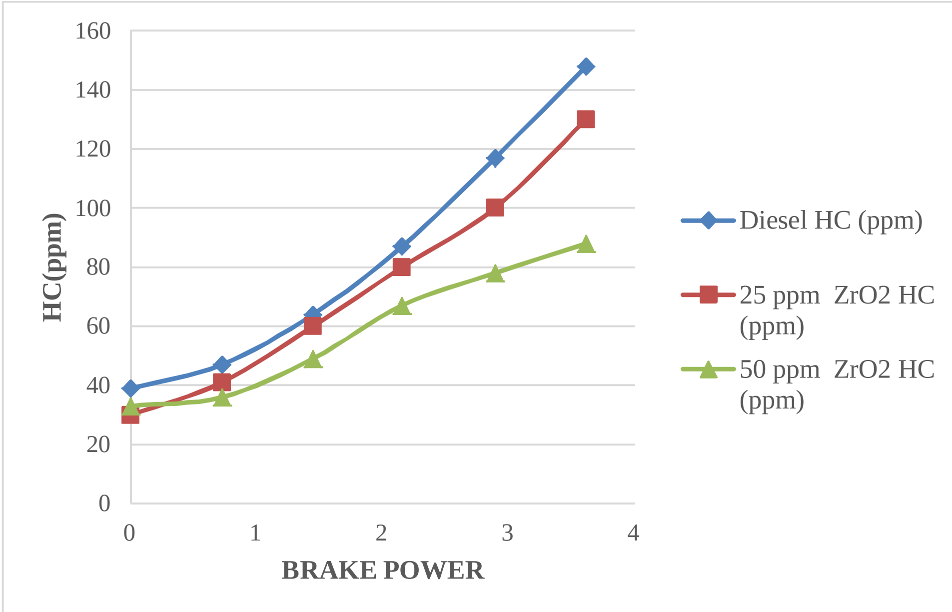

Fig: 20 Brake Power vs HC(ppm)

The un-burnt HC emission variations for Diesel, jamun (B20) with zirconium oxide (ZrO_2) nanoparticle blend are shown in Figure 20. The HC emission for (B20, B60 and B100) operation was higher compared to diesel due to its lower brake thermal efficiency resulting from incomplete combustion. However HC emissions were marginally lower for the nano fuel zirconium oxide blended with (B20) jamun compared to diesel. This could be due to increased catalytic activity and improved combustion characteristics of oxide, zirconium oxide nanoparticles which lead to improved combustion.

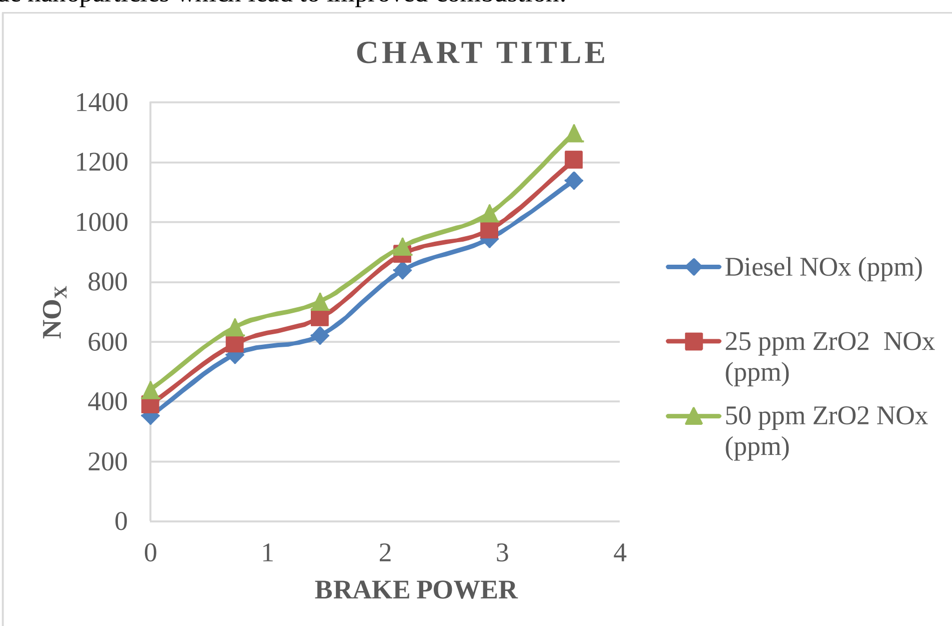

Fig: 21 Brake Power vsNO_x(ppm)

The variations of NOx emissions with respect to the load are shown in the Figure 21. The NOx emissions found increased with the increase in load. The NO emissions are increasing with the load due to the more in-cylinder pressure and the corresponding combustion temperature for all the fuel blends. Similar trend was observed for diesel and B20 blended nano additives of zirconium oxide almost all loads. From the graph it is observed that addition of Nano-fuel additives resulted in an effective in NOx emission. This is due to that nanoparticles oxidize the nitrogen into nitric oxide at the elevated temperatures during the combustion process.

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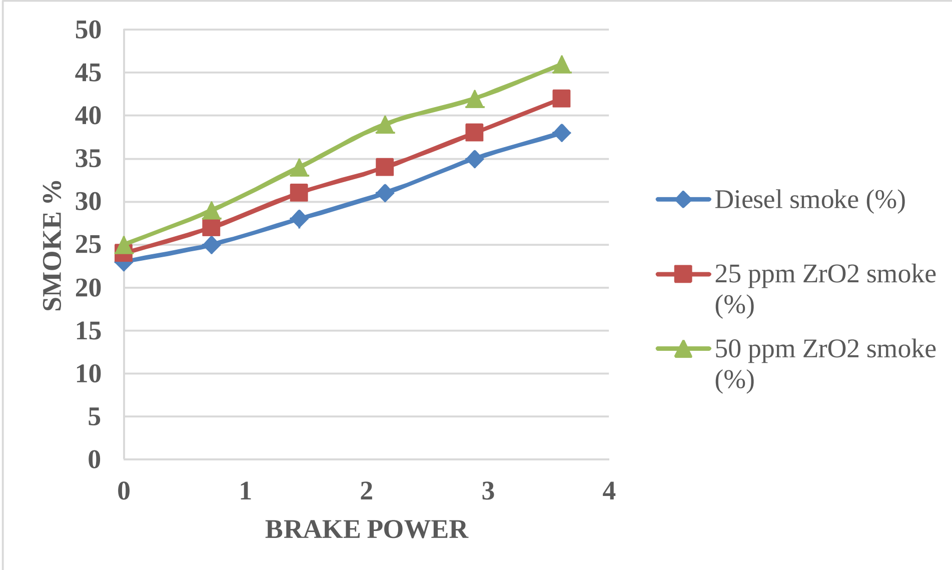

Fig: 22 Brake Power vs Smoke

The smoke density variation with respect to brake power is shown Fig 22. Smoke density for jamun biodiesel blended with ZrO_2 nanoparticles is noticed to be lower than the diesel. This is due to the use of oxygenate fuel (ZrO_2) improves better combustion is the cause for reduction of smoke. It is observed the B20 jamun with 100 ppm of ZrO_2 is very much lesser than diesel.

V. CONCLUSION

The influence of the performance variables, TFC, BSFC, Thermal efficiency and emission variables NOx, Smoke, CO, CO_2, HC of a direct injection single cylinder diesel engine was investigated by using nano metallic additive like cupric oxide and zirconium oxide.

The following conclusions are made about the potential of on selected CI engine.

A. Physiochemical properties and combustion characteristics of jamun biodiesel are examined and compared with ASTM standard.
B. B20, B60 and B100 is having lower efficiency and higher energy consumption due to the poor combustion in the engine.
C. Addition of nanoparticle in biodiesel decrease the ignition delay and accelerates earlier initiation of the combustion which results lower heat release rate and cylinder pressure at full load condition.
D. The addition of nano fuel additives CuO and ZrO_2 in the B20 jaamun biodiesel there is a significant increase in the thermal efficiency compare to the jamun biodiesel without nano additives.
E. The CO emission for B20, B60, and B100 blends operation was higher compared to diesel due to its lower thermal efficiency resulting in incomplete combustion. However CO emissions were marginally lower for the nanoparticles blended fuels than diesel due to the higher catalytic activity and improved combustion characteristics of CuO and ZrO_2 nanoparticles lead to improved combustion of the engine.
F. The CO_2 emission for jamun biodiesel with Nano fuel additive ZrO_2 are comparatively higher than that of diesel fuel. This is due to the complete reaction of carbon and hydrogen with oxygen. This leads to superior combustion of the engine
G. The HC emission for B20, B60 and B100 operation was higher compared to diesel due to its lower brake thermal efficiency resulting from incomplete combustion. However HC emissions were marginally lower for the nano fuel blended with jamun (B20) compared to diesel. This could be due to increased catalytic activity and improved combustion characteristics of oxide, zirconium oxide nanoparticles which lead to improved combustion.
H. The NOx emissions found decrease with the increase in load for (B20, B60 and B100) due to the lower in-cylinder pressure and the corresponding combustion temperature for all the fuel blends. Similar trend was observed for diesel and B20 jamun blended with nano additives of cupric oxide and zirconium oxide almost all loads. It is observed that addition of Nano-fuel additives resulted in an effective in NOx emission. This is due to that nanoparticles oxidize the nitrogen into nitric oxide at the elevated temperatures during the combustion process.
I. Smoke density for jamun blend (B20, B60, B100) were noticed to be higher than that of diesel because due to the heavier molecular structure, poor atomization and high carbon residue .Smoke density for jamun blended with CuO and ZrO_2

nanoparticles is noticed to be lower than the diesel. This is due to the use of oxygenate fuel (CuO and ZrO_2) improves better combustion is the cause for reduction of smoke. It is observed the B20 jamun with 100 ppm of CuO and ZrO_2 is very much lesser than diesel.

J. Finally we concluded that the addition of nano fuel additives cupric oxide (CuO) and zirconium oxide (ZrO_2) to the jamun biodiesel improves the combustion characteristics and reduction in the emission

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